Hydroelectric Dam Environmental Impacts (detailed)

Environmental Impacts of Hydroelectric Power

http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-hydroelectric-power.html December 07, 2014

Hydroelectric power includes both massive hydroelectric dams and small run-of-the-river plants, both of which have associated environmental impacts.

Hydroelectric power includes both massive hydroelectric dams and small run-of-the-river plants. Large-scale hydroelectric dams continue to be built in many parts of the world (including China and Brazil), but it is unlikely that new facilities will be added to the existing U.S. fleet in the future.

Instead, the future of hydroelectric power in the United States will likely involve increased capacity at current dams and new run-of-the-river projects. There are environmental impacts at both types of plants.

The size of the reservoir created by a hydroelectric project can vary widely, depending largely on the size of the hydroelectric generators and the topography of the land. Hydroelectric plants in flat areas tend to require much more land than those in hilly areas or canyons where deeper reservoirs can hold more volume of water in a smaller space.

At one extreme, the large Balbina hydroelectric plant, which was built in a flat area of Brazil, flooded 2,360 square kilometers—an area the size of Delaware—and it only provides 250 MW of power generating capacity (equal to more than 2,000 acres per MW) [1]. In contrast, a small 10 MW run-of-the-rive plant in a hilly location can use as little 2.5 acres (equal to a quarter of an acre per MW) [2].

Flooding land for a hydroelectric reservoir has an extreme environmental impact: it destroys forest, wildlife habitat, agricultural land, and scenic lands. In many instances, such as the Three Gorges Dam in China, entire communities have also had to be relocated to make way for reservoirs [3].

Dammed reservoirs are used for multiple purposes, such as agricultural irrigation, flood control, and recreation, so not all wildlife impacts associated with dams can be directly attributed to hydroelectric power. However, hydroelectric facilities can still have a major impact on aquatic ecosystems. For example, though there are a variety of methods to minimize the impact (including fish ladders and in-take screens), fish and other organisms can be injured and killed by turbine blades.

Apart from direct contact, there can also be wildlife impacts both within the dammed reservoirs and downstream from the facility. Reservoir water is usually more stagnant than normal river water. As a result, the reservoir will have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds can crowd out other river animal and plant-life, and they must be controlled through manual harvesting or by introducing fish that eat these plants [4]. In addition, water is lost through evaporation in dammed reservoirs at a much higher rate than in flowing rivers.

In addition, if too much water is stored behind the reservoir, segments of the river downstream from the reservoir can dry out. Thus, most hydroelectric operators are required to release a minimum amount of water at certain times of year. If not released appropriately, water levels downstream will drop and animal and plant life can be harmed. In addition, reservoir water is typically low in dissolved oxygen and colder than normal river water. When this water is released, it could have negative impacts on downstream plants and animals. To mitigate these impacts, aerating turbines can be installed to increase dissolved oxygen and multi-level water intakes can help ensure that water released from the reservoir comes from all levels of the reservoir, rather than just the bottom (which is the coldest and has the lowest dissolved oxygen).

Global warming emissions are produced during the installation and dismantling of hydroelectric power plants, but recent research suggests that emissions during a facility's operation can also be significant. Such emissions vary greatly depending on the size of the reservoir and the nature of the land that was flooded by the reservoir.

Small run-of-the-river plants emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour. Life-cycle emissions from large-scale hydroelectric plants built in semi-arid regions are also modest: approximately 0.06 pounds of carbon dioxide equivalent per kilowatt-hour. However, estimates for life-cycle global warming emissions from hydroelectric plants built in tropical areas or temperate peatlands are much higher. After the area is flooded, the vegetation and soil in these areas decomposes and releases both carbon dioxide and methane. The exact amount of emissions depends greatly on site-specific characteristics. However, current estimates suggest that life-cycle emissions can be over 0.5 pounds of carbon dioxide equivalent per kilowatt-hour [5,6].

To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour [7].

[1] Fearnside, Phillip M. 1989. Brazil's Balbina Dam: Environment versus the legacy of the Pharaohs in Amazonia. Environmental Management, July/Aug 1989, Volume 13, Issue 4, pp 401-423.

[3] Yardley, Jim. November 19, 2007. Chinese Dam Projects Criticized for Their Human Costs. New York Times.

[5] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 5 & 9).

[6] National Academy of Sciences. 2010. Electricity from Renewable Resources: Status, Prospects, and Impediments. Washington, DC: The National Academies Press. Online at http://www.nap.edu/openbook.php?record_id=12619

Hydroelectricity

http://www.epa.gov/cleanenergy/energy-and-you/affect/hydro.html December 07, 2014

Environmental Impacts. Although hydropower has no air quality impacts, ... Hydroelectric dams can cause erosion along the riverbed upstream and downstream, ...

Hydropower is considered a renewable energy resource because it uses the Earth's water cycle to generate electricity. Water evaporates from the Earth's surface, forms clouds, precipitates back to earth, and flows toward the ocean.

The movement of water as it flows downstream creates kinetic energy that can be converted into electricity. A hydroelectric power plant converts this energy into electricity by forcing water, often held at a dam, through a hydraulic turbine that is connected to a generator. The water exits the turbine and is returned to a stream or riverbed below the dam.

Hydropower is mostly dependent upon precipitation and elevation changes; high precipitation levels and large elevation changes are necessary to generate significant quantities of electricity. Therefore, an area such as the mountainous Pacific Northwest has more productive hydropower plants than an area such as the Gulf Coast, which might have large amounts of precipitation but is comparatively flat.

Although hydropower has no air quality impacts, construction and operation of hydropower dams can significantly affect natural river systems as well as fish and wildlife populations. Assessment of the environmental impacts of a specific hydropower facility requires case-by-case review.

Although power plants are regulated by federal and state laws to protect human health and the environment, there is a wide variation of environmental impacts associated with power generation technologies.

The purpose of the following section is to give consumers a better idea of the specific ecological impacts associated with hydropower.

Hydropower's air emissions are negligible because no fuels are burned. However, if a large amount of vegetation is growing along the riverbed when a dam is built, it can decay in the lake that is created, causing the buildup and release of >methane, a potent greenhouse gas.

Hydropower often requires the use of dams, which can greatly affect the flow of rivers, altering ecosystems and affecting the wildlife and people who depend on those waters.

Often, water at the bottom of the lake created by a dam is inhospitable to fish because it is much colder and oxygen-poor compared with water at the top. When this colder, oxygen-poor water is released into the river, it can kill fish living downstream that are accustomed to warmer, oxygen-rich water.

In addition, some dams withhold water and then release it all at once, causing the river downstream to suddenly flood. This action can disrupt plant and wildlife habitats and affect drinking water supplies.

Hydroelectric power plants release water back into rivers after it passes through turbines. This water is not polluted by the process of creating electricity.

The use of water to create electricity does not produce a substantial amount of solid waste.

The construction of hydropower plants can alter sizable portions of land when dams are constructed and lakes are created, flooding land that may have once served as wildlife habitat, farmland, and scenic retreats. Hydroelectric dams can cause erosion along the riverbed upstream and downstream, which can further disturb wildlife ecosystems and fish populations.

Hydroelectric power plants affect various fish populations in different ways. Most notably, certain salmon populations in the Northwest depend on rivers for their life cycles. These populations have been dramatically reduced by the network of large dams in the Columbia River Basin.1 When young salmon travel downstream toward the ocean, they may be killed by turbine blades at hydropower plants. When adult salmon attempt to swim upstream to reproduce, they may not be able to get past the dams. For this reason, some hydroelectric dams now have special side channels or structures to help the fish continue upstream.

In the United States, hydropower generates nearly nine percent of the total electricity supply. In the Pacific Northwest alone, hydropower provides about two-thirds of the region's electricity supply.2 Currently, facilities in the U.S. can generate enough hydropower to supply electricity to 28 million households, which is equivalent to about 500 million barrels of oil. In 2003, total hydropower capacity in the United States was 96,000 MW.3 The undeveloped capacity for the United States is approximately 30,000 MW.4

Environmental impact of reservoirs

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The environmental impact of reservoirs comes under ever increasing scrutiny as the global demand for water and energy increases and the number and size of reservoirs ...

The environmental impact of reservoirs comes under ever increasing scrutiny as the global demand for water and energy increases and the number and size of reservoirs increases.

Dams and reservoirs can be used to supply drinking water, generate hydroelectric power, increase the water supply for irrigation, provide recreational opportunities, and improve certain aspects of the environment.[citation needed] However, adverse environmental and sociological impacts have been identified during and after many reservoir constructions.[citation needed] Whether reservoir projects are ultimately beneficial or detrimental to either the environment or surrounding human populations has been debated since the 1960s and likely before then, as well.[citation needed] In 1960 the construction of Llyn Celyn and the flooding of Capel Celyn provoked political uproar which continues to this day. More recently, the construction of Three Gorges Dam and other similar projects throughout Asia, Africa and Latin America have generated considerable environmental and political debate.

A dam also acts as a barrier between the upstream and downstream movement of migratory river animals, such as salmon and trout.[2]

Some communities have also begun the practice of transporting migratory fish upstream to spawn via a barge.[2]

Rivers carry sediment down their riverbeds, allowing for the formation of depositional features such as river deltas, alluvial fans, braided rivers, oxbow lakes, levees and coastal shores. The construction of a dam blocks the flow of sediment downstream, leading to downstream erosion of these Sedimentary depositional environments, and increased sediment build-up in the reservoir. While the rate of sedimentation varies for each dam and each river, eventually all reservoirs develop a reduced water-storage capacity due to the exchange of storage space for sediment.[3] Diminished storage capacity results in decreased ability to produce hydroelectric power, reduced availability of water for irrigation, and if left unaddressed, may ultimately result in the expiration of the dam and river.[4]

As all dams result in reduced sediment load downstream, a dammed river is said to be "hungry" for sediment. Because the rate of deposition of sediment is greatly reduced since there is less to deposit but the rate of erosion remains nearly constant, the water flow erodes the river shores and riverbed, threatening shoreline ecosystems, deepening the riverbed, and narrowing the river over time. This leads to a compromised water table, reduced water levels, homogenization of the river flow and thus reduced ecosystem variability, reduced support for wildlife, and reduced amount of sediment reaching coastal plains and deltas.[4] This prompts coastal erosion, as beaches are unable to replenish what waves erode without the sediment deposition of supporting river systems. Channel erosion of rivers has its own set of consequences. The eroded channel could create a lower water table level in the affected area, impacting bottomland crops such as alfalfa or corn, and resulting in a smaller supply.[5]

The water of a deep reservoir in temperate climates typically stratifies with a large volume of cold, oxygen poor water in the hypolimnion. If this water is released to maintain river flow, it can cause adverse impacts on the downstream ecosystem including fish populations. [6]

Diseases

Whilst reservoirs are helpful to humans, they can also be harmful as well. One negative effect is that the reservoirs can become breeding grounds for disease vectors. This holds true especially in tropical areas where mosquitoes (which are vectors for malaria) and snails (which are vectors for Schistosomiasis) can take advantage of this slow flowing water.[7]

Resettlement

Dams and the creation of reservoirs also require relocation of potentially large human populations if they are constructed close to residential areas.

The record for the largest population relocated belongs to the Three Gorges dam built in China. Its reservoir submerged a large area of land, forcing over a million people to relocate. "Dam related relocation affects society in three ways: an economic disaster, human trauma, and social catastrophe", states Dr. Michael Cernea of the World Bank and Dr. Thayer Scudder, a professor at the California Institute of Technology.[1] As well, as resettlement of communities, care must also be taken not to damage irreparable sites of historical or cultural value. The Aswan Dam forced the movement of the Temple at Aswan to prevent its destruction by the flooding of the reservoir.

Dams occasionally break causing catastrophic damage to communities downstream. Dams break due to engineering errors, attack or natural disaster. The greatest dam break disaster happened in China killing 200,000 Chinese citizens. However, they have happened in California killing 600 people, Germany during World War II and other countries.

In many developing countries the savanna and forest ecology of the floodplains depend on seasonal flooding from rivers. Also, flood recession cropping is practiced extensively whereby the land is cultivated taking advantage of the residual soil moisture after floods recede. Dams attenuate floods which may affect the ecology and agriculture seriously.[citation needed]

Reservoirs may contribute to changes in the Earth's climate. Warm climate reservoirs generate methane, a greenhouse gas when the reservoirs are stratified, in which the bottom layers are anoxic (i.e. they lack oxygen), leading to degradation of biomass through anaerobic processes.[11][page needed] In some cases, where flooded basins are wide and biomass volumes are high the amount of biomass converted to methane results in pollution potential 3.5 times more than an oil-fired power plant would for the same generation capacity.[12] Hydroelectric dams are the number one source of methane gas emissions caused by humans.[13] Methane gas contributes much more to climate change then carbon dioxide.

The Environmental Literacy Council

http://enviroliteracy.org/article.php/59.html December 07, 2014

Hydroelectric Power. ... Hydroelectric plants can also have an impact ... This National Geographic activity examines the effects existing dams have on the environment ...

Water has long been used as a source of energy, beginning with the Greeks use of water wheels over 2,000 years ago. For over a century, hydropower has been used to generate electricity from falling water. Hydroelectric power stems from the process of using water's energy as it flows from higher to lower elevation, rotating hydraulic turbines to create electricity. Tidal power, although not widely used, can also generate hydroelectricity by utilizing the same principle.

Hydropower is considered to be a clean, renewable source of energy, emitting a very low level of greenhouse gases when compared to fossil fuels. It has a low operating cost once installed and can be highly automated. An additional benefit is that the power is generally available on demand since the flow of water can be controlled. Using hydroelectric power also has disadvantages. Dams can block fish passage to spawning grounds or to the ocean, although many plants now have measures in place to help reduce this impact. The diversion of water can impact stream flow, or even cause a river channel to dry out, degrading both aquatic and streamside habitats. Hydroelectric plants can also have an impact on water quality by lowering the amount of dissolved oxygen in the water. In the reservoir, sediments and nutrients can be trapped and the lack of water flow can create a situation for undesirable growth and the spread of algae and aquatic weeds.

One incentive for hydroelectric facilities to help mitigate their overall impact on the environment is through green power certification. The Low Impact Hydropower Institute (LIHI) created a voluntary certification program whereby facilities are classified as low impact after passing a series of tests that demonstrate minimal impact. In 2007, less than 30 facilities in the U.S. had that distinction. Certification programs, such as the one set by the LIHI, can benefit hydropower efforts by attracting consumers concerned about energy source impacts.

While the use of water to produce electricity is an attractive alternative to fossil fuels, the technology must still overcome obstacles related to space requirements, building costs, environmental impacts, and the displacement of people. However, within the U.S., possible locations for new hydropower projects are beginning to diminish.

How Hydropower Plants Work

HowStuffWorks.com details the basic components of a hydropower plant and how it operates.

Wind & Hydropower Technologies Program: Hydropower Technologies

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy's website for their hydropower technologies program gives an overview of how hydropower works, advantages and disadvantages of using hydropower, the history of the technology, and the latest in research developments.

Idaho National Laboratory (INL): State Resource Assessment Reports

INL's website includes individual reports on the hydropower potential and current capacity of each state (except Delaware).

Water Power

The U.S. Federal Energy Regulatory Commission (FERC) provides information on the licensing, compliance, and safety and inspection of hydroelectric power in the U.S.

New Scientist: Hydroelectric Power's Dirty Secret Revealed

In this February 2005 article from NewScientist.com, Duncan Graham-Rowe argues that hydroelectric power can damage the climate via greenhouse gas emissions, sometimes emitting more greenhouse gases than fossil fuels.

PBS: Great Wall Across the Yangtze

PBS details the Three Gorges Dam project and presents both sides of the controversy surrounding its construction, including an international perspective on the issue.

Energy Story: Hydro Power

The California Energy Commission's Energy Quest website presents a simple chapter about hydroelectric power that describes the technology's history, its use in the U.S., and how dams operate.

Foundation for Water and Energy Education (FWEE): Hydro Tours

The FWEE website offers a variety of visual tours, including a 'walk' through a hydroelectric project. They also provide a list of educational activities and resources, including a hands-on science curriculum for middle school called ?The Nature of Water Power?.

Big Dams, Big Dilemmas

This National Geographic activity examines the effects existing dams have on the environment and predicts possible effects of proposed dams. [Grades 9-12]

Three Gorges Dam: The Biggest Dam in the World

Discovery Education created this activity for students to learn about the background and controversy surrounding the Three Gorges Dam. Students will also build their own dams in order to learn about the engineering principles used in their construction. [Grades 6-8]

Great Wall Across the Yangtze from PBS.

Griffiths, Dan. Three Gorges Dam Reaches for the Sky, BBC News, May 19, 2006.

Wind & Hydropower Technologies Program: Hydropower Technologies from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, August 2005.

How a Hydroelectric Project Can Affect a River

http://fwee.org/environment/how-a-hydroelectric-project-can-affect-a-river/ December 07, 2014

Reviewing possible changes to a river's ecosystem is a good place to begin considering the environmental impacts that a hydroelectric ... Hydroelectric Dams ...

Hydropower has traditionally been considered environmentally friendly because it represents a clean and renewable energy source. The term renewable refers to the hydrologic cycle that circulates water back to our rivers, streams, and lakes each year. At hydroelectric projects, this water is used as fuel to generate electricity. In contrast, fossil fuels like coal, natural gas, or oil must be extracted from the earth and burned to produce electricity. The term clean is also used because production of electricity with hydropower does not pollute the air, contribute to acid rain or ozone depletion because of carbon dioxide emissions, or (like nuclear power) leave highly toxic waste that is difficult to dispose of.

As the section Hydropower Facts graphically illustrates, hydropower accounts for 98% of renewable energy in the United States. Wind, solar and other sources account for the other 2%. And while there are many benefits to using hydropower as a renewable source of electricity, there are also environmental impacts. These impacts generally relate to how a hydroelectric project affects a river's ecosystem and habitats.

Because there are over 250 hydroelectric projects in the Northwest, understanding such ecosystem and habitat issues is vitally important. Examining these issues, however, needs to be done in a broad context for three reasons. First, no two hydroelectric projects are exactly alike, and many are very different. Thus, while issues can be examined in general terms, one should not draw conclusions that all or even most projects have similar environmental impacts.

Second, while this discussion focuses on hydroelectric projects, one should not conclude that all dams are used to produce electricity. Nationally, for instance, only three percent of the nation's 80,000 dams are used to produce electricity. Most dams are used for purposes such as irrigation, flood control, and water treatment. Further, many dams support a combination of activities. For example, dams on the mainstem of the Columbia River are used for irrigation, flood control, transportation, recreation, and the production of electricity.

Third, this section does not provide detailed information about a host of other activities that can significantly impact a river's ecosystem and the species that rely on it for survival. Examples of other non-hydropower related impacts include grazing, logging, agricultural activities, mining, land development, and the harvesting of fish. Determining the relative impact of these activities versus hydroelectric projects is very complex and the subject of ongoing debate.

For information about the many steps that are being taken to reduce or eliminate ongoing impacts, refer to the Protection, Mitigation, and Enhancement Strategies At Hydroelectric Projects. Reviewing possible changes to a river's ecosystem is a good place to begin considering the environmental impacts that a hydroelectric project may cause. From this understanding, possible changes to fish and wildlife habitat can be explored.

Wikipedia, the free encyclopedia

http://en.wikipedia.org/wiki/Hydroelectricity December 07, 2014

This decreased environmental impact depends strongly on the balance between stream flow and power production. ... Since hydroelectric dams do not burn fossil fuels, ...

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010,[1] and is expected to increase about 3.1% each year for the next 25 years.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now four hydroelectricity stations larger than 10 GW: the Three Gorges Dam and Xiluodu Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela.[1]

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro station larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour.[1] It is also a flexible source of electricity since the amount produced by the station can be changed up or down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife.[1] Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO

2) than fossil fuel powered energy plants.[2]

Hydropower has been used since ancient times to grind flour and perform other tasks. In the mid-1770s, French engineer Bernard Forest de Bélidor published Architecture Hydraulique which described vertical- and horizontal-axis hydraulic machines. By the late 19th century, the electrical generator was developed and could now be coupled with hydraulics.[5] The growing demand for the Industrial Revolution would drive development as well.[6] In 1878 the world's first hydroelectric power scheme was developed at Cragside in Northumberland, England by William George Armstrong. It was used to power a single arc lamp in his art gallery.[7] The old Schoelkopf Power Station No. 1 near Niagara Falls in the U.S. side began to produce electricity in 1881. The first Edison hydroelectric power station, the Vulcan Street Plant, began operating September 30, 1882, in Appleton, Wisconsin, with an output of about 12.5 kilowatts.[8] By 1886 there were 45 hydroelectric power stations in the U.S. and Canada. By 1889 there were 200 in the U.S. alone.[5]

At the beginning of the 20th century, many small hydroelectric power stations were being constructed by commercial companies in mountains near metropolitan areas. Grenoble, France held the International Exhibition of Hydropower and Tourism with over one million visitors. By 1920 as 40% of the power produced in the United States was hydroelectric, the Federal Power Act was enacted into law. The Act created the Federal Power Commission to regulate hydroelectric power stations on federal land and water. As the power stations became larger, their associated dams developed additional purposes to include flood control, irrigation and navigation. Federal funding became necessary for large-scale development and federally owned corporations, such as the Tennessee Valley Authority (1933) and the Bonneville Power Administration (1937) were created.[6]

Additionally, the Bureau of Reclamation which had begun a series of western U.S. irrigation projects in the early 20th century was now constructing large hydroelectric projects such as the 1928 Hoover Dam.[9] The U.S. Army Corps of Engineers was also involved in hydroelectric development, completing the Bonneville Dam in 1937 and being recognized by the Flood Control Act of 1936 as the premier federal flood control agency.[10]

Hydroelectric power stations continued to become larger throughout the 20th century. Hydropower was referred to as white coal for its power and plenty.[11] Hoover Dam's initial 1,345 MW power station was the world's largest hydroelectric power station in 1936; it was eclipsed by the 6809 MW Grand Coulee Dam in 1942.[12] The Itaipu Dam opened in 1984 in South America as the largest, producing 14,000 MW but was surpassed in 2008 by the Three Gorges Dam in China at 22,500 MW. Hydroelectricity would eventually supply some countries, including Norway, Democratic Republic of the Congo, Paraguay and Brazil, with over 85% of their electricity. The United States currently has over 2,000 hydroelectric power stations that supply 6.4% of its total electrical production output, which is 49% of its renewable electricity.[6]

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head. A large pipe (the "penstock") delivers water to the turbine.[13]

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine. Pumped-storage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system. Pumped storage is not an energy source, and appears as a negative number in listings.[14]

Run of the river hydroelectric stations are those with small or no reservoir capacity, so that the water coming from upstream must be used for generation at that moment, or must be allowed to bypass the dam. In the United States, run of the river hydropower could potentially provide 60,000 MW (about 13.7% of total use in 2011 if continuously available).[15]

A tidal power station makes use of the daily rise and fall of ocean water due to tides; such sources are highly predictable, and if conditions permit construction of reservoirs, can also be dispatchable to generate power during high demand periods. Less common types of hydro schemes use water's kinetic energy or undammed sources such as undershot waterwheels. Tidal power is viable in a relatively small number of locations around the world. In Great Britain, there are eight sites that could be developed, which have the potential to generate 20% of the electricity used in 2012.[16]

Although no official definition exists for the capacity range of large hydroelectric power stations, facilities from over a few hundred megawatts to more than 10 GW are generally considered large hydroelectric facilities. Currently, only three facilities over 10 GW (10,000 MW) are in operation worldwide; Three Gorges Dam at 22.5 GW, Itaipu Dam at 14 GW, and Guri Dam at 10.2 GW. Large-scale hydroelectric power stations are more commonly seen as the largest power producing facilities in the world, with some hydroelectric facilities capable of generating more than double the installed capacities of the current largest nuclear power stations.

Small hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The definition of a small hydro project varies but a generating capacity of up to 10 megawatts (MW) is generally accepted as the upper limit of what can be termed small hydro. This may be stretched to 25 MW and 30 MW in Canada and the United States. Small-scale hydroelectricity production grew by 28% during 2008 from 2005, raising the total world small-hydro capacity to 85 GW. Over 70% of this was in China (65 GW), followed by Japan (3.5 GW), the United States (3 GW), and India (2 GW).[19]

Small hydro stations may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, small hydro projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network. Since small hydro projects usually have minimal reservoirs and civil construction work, they are seen as having a relatively low environmental impact compared to large hydro. This decreased environmental impact depends strongly on the balance between stream flow and power production.

Micro hydro is a term used for hydroelectric power installations that typically produce up to 100 kW of power. These installations can provide power to an isolated home or small community, or are sometimes connected to electric power networks. There are many of these installations around the world, particularly in developing nations as they can provide an economical source of energy without purchase of fuel.[20] Micro hydro systems complement photovoltaic solar energy systems because in many areas, water flow, and thus available hydro power, is highest in the winter when solar energy is at a minimum.

Pico hydro is a term used for hydroelectric power generation of under 5 kW. It is useful in small, remote communities that require only a small amount of electricity. For example, to power one or two fluorescent light bulbs and a TV or radio for a few homes.[21] Even smaller turbines of 200-300W may power a single home in a developing country with a drop of only 1 m (3 ft). A Pico-hydro setup is typically run-of-the-river, meaning that dams are not used, but rather pipes divert some of the flow, drop this down a gradient, and through the turbine before returning it to the stream.

An underground power station is generally used at large facilities and makes use of a large natural height difference between two waterways, such as a waterfall or mountain lake. An underground tunnel is constructed to take water from the high reservoir to the generating hall built in an underground cavern near the lowest point of the water tunnel and a horizontal tailrace taking water away to the lower outlet waterway.

A simple formula for approximating electric power production at a hydroelectric station is: , where

Annual electric energy production depends on the available water supply. In some installations, the water flow rate can vary by a factor of 10:1 over the course of a year.

Hydro is a flexible source of electricity since stations can be ramped up and down very quickly to adapt to changing energy demands.[1] Hydro turbines have a start-up time of the order of a few minutes.[22] It takes around 60 to 90 seconds to bring a unit from cold start-up to full load; this is much shorter than for gas turbines or steam plants.[23] Power generation can also be decreased quickly when there is a surplus power generation.[24] Hence the limited capacity of hydropower units is not generally used to produce base power except for vacating the flood pool or meeting downstream needs.[25] Instead, it serves as backup for non-hydro generators.[24]

The major advantage of hydroelectricity is elimination of the cost of fuel. The cost of operating a hydroelectric station is nearly immune to increases in the cost of fossil fuels such as oil, natural gas or coal, and no imports are needed. The average cost of electricity from a hydro station larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour.[1]

Hydroelectric stations have long economic lives, with some plants still in service after 50–100 years.[26] Operating labor cost is also usually low, as plants are automated and have few personnel on site during normal operation.

Where a dam serves multiple purposes, a hydroelectric station may be added with relatively low construction cost, providing a useful revenue stream to offset the costs of dam operation. It has been calculated that the sale of electricity from the Three Gorges Dam will cover the construction costs after 5 to 8 years of full generation.[27] Additionally, some data shows that in most countries large hydropower dams will be too costly and take too long to build to deliver a positive risk adjusted return, unless appropriate risk management measures are put in place.[28]

While many hydroelectric projects supply public electricity networks, some are created to serve specific industrial enterprises. Dedicated hydroelectric projects are often built to provide the substantial amounts of electricity needed for aluminium electrolytic plants, for example. The Grand Coulee Dam switched to support Alcoa aluminium in Bellingham, Washington, United States for American World War II airplanes before it was allowed to provide irrigation and power to citizens (in addition to aluminium power) after the war. In Suriname, the Brokopondo Reservoir was constructed to provide electricity for the Alcoa aluminium industry. New Zealand's Manapouri Power Station was constructed to supply electricity to the aluminium smelter at Tiwai Point.

Since hydroelectric dams do not burn fossil fuels, they do not directly produce carbon dioxide. While some carbon dioxide is produced during manufacture and construction of the project, this is a tiny fraction of the operating emissions of equivalent fossil-fuel electricity generation. One measurement of greenhouse gas related and other externality comparison between energy sources can be found in the ExternE project by the Paul Scherrer Institut and the University of Stuttgart which was funded by the European Commission.[29] According to that study, hydroelectricity produces the least amount of greenhouse gases and externality of any energy source.[30] Coming in second place was wind, third was nuclear energy, and fourth was solar photovoltaic.[30] The low greenhouse gas impact of hydroelectricity is found especially in temperate climates. The above study was for local energy in Europe; presumably similar conditions prevail in North America and Northern Asia, which all see a regular, natural freeze/thaw cycle (with associated seasonal plant decay and regrowth). Greater greenhouse gas emission impacts are found in the tropical regions because the reservoirs of power stations in tropical regions produce a larger amount of methane than those in temperate areas.[31]

Reservoirs created by hydroelectric schemes often provide facilities for water sports, and become tourist attractions themselves. In some countries, aquaculture in reservoirs is common. Multi-use dams installed for irrigation support agriculture with a relatively constant water supply. Large hydro dams can control floods, which would otherwise affect people living downstream of the project.[32]

Large reservoirs required for the operation of hydroelectric power stations result in submersion of extensive areas upstream of the dams, destroying biologically rich and productive lowland and riverine valley forests, marshland and grasslands. The loss of land is often exacerbated by habitat fragmentation of surrounding areas caused by the reservoir.[33]

Hydroelectric projects can be disruptive to surrounding aquatic ecosystems both upstream and downstream of the plant site. Generation of hydroelectric power changes the downstream river environment. Water exiting a turbine usually contains very little suspended sediment, which can lead to scouring of river beds and loss of riverbanks.[34] Since turbine gates are often opened intermittently, rapid or even daily fluctuations in river flow are observed.

When water flows it has the ability to transport particles heavier than itself downstream. This has a negative effect on dams and subsequently their power stations, particularly those on rivers or within catchment areas with high siltation. Siltation can fill a reservoir and reduce its capacity to control floods along with causing additional horizontal pressure on the upstream portion of the dam. Eventually, some reservoirs can become full of sediment and useless or over-top during a flood and fail.[35][36]

Changes in the amount of river flow will correlate with the amount of energy produced by a dam. Lower river flows will reduce the amount of live storage in a reservoir therefore reducing the amount of water that can be used for hydroelectricity. The result of diminished river flow can be power shortages in areas that depend heavily on hydroelectric power. The risk of flow shortage may increase as a result of climate change.[37] One study from the Colorado River in the United States suggest that modest climate changes, such as an increase in temperature in 2 degree Celsius resulting in a 10% decline in precipitation, might reduce river run-off by up to 40%.[37] Brazil in particular is vulnerable due to its heaving reliance on hydroelectricity, as increasing temperatures, lower water flow and alterations in the rainfall regime, could reduce total energy production by 7% annually by the end of the century.[37]

Lower positive impacts are found in the tropical regions, as it has been noted that the reservoirs of power plants in tropical regions produce substantial amounts of methane. This is due to plant material in flooded areas decaying in an anaerobic environment, and forming methane, a greenhouse gas. According to the World Commission on Dams report,[38] where the reservoir is large compared to the generating capacity (less than 100 watts per square metre of surface area) and no clearing of the forests in the area was undertaken prior to impoundment of the reservoir, greenhouse gas emissions from the reservoir may be higher than those of a conventional oil-fired thermal generation plant.[39]

In boreal reservoirs of Canada and Northern Europe, however, greenhouse gas emissions are typically only 2% to 8% of any kind of conventional fossil-fuel thermal generation. A new class of underwater logging operation that targets drowned forests can mitigate the effect of forest decay.[40]

Another disadvantage of hydroelectric dams is the need to relocate the people living where the reservoirs are planned. In 2000, the World Commission on Dams estimated that dams had physically displaced 40-80 million people worldwide.[41]

Because large conventional dammed-hydro facilities hold back large volumes of water, a failure due to poor construction, natural disasters or sabotage can be catastrophic to downriver settlements and infrastructure. Dam failures have been some of the largest man-made disasters in history.

The Banqiao Dam failure in Southern China directly resulted in the deaths of 26,000 people, and another 145,000 from epidemics. Millions were left homeless. Also, the creation of a dam in a geologically inappropriate location may cause disasters such as 1963 disaster at Vajont Dam in Italy, where almost 2,000 people died.[42]

Smaller dams and micro hydro facilities create less risk, but can form continuing hazards even after being decommissioned. For example, the small Kelly Barnes Dam failed in 1967, causing 39 deaths with the Toccoa Flood, ten years after its power station was decommissioned.[43]

Hydroelectricity eliminates the flue gas emissions from fossil fuel combustion, including pollutants such as sulfur dioxide, nitric oxide, carbon monoxide, dust, and mercury in the coal. Hydroelectricity also avoids the hazards of coal mining and the indirect health effects of coal emissions. Compared to nuclear power, hydroelectricity generates no nuclear waste, has none of the dangers associated with uranium mining, nor nuclear leaks.

Compared to wind farms, hydroelectricity power stations have a more predictable load factor. If the project has a storage reservoir, it can generate power when needed. Hydroelectric stations can be easily regulated to follow variations in power demand.

The ranking of hydro-electric capacity is either by actual annual energy production or by installed capacity power rating. Hydro accounted for 16 percent of global electricity consumption, and 3,427 terawatt-hours of electricity production in 2010, which continues the rapid rate of increase experienced between 2003 and 2009.[1]

Hydropower is produced in 150 countries, with the Asia-Pacific region generated 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. Brazil, Canada, New Zealand, Norway, Paraguay, Austria, Switzerland, and Venezuela have a majority of the internal electric energy production from hydroelectric power. Paraguay produces 100% of its electricity from hydroelectric dams, and exports 90% of its production to Brazil and to Argentina. Norway produces 98–99% of its electricity from hydroelectric sources.[44]

There are now three hydroelectric stations larger than 10 GW: the Three Gorges Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela.[1]

A hydro-electric station rarely operates at its full power rating over a full year; the ratio between annual average power and installed capacity rating is the capacity factor. The installed capacity is the sum of all generator nameplate power ratings.[45]

Environmental Impact of Hydroelectricity

http://renewableenergyindex.com/hydro/environmental-impact-of-hydroelectricity December 07, 2014

Hydroelectricity: Environmental Impact Summary. Although it is considered a clean source of energy, hydroelectric power is not without its environmental problems.

Hydroelectric power is considered to be a clean, renewable source of electricity and in fact currently accounts for up to 96% of the renewable energy in the United States. Hydroelectric power generation has the advantage of being able to create large amounts of electricity while producing zero pollutants. It burns no fuel during operation so there is no air pollution and it puts nothing into the water or soil. Outside of the impact of producing concrete and other construction materials hydro power would seem to be the ideal solution to our electrical needs. But what environmental impacts come with hydro power? Everything man-made comes with a price. This article will examine the environmental impact of hydroelectricity.

Building a hydroelectric dam is a huge undertaking. For example, the construction of Hoover Dam, the most famous hydroelectric dam in the United States, produced a tremendous amount of land damage. While the construction firms were busy building Boulder City, Nevada to house the work force, it was necessary to divert the Colorado River from its natural course. Four diversionary tunnels 56 feet in diameter and nearly 3 miles long were blasted through the canyon walls. These tunnels were later incorporated into the dam and form the main bodies of the dam’s spillways. With the river diverted, precautionary cofferdams were built upstream to protect against the river accidentally flooding. The upper cofferdam alone was 96 feet high, 750 feet thick at its base, and contained 650,000 cubic yards of material.

Additionally, two massive concrete plants were built to supply the construction effort, as well as dedicated railways and a series of aerial cableways to move the concrete from each plant to where it was needed on the dam. In all, 4.4 million cubic yards of concrete were used in the construction of Hoover Dam. The dam created Lake Mead by flooding 247 square miles of land behind it. It took 6.5 years to fill Lake Mead, a requirement to prevent small earthquakes from the land settling under the weight of the water. Lake Mead submerged a massive area of land below water which is the most significant impact of hydroelectricity on land, it eliminates it.fail

Even though some dams are built to prevent flooding and increase usable land downstream they occasionally fail causing even larger floods. The video below shows the failure of the Teton Dam when a reservoir wall developed cracks and eventually burst.

The construction of Hoover Dam had a profound impact on the ecosystem of the Colorado River. The river delta estuary once had a saltwater/freshwater mixing zone that reached 40 miles south of the river’s mouth. While the dam was filling, almost no fresh water reached the mouth of the river, allowing salt water to flow upstream. The Colorado River now has an inverse estuary with high salt levels closer to the mouth of the river. Native fish populations were destroyed and four species are currently listed as endangered.

Things become worse if a dam in constructed in an area with high levels of vegetation. When the reservoir behind a dam fills, plants, trees, and leaves, or biomass, will begin to rot. When the Nam Leuk Hydropower Project in Laos was completed, the rotting biomass caused an immediate drop in water quality. The artificial lake created habitats for disease-carrying mosquitoes and snails, increasing the likelihood of outbreaks of malaria, dengue fever, and schistosomiasis. Water quality deteriorated to the extent that useful species of fish disappeared and were replaced by undesirable ones.

Removing the biomass comes with its own problems. The most obvious solution to removing such a huge amount of vegetation would be to cut and burn it. The problem is that burning biomass releases greenhouse gasses into the air. Nutrients such as nitrogen and phosphorous are also released from burning biomass, which in turn would facilitates the growth of bacterial and algae blooms when the reservoir is filled. This can cause a chain reaction of water quality problems that may never go away. Reduced oxygen levels produce fish kills, cyanobacteria release toxic metabolites, and reservoir sediments release toxic substances such as mercury and hydrogen sulfide.

Another unforeseen problem relating to hydroelectric dams and water is droughts and geological changes triggering earthquakes and landslides. The video below outlines these effect after the building of the three gorges dam on the Yangtze river, China.

Perhaps the cleanest form of hydropower, tidal power generation is not without its own environmental problems. A tidal barrage is a dam-like structure that is built across a river estuary to take advantage of the ebb and flow of the tides. Rather than retaining the water, however, a tidal barrage allows it to pass freely through a series of turbines to produce power. A barrage built across an estuary will have a significant impact on the water in its basin (the area upstream of the barrage) and on the fish population as well.

Less water is exchanged between the basin and the sea, reducing the amount of matter suspended in the water (turbidity). As turbidity decreases, sunlight is better able to penetrate the water, creating ideal conditions for the growth of phytoplankton. A larger plankton population causes a ripple effect up the food chain and affects the entire ecosystem. Another result of the decreased amount of water exchange is that less salt water is allowed into the basin, reducing salinity and again affecting the ecosystem particular species that prefer brackish water.

Water flowing down stream toward the sea carries high amounts of sediment with it. This sediment could build up behind and within the barrage, affecting the environment and possibly the operation of the barrage itself. Any pollutants flowing downstream may also become trapped behind the barrage and can become concentrated. If those pollutants were biodegradable, the resulting growth in bacterial may impact human health and the ecosystem.

Fish attempt to swim through the turbines with dire results. When the tides are not moving and the turbines are idle, all is well. When the turbines are in use, however, fish can be sucked into them. The mortality rate for fish passing through a turbine is approximately 15%, which can be devastating for fish that move to and from the basin every day. So far, an effective solution to allow the safe passage of fish around a tidal barrage has yet to be developed although some barrages try to discourage and redirect fish populations through specially designed passages.

Below is a video outlining and discussing the above issues. Is tidal power as “green” as we think?

Although it is considered a clean source of energy, hydroelectric power is not without its environmental problems. The construction of a dam is a tremendous undertaking, one that will leave the footprint of man scarred onto the area for generations. The habitats of many creatures are destroyed by the immense amount of work that goes into building one. Greatest among these causes for concern seems to be water quality issues that arise when the reservoir is filled. If the biomass is not properly removed, the gases released by its decomposition could create an environmental disaster for both humans and animals.

If properly implemented hydroelectric power is one of the cleanest and cost effective ways of producing electricity in the long run. It uses no fuel and produces no pollutants. The cost of producing hydroelectric power is constant. The infrastructure is built to last; dams can last for decades with the proper maintenance. If proper care is taken to protect the environment at the start of a hydroelectric project impact can be minimized.

Environmental Impact of Hydroelectric Dams

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Rivers around the world are being tamed by massive hydroelectric dams, with high-profile projects under construction in Laos and China and several proposed for the ...

“After dam construction, there is an immediate drop in water quality that destroys useful fish populations and poses a threat to livestock and humans,” says Lanza, an aquatic biologist and microbiologist who consults for the environmental organization International Rivers. “Converting river systems into lakes also creates more habitat for the snails and mosquitoes that carry malaria, dengue fever and schistosomiasis, leading to an increase in the number of cases of these diseases.”

Lanza recently critiqued the Nam Theun 2 Hydroelectric Project, a 1,200 foot wide expanse across the Nam Theun River in Laos that will be completed in December 2009. Dam gate closure and reservoir filling will begin in June 2008, and power from the dam will be exported to Thailand as part of the Laotian government's plan to generate export revenue by building more than 30 dams by 2020.

After reviewing the NT2 Environmental Assessment and Management Plan, Lanza worked with International Rivers, and together their efforts helped to convince the Nam Theun 2 Power Company to remove some of the biomass, in the form of fallen trees and leaves, prior to filling the reservoir instead of simply leaving it behind to rot. The experience with Nam Theun 2 has highlighted the importance of clearing biomass from future dam projects, a requirement the Laotian government is reportedly considering.

Lanza says, however, that the Nam Theun 2 biomass clearance plans, which include cutting and burning biomass from part of the reservoir area, may not prevent significant water quality problems. "Burning biomass adds air pollutants, including carbon dioxide, ozone and other greenhouse gasses, and toxic substances such as mercury," he says. "Burning will also release mercury to the soil and greatly accelerate the release of nutrients such as nitrogen and phosphorus from the biomass."

After burning, nutrients from the ash would trigger and support the sudden growth of excess bacteria and algae in the water as the reservoir fills, triggering a cascade of water-quality problems, including greatly reduced dissolved oxygen, fish kills, the formation of toxic metabolites by cyanobacteria and the release of toxic gasses and metals such as hydrogen sulfide and mercury from reservoir sediments.

Leaving the biomass behind would also be problematic, says Lanza, since rotting vegetation would increase greenhouse gas emissions from the reservoir, use the available oxygen in the water, cause fish kills and result in water that was unsuitable for drinking and irrigation.

Lanza started his career as an aquatic ecologist for the Smithsonian Institution in 1971, living in Thailand and doing the detective work to predict the ecological impacts of a proposed hydroelectric dam on the Mekong River. That research led to two new discoveries: a new species of schistosome parasite (the Mekong schistosome), and a new species of snail that transmits the Mekong schistosome. He says it was obvious then that water quality would decrease, and the shores of lake behind the dam would provide the ideal habitat for the snails and insects that carry disease.

In 1996, Lanza reviewed the environmental impact report for the Nam Leuk Hydropower Project in Laos and visited the site after the dam was complete, which reinforced his concerns and confirmed his predictions.

"After the completion of Nam Leuk, there was a sharp drop in the oxygen content of water in the lake and blooms of cyanobacteria that release toxins that are deadly to livestock and can cause liver cancer in humans," says Lanza. "The data show that water-quality problems eliminated useful species of fish that people depend on for food and livelihood, replacing them with less desirable species."

Villagers downstream of the project were experiencing water-quality problems, and the Nam Leuk reservoir provided expanded habitats for the snails and mosquitoes that carry schistosomiasis and malaria, threatening a rise in the number of cases of these diseases.

"Midstream dams are again being proposed for the Mekong River, and we are finding that disease-causing schistosomes are much more prevalent in this area than we originally thought. This must be considered when developing future environmental assessment and management plans," says Lanza.

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http://www.law.fsu.edu/journals/lawreview/downloads/363/clemons.pdf December 07, 2014

comment hydroelectric dams: transboundary environmental effects and international law karlie shea clemons i. introduction ...

COMMENT

HYDROELECTRIC DAMS: TRANSBOUNDARY ENVIRONMENTAL EFFECTS AND INTERNATIONAL LAW

KARLIE SHEA CLEMONS

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J.D., May 2009, Florida State University College of Law 2009; B.S., May 2006, Finance, Florida State University. I would like to thank the Florida State University Law Review's editorial staff for their helpful commentary and advice. Also, special thanks to my friends and family for their constant encouragement.

I. INTRODUCTION

By the year 2050, the human population is expected to increase by more than thirty-five percent.[1] At present, we are thus simultaneously facing pressure for an efficient energy increase,[2] while also trying to adhere to an international regime to slow climate change.

The result is an international struggle between each State's ability to provide efficient and reliable energy while also doing its part to preserve the atmosphere. The major complication to all of this is the question of how far each State will go to accomplish such efficient energy: will a State stay within the bounds of its duties presented by international environmental law and adhere to its duties for environmental and atmospheric preservation, or will it push further with no adherence to either the law or recognition of the environmental harm to its own territory or the territory of others?

This Comment will present and analyze international environmental law as it applies to the construction and use of hydroelectric dams. Overall, this Comment will show that while there are relevant laws, many times a harmed State still has no recourse. To demonstrate this conclusion, this Comment will first provide general background regarding hydroelectric dams and follow with an explanation of the resulting benefits and harms, focusing primarily on environmental concerns. Second, this Comment will identify and thoroughly analyze relevant sources of international environmental law, and it will highlight both strengths and weaknesses of these sources. Third, this Comment will offer specific examples of transboundary agree-

1. U.N. Dep't of Econ. and Soc. Aff., Population Div., World Population Prospects: The 2006 Revision Executive Summary, ¶ 2, U.N. Doc. ST/ESA/SER.A/261/ES [hereinafter World Population Prospects], available at http://www.un.org/esa/population/publications/wpp2006/English.pdf. Specifically, the 2006 Revision estimates that by 2050 the world population will reach 9.2 billion from the 6.7 billion estimate at the time. Id.

2. In addition to needing more energy as a result of increased population, almost two billion people do not have access to affordable energy services at all, particularly in developing countries. U.N. DEV. PROGRAMME ET AL., WORLD ENERGY ASSESSMENT: OVERVIEW, 2004 UPDATE, at 34, U.N. Sales No. E.04.111.B.6 (2004) [hereinafter WORLD ENERGY ASSESSMENT], available at http://www.undp.org/energy/docs/WEAOU_full.pdf; see also World Population Prospects, supra note 1. Thus, an increase in energy sources is necessary in order to alleviate significant health impacts, and such an increase may even raise the level of education, especially for women and children. WORLD ENERGY ASSESSMENT, supra. In order to cook, women and children are forced to spend long periods of time gathering firewood and water. Id. Because of the physical energy required, "women and children often have no opportunities for education and other productive activities, while their health suffers." Id.

ments or, in many situations, the lack of agreements. These examples will illustrate direct application of international laws and portray the extreme deficiencies in enforceability. Lastly, this Comment will offer a brief conclusion regarding both a specific hydroelectric dam dispute and the state of the relevant law in general.

II. BACKGROUND

Hydroelectric dams exist on international watercourses worldwide, and some States even use hydropower as their primary source of energy.[3] There are approximately 45,000 large dams in the world, including both hydroelectric and nonhydroelectric dams.[4] Between 1990 and 1997, hydropower generated approximately 18.5% of the world's electricity, and as of 2004, hydropower accounted for 16% of the world's energy production.[5]

While hydroelectric dams contribute to atmospheric preservation, they still present much concern. Whether these benefits outweigh the concerns is controversial, debatable, and a contributing factor to many international political disputes. The main problem is addressing the issues that arise between States given the applicable international environmental law. While one State may determine that the advantages of a particular hydroelectric dam outweighs the potential disadvantages, another nation, also affected by the potential dam, may not agree. The possibility for this scenario is quite likely since nearly fifty percent of Earth's land surface (not including Antarctica) and sixty percent of all fresh water are part of transboundary water

3. ROY L. NERSESIAN, ENERGY FOR THE 21ST CENTURY: A COMPREHENSIVE GUIDE TO CONVENTIONAL AND ALTERNATIVE SOURCES 290-91 (2007) (noting that sixty-five countries rely on hydropower for more than fifty percent of their electricity generation); see also Mustafa Balat, Electricity from Worldwide Energy Sources, 1 ENERGY SOURCES PART B: ECON. PLAN. & POL'Y 395, 401 (2006) (citing G. Bergkamp et al., Dams, Ecosystem Functions, and Environmental Restoration (2000)). Canada is the largest producer of hydroelectric power, followed by Norway and the United States. Id.

Hydroelectric power, also known as hydropower, refers to the process of using water's energy to create electricity. U.S. Dep't of Energy, Wind and Hydropower Technologies Program: How Hydropower Works, http://www1.eere.energy.gov/windandhydro/hydro_how.html (last visited June 1, 2009) [hereinafter How Hydropower Works]. While several types of hydropower plants exist, this Comment specifically pertains to hydroelectric dam use through an impoundment facility, which is the most common type of hydroelectric power facility. U.S. Dep't of Energy, Wind & Hydropower Technologies Program: Types of Hydropower Plants, http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html (last visited June 1, 2009). Once a dam is built, a reservoir (an artificial man-made lake) is created on the upstream side of the dam. See id. When it is time to generate electricity, water is released from the reservoir, moving through a turbine creating energy. Id. This energy is then put onto the electrical grid and eventually used in homes, businesses, and industries. How Hydropower Works, supra.

4. NERSESIAN, supra note 3, at 290-91.

5. Id. at 300.

basins, meaning that the majority of Earth's water is shared water.6 When faced with disputes, a harmed State is ultimately left only to rely on sources of international environmental law for guidance.

III. BENEFITS OR HARMS: WHICH PREVAILS?

A. Benefits

In comparison to other existing forms of energy production, the most notable benefit of hydropower is that hydroelectric dams do not directly emit greenhouse gasses.7 Specifically, since water is the main component of hydropower generation, burning of coal or use of either oil or fuels is not necessary.8 Likewise, the water used—and thus the river as a whole—is not polluted.9 Additionally, although the construction of hydroelectric dams and their turbines is quite costly,10 the cost of energy generation is rather inexpensive.11

In comparison to other sources of energy production, hydroelectric dams also provide power that is both predictable and reliable.12 These dams allow the storage of water (in the reservoir) until it is needed and then allow a rapid increase in energy production (more

6. Water Encyclopedia, Transboundary Water Treaties, http://www.waterencyclopedia.com/St-Ts/Transboundary-Water-Treaties.html (last visited June 1, 2009) ("A transboundary waterway is defined as all territory which contributes to a stream, at least one of the tributaries of which crosses a boundary."); see also LUDWIK A. TECLAFF, THE RIVER BASIN IN HISTORY AND LAW 42-46 (1967) (emphasizing, through multiple examples, the vast amount of trade that was facilitated because of the existence of a large number of transboundary rivers and noting that "[t]he influence of the physical unity of the basin proved stronger than political divisions").

7. See U.S. Dep't of Energy, Wind and Hydropower Technologies Program: Advantages and Disadvantages of Hydropower, http://www1.eere.energy.gov/windandhydro/hydro_ad.html (last visited June 1, 2009); see also Thomas Moran, The Environmental and Socio-Economic Impacts of Hydroelectric Dams in Turkish Kurdistan 24-25 (June 10, 2004) (unpublished thesis, Roskilde University), available at http://rudar.ruc.dk/handle/1800/403.

8. See WILLIAM WHIPPLE, JR., WATER RESOURCES: A NEW ERA FOR COORDINATION 64-65 (1998); see also U.S. Dep't of Energy, supra note 7.

9. See NERSESIAN, supra note 3, at 291.

10. Id.; see, e.g., NASA Satellites Watch as China Constructs Giant Dam, SCIENCEDAILY, June 13, 2007, http://www.sciencedaily.com/releases/2007/06/070612134358.htm (stating that the total construction cost of the Three Gorges Dam on the Yangtze River in China, which is now the largest hydroelectric dam in the world, was at least $625 billion).

11. NERSESIAN, supra note 3, at 291 (noting that "hydropower has no fuel cost and a low operating cost"); see also 25x'25, Why Renewables: Hydroelectric and Tidal Power, http://www.25x25.org/index.php?option=com_content&task=view&id=19&Itemid=48 (last visited June 1, 2009). "25x'25" is an alliance originally created by a group of farm leaders who had a goal of obtaining twenty-five percent of America's energy from renewable sources—such as wind, solar, and biofuels—by 2025. About 25x'25, http://www.25x25.org/index.php?option=com_content&task=view&id=12&Itemid=41 (last visited June 1, 2009).

Additionally, hydroelectric power can be highly automated. See U.S. Dep't of Energy, supra note 7 (noting that engineers can control the amount of water flowing through the turbines to "produce electricity on demand").

12. 25x'25, supra note 11.

quickly than power plants using fossil fuel for energy production) during periods of higher demand.13

Similar to other types of dams, hydroelectric dams also serve as a flood control mechanism.14 Compared to a river functioning in its natural state, a dam can maintain more water in the reservoir and thus allow less water to move downstream.15 Many times, this can protect downstream communities from flooding.16

Additional indirect benefits of hydroelectric dam construction are that it "[e]nhances knowledge and improves management of valued species due to study results" and that it can sometimes create new freshwater ecosystems which are more productive.17 Immediately after floods, fish populations typically increase because the floods "enable fish to move out into floodplain[18] wetlands to feed and reproduce."19 Similarly, floods recharge groundwater supplies and wetlands and natural fertilize farmland.20

B. Harms

Despite the undoubted benefits, many still feel that hydroelectric dams present serious environmental concerns, which should be considered in conjunction.21

1. Methane Gas and Carbon Dioxide Emissions

Hydroelectric dams are considered a "clean" source of renewable energy22 because they do not directly emit greenhouse gases. However, evidence that dams' reservoirs emit methane gas may arguably

13. Id.

14. Id.

15. See id.

16. Id. But see infra text accompanying notes 84-86 (questioning dams' efficacy in protecting downstream communities).

17. Moran, supra note 7, at 25.

18. A river's floodplain is an important part of the river system. Institute for Ecological Health, Floodplain Management, http://www.instituteforecologicalhealth.org/floodplain_management.html (last visited June 1, 2009). In a river's natural state, "a dynamic river will move its course to and fro over a long time frame . . . . Riparian vegetation and wetlands associated with streams and rivers are essential habitats for a great number of animal and plant species." Id.

19. Misty Herrin, The Nature Conservancy, China: Minimizing Dam Impact on the Yangtze River, http://www.nature.org/wherewework/asiapacific/china/features/

yangtzedams.html (last visited June 1, 2009) (interview with Qiaoyu Gou, Project Manager, The Nature Conservancy's China Program).

20. Id.

21. See NERSESIAN, supra note 3, at 291.

22. Environmental Literacy Council, Hydroelectric Power, http://www.enviroliteracy.org/article.php/59.html (last visited June 1, 2009) [hereinafter ELC, Hydroelectric Power]. The Environmental Literacy Council is an independent, non-profit organization providing general environmental science information for educators and the public. Environmental Literacy Council, About Us, http://www.enviroliteracy.org/subcategory.php?id=1 (last visited June 1, 2009).

refute the claim that these dams are environmentally friendly.23 Essentially, "man-made reservoirs convert carbon dioxide in the atmosphere into methane."24 According to critics, in tropical areas of Brazil where large dams produce more than ninety percent of electricity, the dams' reservoirs emit such a high amount of methane gas that the dams' contribution to climate change is even greater than that of equivalent fossil fuel power plants.25 For example, estimates show that the Balbina Dam in Brazil produces between twenty and forty times more carbon dioxide than power plants using coal.26 According to the estimates of Philip Fearnside of Brazil's National Institute for Research in the Amazon in Manaus, such high emission rates are from carbon that is "tied up in trees and other plants [which is] released when the reservoir is initially flooded and the plants rot."27 After the initial decay, plant parts then settle on the floor of the reservoir and continue to decompose, which results in an increase of dissolved methane because the plants are decomposing with no oxygen.28 When water passes through the turbine, this dissolved methane is released into the air.29 Fernando Ramos, lead scientist for the National Space Research Institute (INPE) in Brazil, stated that " '[i]t's like opening a bottle of soda. A large part of the methane is dissolved in the water bubbles, and it's released to the atmosphere.' "30

While great uncertainty exists as to how much methane hydroelectric dams actually emit into the atmosphere,31 INPE scientists estimate that large dams may be responsible for worldwide annual emissions of 800 million tons of carbon dioxide, whereas the United Kingdom's total greenhouse gas emissions in 2006 was around 660 million tons.32

23. See Duncan Graham-Rowe, Hydroelectric Power's Dirty Secret Revealed, NEWSCIENTIST, Feb. 24, 2005, http://www.newscientist.com/article.ns?id=dn7046; Tim Hirsch, Project Aims to Extract Dam Methane, BBC NEWS, May 10, 2007, http://news.bbc.co.uk/1/hi/sci/tech/6638705.stm.

24. Graham-Rowe, supra note 23.

25. Id.

26. International Rivers, Frequently Asked Questions About Dams, http://www.internationalrivers.org/en/node/480 (last visited June 1, 2009) [hereinafter Frequently Asked Questions About Dams].

27. Graham-Rowe, supra note 23.

28. Id.

29. Id.

30. Hirsch, supra note 23.

31. See id. Each dam may emit different levels of methane gas. Id. The amount of methane gas emitted depends on, among other things, the amount of vegetation in the water, the water's temperature, and the reservoir's shape. Id.

32. Id. Although not within the scope of this Comment, it is relevant to note that the INPE scientists have proposed that "with relatively simple technology, this unwanted by-product of hydro-electric power generation could be turned into an extra source of clean, renewable electricity." See id. (providing a brief note on and a detailed chart regarding such technology).

2. River Flow and Affected Ecosystems

Freshwater ecosystems provide many things that humans depend on, such as "food and fiber, water purification," and "fish and wildlife."33 But in order to provide these things, freshwater ecosystems are dependent upon the "cycling of water and on functioning ecological processes and species assemblages."34 In order to maintain the health of these ecosystems, the water must maintain a particular level of both quality and quantity.35 Thousands of species and activities depend upon freshwater ecosystems.36 Specifically, approximately forty percent of fish are of a freshwater species and approximately 200 new freshwater species are identified yearly.37 And, of the 10,000 freshwater species that have already been identified, approximately 2,000 are already endangered, vulnerable, or extinct.38 Given the large number of species relying on these ecosystems and the number of these species that are endangered and vulnerable, maintaining the ecosystems is of grave importance.39

The most significant environmental impact of hydroelectric dams is, arguably, the alteration of the affected river's flow.40 When river flows are altered, it is not merely the visible appearance of the river that is changed. Rather, it is a cycle that has much deeper impacts—even beyond the river itself.41

(a) Natural Flooding

While flood control is undoubtedly beneficial to some extent, especially for those who would otherwise lose their communities and businesses, arguably "[t]he elimination of the benefits provided by

33. Karin M. Krchnak, The Nature Conservancy, "Greening" Hydropower: Integrating Environmental Flow Considerations 2 (2006), http://www.nature.org/initiatives/freshwater/files/hydropower_2006_krchnak_paper_final.pdf.

34. Id.

35. Id.

36. Id.
37. Id.
38. Id.
39. See id.
40. International Rivers, Environmental Impacts of Dams, http://internationalrivers.org/en/node/1545 (last visited June 1, 2009) [hereinafter Environmental Impacts of Dams]. Note that this impact is caused by other types of large dams as well. Id. Also note that hydroelectric dams impact groundwater and wetlands. See Krchnak, supra note 33, at 2. Other than general references, however, these issues are outside the scope of this Comment.
41. See infra Part III.B.2 (focusing on the harms to a river's flow and surrounding ecosystem caused by hydroelectric dam construction and use).

natural flooding may be the single most ecologically damaging impact of a dam."42

Biologists generally recognize dams as the most damaging of the sources that contribute to the disappearance of riverine species.43 The loss of natural flooding affects river and floodplain ecosystems overall. Such ecosystems "are closely adapted to a river's flooding cycle. The native plants and animals depend on its variations for reproduction, hatching, migration, and other important lifecycle stages. Annual floods deposit nutrients on the land, flush out backwater channels, and replenish wetlands."44

(b) Ecosystem Fragmentation

Damming a river fragments the riverine ecosystem by isolating the upstream and downstream ecosystems and cutting off species' migration habits;45 this causes serious changes to species' historical spawning habits.46 For example, in the current construction of the Brazilian Madeira River hydroelectric dams,47 catfish have become "the main symbol of the controversy."48 These fish have an intricate 2,000-mile migration to the "mouth of the Amazon," and, according to experts, the dams will disrupt this migration.49 River ecosystem fragmentation has resulted in a serious reduction in watershed species.50 For example, in the Northwest United States, as a result of hydroelectric dam construction (among other reasons, such as over-

42. PATRICK MCCULLY, SILENCED RIVERS: THE ECOLOGY AND POLITICS OF LARGE DAMS 31 (2001).
43. Lori Pottinger, International Rivers, Environmental Impacts of Large Dams: African Examples (Oct. 1, 1996), http://www.internationalrivers.org/en/africa/environmental-impacts-large-dams-african-examples.
44. Id.
45. MCCULLY, supra note 42, at 31; see also WHIPPLE, supra note 8, at 65. It should be noted that certain technologies have been used on hydroelectric dams in order to alleviate some fish migration problems. See WHIPPLE, supra note 8, at 66-67 ("[T]he dams on the Columbia [River] and many other rivers have fish ladders, which are quite efficient in allowing movement of adult fish migrating upstream in order to spawn. However, the problems of moving the immature 'fingerlings' downstream after spawning have proved much more difficult to handle.").
46. See generally D.D. Dauble et al., Impacts of the Columbia River Hydroelectric System on Main-Stem Habitats of Fall Chinook Salmon, 23 N. AM. J. FISHERIES MGMT. 641 (2003) (describing the changes in the spawning habits and the resulting decrease in anadromous fish run populations in the Columbia and Snake rivers as a result of hydroelectric dams).
47. See infra Part VI.C.
48. Larry Rohter, Both Sides Say Project Is Pivotal Issue for Brazil, N.Y. TIMES ONLINE, June 11, 2007, http://www.nytimes.com/2007/06/11/world/americas/11amazon.html.
49. Id.
50. MCCULLY, supra note 42, at 31. It is noteworthy, however, that species isolation may be beneficial for some species, because dams provide a reservoir that allows for the creation of habitat for lake fish. Id. Additionally, the increase in the amount of cool water—released as a result of creation of the reservoir—may allow some fish to thrive that could not have done so when the water was warm. Id.

fishing) on the Columbia River, anadromous fish populations have decreased from an average of 10 to 16 million fish per year at the beginning of the twentieth century to an annual run size of only 2.5 million.51

Currently, the exact global extent of river ecosystem fragmentation caused by dams has not been determined.52 However, Swedish ecologists, Mats Dynesius and Christer Nilsson, from the University of Umeå,

> estimated the degree of damage to river systems in the US, Canada, Europe and the former USSR. . . . [and] found that fully 77 per cent of the total water discharge of the 139 largest river systems in these countries is 'strongly or moderately affected by fragmentation of the river channels by dams and by water regulation resulting from reservoir operation, interbasin diversion and irrigation'.53

Dynesius and Nilsson also concluded that " '[a]s a result of habitat destruction and obstruction to organism dispersal,' . . . 'many riverine species may have become extinct over vast areas, whereas populations of others have become fragmented and run the risk of future extinction.' "54

(c) Sediment Displacement

Sedimentary deposits, to both river channels and banks, are pertinent: "too much sediment can aggrade channels and cause flooding problems, whereas erosion of sediment can degrade habitat."55 While natural sediment levels vary between regions of the world (and thus sedimentation affects areas differently) according to the World Commission on Dams, assuming that no controls are implemented to control sedimentation, in the next twenty-five to fifty years, reservoir

51. Dauble et al., supra note 46, at 641 ("Although the exact amount of fish lost to hydropower development is uncertain, salmonid habitats in the main-stem Columbia and

Snake rivers have changed dramatically during the past 60 years. For example, many areas where salmonids spawned are now a series of low-velocity impoundments, and access to other habitats is blocked by impassable barriers.”). For a more recent example of a major reduction in freshwater species resulting from dam construction, see infra notes 334-37 and accompanying text, which discuss a recent “mass killing” of fish during the initial construction phases of the Santo Antonio dam in Brazil.

52. MCCULLY, supra note 42, at 31; accord, e.g., Dauble et al., supra note 46, at 641.

53. MCCULLY, supra note 42, at 31.

54. Id.

55. MICHAEL COLLIER ET AL., U.S. DEPT. OF THE INTERIOR, CIRCULAR NO.1126, DAMS AND RIVERS: A PRIMER ON THE DOWNSTREAM EFFECTS OF DAMS, U.S. GEOLOGICAL SURVEY 3 (2d rev. ed. 2000).

sedimentation will eliminate twenty-five percent of the world’s storage capacity for fresh water.56

In a river’s normal state, sediments allow natural replenishment of the downstream ecosystems by moving sediments downstream and depositing them along the riverbeds and river banks; this essentially serves as a natural fertilizer.57 A dam, however, captures these natural sediments and prevents them from moving downstream, thus depriving the downstream portion of the river.58 When a river is deprived of normal sediment placement, the river seeks to nourish itself by eroding the river’s bank and downstream riverbed.59 This can even undermine bridges and structures built along the riverbank.60 Within a decade of a dam’s initial operation, downstream riverbeds may be eroded by several meters, and damage may even be felt hundreds of kilometers downstream of the dam.61

Sediment reduction also affects the fish and wildlife relying on the natural sediment process.62 For example, because sediment reduction causes the water to become clearer, many fish and wildlife species will be at greater risk of danger because they are less camouflaged.63

A river’s loss of natural sediments also affects the upstream portion of the river.64 Just as the downstream portion of the river is deprived of these valuable sediments, a dam’s reservoir can be damaged by an accumulation and buildup of these same sediments.65 Because sediments and nutrients are trapped behind the dam, the lack of water flow is then likely to cause growth and spread of algae and other aquatic weeds.66 Further, due to lack of movement, water in the reservoir becomes stagnant, resulting in loss of oxygen.67 Ultimately, this cycle can reduce the number of organisms living in the reservoir.68 In extreme cases, sediment buildup can put additional pressure on the dam itself, which can actually weaken the dam.69

56. Moran, supra note 7, at 22-23 (noting that “the WCD predicts that most of the global loss of fresh water storage capacity will occur in the developing countries as well as those with higher sedimentation rates”).

57. Environmental Impacts of Dams, supra note 40.

58. Id; see, e.g., infra note 322 and accompanying text (describing study of the expected effects of Brazil’s Madeira River dam projects with regard to sedimentation).

59. Environmental Impacts of Dams, supra note 40.

60. Id.

61. Id.

62. See Moran, supra note 7, at 23.

63. Id. at 24.

64. See id. at 23-24.

65. Id. at 22.

66. ELC, Hydroelectric Power, supra note 22.

67. Moran, supra note 7, at 23.

68. Id.

69. Id. at 22.

Groundwater pollution may also result from sediment deprivation.70 Specifically, farmers downstream who rely on the water as a source of fertilizer are then forced to use substitute types of fertilizer, which may ultimately pollute both the river and the related groundwater.71

3. Cultural, Historical, and Health Concerns

The human effect is one of the most significant harms of hydroelectric dams.72 The initial construction itself results in mass numbers of individuals losing their homes, villages, communities, and ways of life.73 Consider the Three Gorges Dam on the Yangtze River in China, for example.74 It was anticipated that the rising waters of the expansive reservoir could submerge over 140 towns, 326 townships, and 1,351 villages, causing over one million people to be moved from the general area.75

The World Commission on Dams estimated that between forty and eighty million people have been physically displaced,76 but this may be a conservative estimate. The World Bank estimates that approximately four million people are displaced annually from “approximately 300 large dams (above 15m high) that on average enter construction phase annually.”77 This number, however, does not account for those whose livelihoods are affected by dams.78 For example, a city’s unemployment may ultimately rise as a result of dam construc-

70. Id.

71. Id.

72. While the social and economic impacts of hydroelectric dams are important and relevant to a State’s construction decision, they are outside the scope of this Comment.

73. See Matthew Coon Come, Survival in the Context of Mega-Resource Development: Experiences of the James Bay Crees and the First Nations of Canada, in IN THE WAY OF DEVELOPMENT: INDIGENOUS PEOPLES, LIFE PROJECTS AND GLOBALIZATION 153, 155 (Mario Baser et al. eds., 2004). Matthew Come described the effects of development on indigenous communities in Northern Canada in the early 1970s:

> In 1972 I was a young student . . . , and I read in the newspaper one day about Quebec’s ‘hydroelectric project of the century’. [sic] I looked at a map and saw that my community’s lands at Mistissini were to be submerged because they were going to use Lake Mistissini as a reservoir. It was then that our people

realized that the plans of Hydro-Quebec to dam and divert more than a dozen rivers in our territory would spell an end to our way of life.

Id.; see also ELC, Hydroelectric Power, supra note 22.

74. See infra Part III.C.

75. DAI QING, THE RIVER DRAGON HAS COME!: THE THREE GORGES DAM AND THE FATE OF CHINA'S YANGTZE RIVER AND ITS PEOPLE 41, 52 (John G. Thibodeau & Philip B. Williams eds., Yi Ming Trans., 1998).

76. THAYER SCUDDER, THE FUTURE OF LARGE DAMS: DEALING WITH SOCIAL, ENVIRONMENTAL, INSTITUTIONAL AND POLITICAL COSTS 22 (2005); WORLD COMM'N ON DAMS, DAMS AND DEVELOPMENT: A NEW FRAMEWORK FOR DECISION-MAKING 104 (2000), available at http://www.dams.org//docs/report/wcdreport.pdf.

77. SCUDDER, supra note 76, at 22.

78. Id.

tion because farmers are displaced as a result of their land being flooded for the creation of the reservoir.79

Even if river dwellers are not physically displaced by dam construction, they are still impacted. Where dam construction blocks migration and ultimately causes complete or partial diminishment of a species, river dwellers relying on those species also suffer.80 For example, in the case of the Madeira River construction in Brazil,81 fish species likely to be negatively affected (which some claim could become extinct) serve as the main protein source of those living along the Madeira and Amazon.82 Additionally, since these fish provide economically for people living along the rivers,83 elimination of the species in the area would, presumably, further contribute to the large number of indigent people in the area.

Another problem is overreliance on dams as flood protection.84 Often times, this reliance may prove to be a "false sense of security" during large floods, when dams are not sufficient to hold back all of the water.85 Specifically, reliance has led people to increase development in floodplains, and thus during large floods the resulting damage may be even greater than it otherwise would have been without the dam.86

C. Three Gorges Dam: Yangtze River, China

The Three Gorges Dam project on the Yangtze River in China demonstrates the difficulty of striking a balance between the benefits and harms of hydroelectric dams. The dam was structurally completed in May 2006 and is the world's largest reinforced concrete hydroelectric dam.87 In late 2008, the final generating unit was installed, and on March 3, 2009, the project announced that, like the other twenty-five generating units, the final generating unit had suc-

79. Moran, supra note 7, at 7.

80. See, e.g., Glenn Switkes, The Americas Program, Brazilian Government Moves to Dam Principal Amazon Tributary 2 (2007), http://americas.irc-online.org/pdf/reports/0706amazon-eng.pdf.

81. Id.; see also infra Part VI.C.

82. Switkes, supra note 80, at 2. For a recent "mass killing" of these fish along the Madeira River, see infra notes 334-37 and accompanying text.

83. Id.

84. See Institute for Ecological Health, supra note 18.

85. Id.

86. See Bob Schildgen, Unnatural Disasters, SIERRA MAG, May-June 1999, available at http://www.sierraclub.org/sierra/199905/floods.asp.

87. Three Gorges Dam Wall Completed, BBC NEWS, May 20, 2006, http://news.bbc.co.uk/2/hi/asia-pacific/5000092.stm. Proposals for dam construction on the Yangtze River date back to around 1918, but such a project was not actually accepted until 1992 and not actually begun until 1994. See China Three Gorges Project, History, http://www.ctgpc.com/history/history_a.php (last visited June 1, 2009).

cessfully operated for its first 100 days.88 The completed reservoir spans 401 square miles.89

Construction of the Three Gorges Dam has always been, and remains, controversial—especially between scientists who claim that the dam will cause extreme environmental harm and the political proponents within the Chinese government.90 The Chinese government supported the dam for two main reasons—energy generation and flood control.91 Regarding energy generation, in comparison to coal-fired power stations with electricity generation, the plant will decrease carbon dioxide emissions by 100 million tons and will help prevent acid rain and the greenhouse effect.92 And, with regard to flood control, the Yangtze River is known to have devastating floods; for example, a flood in 1998 affected 300 million people.93 Previous estimates predicted that upon completion, the flood control standard would be upgraded from preventing floods categorized as less than 10-year floods to preventing 100-year floods.94 Estimates show that this upgrade will relieve approximately 15 million people and 1.5 million hectares of farmland from flooding.95

In addition to these main goals, the Chinese government intended the dam to increase navigability, which would extend the travel route into China's mainland.96 The ultimate hope for this navigability

88. China Three Gorges Project, All 26 Generating Units in Smooth Operation for First 100 Days, http://www.ctgpc.com/news/news1.php?NewsId=32399 (last visited June 1, 2009).

89. NASA Satellites Watch as China Constructs Giant Dam, supra note 10.

90. See generally Jim Yardley, Chinese Dam Projects Criticized for Their Human Costs, N.Y. TIMES, Nov. 19, 2007, available at http://www.nytimes.com/2007/11/19/world/asia/19dam.html.

91. Samuel Robert Fishleigh Allin, An Examination of China's Three Gorges Dam Project Based on the Framework Presented in the Report of the World Commission on Dams 16-17 (Nov. 30, 2004) (unpublished Master's thesis, Virginia Polytechnic Institute and State University), available at http://scholar.lib.vt.edu/theses/available/etd-12142004-125131/unrestricted/SAllin_010304.pdf. Chinese Government documents, especially those released by the Ministry of Water Resources, commonly note

> that overall ecosystem enhancement will occur because of the [Three Gorges Dam]. This will include the establishment of new ecosystems supported by the [Three Gorges Dam] reservoir and better, more controlled conditions in the areas downstream of the dam. Based on the literature and findings of the WCD, this statement should be questioned. There are a few recognized ecosystem benefits that occur from the construction of large dams, however the net environmental effect is almost always negative.

Id. at 22-23.

92. China Three Gorges Project, Environment, http://www.ctgpc.com/environmental/environmental_a.php (last visited June 1, 2009).

93. Allin, supra note 91, at 16 (citations omitted).

94. China Three Gorges Project, Biggest Flood Control Benefit in the World, http://www.ctgpc.com/benefifs/benefifs_a.php (last visited June 1, 2009).

95. Id.

96. Allin, supra note 91, at 17.

increase was to "cause the emergence of new markets, job creation, and economic vitality."97 Earlier estimates provided that when complete, as it now is, the annual one-way navigation capacity of the Yangtze River at the dam would increase from ten million to fifty million tons.98 Yet another goal of the Chinese Government was accessibility to fresh water.99 The dam was projected to increase fresh water access for both agriculture and consumption purposes.100

While many economic benefits are (or at least are expected to be) derived from construction and operation of the Three Gorges Dam, the environmental concerns may arguably undermine these benefits.101 Currently, obvious problems caused by the dam include drastic changes to the river's water temperature, silt levels, and seasonal fluctuations in the river's flow.102 Additionally, significant amounts of reservoir greenhouse gas emissions will result from vegetation breakdown, silt, and other organics, which decompose at the bottom of the reservoir.103 Thus, the alleged "clean energy" theory for the Three Gorges Dam is undermined because of these reservoir greenhouse gas emissions.104 Furthermore, silting may eventually cause an increase in flooding because of silt buildup in the dam's reservoir.105 Even more extreme is that this silt buildup may "reduce the effectiveness of power generation schemes, while upstream siltation may impact navigability."106

The downstream portion of the river is also affected by this silt buildup in the reservoir. This buildup results in less silt flowing downstream, thus compromising the river's ability to naturally replenish itself.107 Loss of nutrients then reduces "fertility" of the agricultural lands downstream,108 and the "[d]isruption of the natural distribution and timing of streamflow disrupt[s] aquatic ecosystems."109

After supporting the Three Gorges Dam project for over a decade, on September 26, 2007, China's Communist Party gave a firm warning that unless preventative measures were quickly taken, an environmental disaster was approaching for the areas surrounding the

97. Id.

98. China Three Gorges Project, Remarkable Navigation Benefit, http://www.ctgpc.com/benefifs/benefifs_a_3.php (last visited June 1, 2009).

99. Allin, supra note 91, at 17.

100. Id.

101. NERSESIAN, supra note 3, at 301.

102. Allin, supra note 91, at 20.

103. Id. at 19.

104. Id.

105. Id. at 20.

106. Id.

107. Id. at 20-21.

108. Id. at 20.

109. Id.

dam and that the same areas were paying a serious and possibly catastrophic environmental cost.110 Further, Wang Xiaofeng, the director of the administrative office that built the dam, noted that "it was time to face up to the environmental consequences of a project hailed as an achievement to rival the Great Wall."111 Specifically, Xiaofeng stated: " 'We absolutely cannot relax our guard against ecological and environmental security problems sparked by the Three Gorges project. We cannot win passing economic prosperity at the cost of the environment.' "112

Overall, while there are nonenvironmental benefits resulting from the Three Gorges Dam and hydroelectric dams in general, there are many negative environmental impacts, which a State should thoroughly analyze when deciding whether to construct such a dam. The previous discussion of the Three Gorges Dam demonstrates the seriousness of dams' potential environmental harm and shows one State's realization that further analysis of the benefits and harms was necessary: "It was hailed as one of the engineering feats of the 20th century. Now the Three Gorges Dam across China's mighty Yangtze River threatens to become an environmental catastrophe."113

IV. INTERNATIONAL ENVIRONMENTAL LAW

Beyond the actual environmental impacts on a State, an additional concern is that dam construction may also cause harm to the other States that have rights to the same transboundary watercourse. Thus, the focus of this Comment now turns to the relevant sources of international environmental law in an attempt to address States' legal duties in the construction and use of hydroelectric dams.

International environmental law, while not as well established or readily enforceable as many States' domestic law, essentially operates through customary international law and treaties.114 Customary

110. Jane Macartney, Three Gorges Dam Is a Disaster in the Making, China Admits, TIMES ONLINE, Sept. 27, 2007, http://www.timesonline.co.uk/tol/news/world/article2537279.ece.

111. Id.

112. Id. For a further look at the events surrounding these comments by the Chinese government, see generally Yardley, supra note 90, and Jim Yardley, China Says Three Gorges Dam Is Not Responsible for Landslides, N.Y. TIMES, Nov. 28, 2007, available at http://www.nytimes.com/2007/11/28/world/asia/28gorges.html.

113. Macartney, supra note 110.

114. Customary International Law consists of principles that have become standard either in a particular region or internationally; such practices are "undertaken out of a sense of legal obligation (the opinio juris)." Joseph W. Dellapenna, Treaties as Instruments for Managing Internationally-Shared Water Resources: Restricted Sovereignty vs. Community of Property, 26 CASE W. RES. J. INT'L L. 27, 33 (1994) (citation omitted). "Practices that crystallize as customary international law can include multilateral decisions reflected in votes in international assemblies, decisions by international courts or international arbitrators, or apparently unilateral actions of states. Even treaties or other international agreements can express customary rules of international law." Id. at 34 (citations omitted).

international law is binding on all States, and a particular treaty is binding on those States that have signed on.115

For clarity purposes, this Section is organized by first detailing those broad themes of international environmental law that, among many other issues, are relevant to transboundary watercourses. Next, this Section will present several sources of international environmental law specifically applicable to transboundary watercourses and thus applicable to hydroelectric dam construction and use on such waters. Finally, this Section will focus on recurring themes presented in these sources, highlight strengths and weaknesses, and discuss the enforceability of these sources.

A. Broad Sources of International Environmental Law

1. Relevant Sources

Both the Declaration of the United Nations Conference on the Human Environment ("Stockholm Declaration"),116 adopted in 1972, and the Rio Declaration on Environment and Development ("Rio Declaration"),117 adopted in 1992, present general principles of international law that are applicable to, among other issues, transboundary watercourses and hydroelectric dams.118 While neither the Stockholm Declaration119 nor the Rio Declaration were originally binding,120

Customary international law, however, is not sufficient to deal with all global environmental problems; "even on the most optimistic view, customary international law can hardly be said to have sufficient scope or content to prevent damage and provide sufficient sanctions to be directed against the perpetrators of the damage when it occurs." INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY 14 (Anthony D'Amato & Kirsten Engel eds., 1996).

115. See generally INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 109.

116. United Nations Conference on the Human Environment, Stockholm, Swed., June 5-16, 1972, Declaration of the United Nations Conference on the Human Environment, U.N. Doc. A/CONF.48/14 (June 16, 1972), revised by U.N. Doc. A/CONF.48/14/Corr.1 (1972), reprinted in 11 I.L.M. 1416 (1972) [hereinafter Stockholm Declaration]. The Stockholm Declaration was adopted after the United Nations Conference on the Human Environment met in Stockholm from June 5 through June 16, 1972. Id. The Conference adopted this declaration after it "considered the need for a co[m]mon outlook and for common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment." Id.

117. Twenty years after the Stockholm Declaration was created, the Rio Declaration on Environment and Development was adopted following the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil from June 3 through June 14, 1992. United Nations Conference on Environment and Development, Rio de Janeiro, Braz., June 3-14, 1992, Rio Declaration on Environment and Development, U.N. Doc. A/CONF.151/5/Rev. 1 (June 13,1992), reprinted in 31 I.L.M. 874 (1992) [hereinafter Rio Declaration]. Endorsed by 172 nations, the declaration reaffirms the Stockholm Declaration and builds on it, "[w]ith the goal of establishing a new and equitable global partnership through the creation of new levels of cooperation among States." Id.

118. See id.; see also Stockholm Declaration, supra note 116.

119. See Stockholm Declaration, supra note 116 (describing itself as "common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment," as opposed to requiring such actions); see also INTERNATIONAL

even on those States that signed on to the Declarations, each offers much to the field of international environmental law.121 The Stockholm Declaration, in particular, has proven especially influential in the field of international environmental law,122 as it was the first "widely accepted effort to set forth basic concepts and principles," and certain Stockholm principles are indeed considered customary international law.123 At present, the Rio Declaration has not received such widespread acceptance; however, certain Rio principles are accepted as customary international law and are therefore binding.124

2. Relevant Themes

(a) Development and Resource Exploitation

The well-established Principle 21 of the Stockholm Declaration,125 which is widely considered customary international law,126 provides that States have "the sovereign right to exploit their own resources pursuant to their own environmental policies."127 Important, howev-

ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 17 ("The view prevailed that the [Stockholm] Declaration should merely outline 'broad goals and objectives . . . .' ").

120. JOHN O'BRIEN, INTERNATIONAL LAW 555-56 (2001); see also Rio Declaration, supra note 117 (providing that its "goal" was to "establish[] a new and equitable global partnership through the creation of new levels of cooperation among States," but not mentioning any requirement of such cooperation).

121. See DAVID HUNTER ET AL., INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 464-66 (3d ed. 2007).

122. See Said Mahmoudi, Introduction to CTR. FOR OCEANS LAW & POLICY, THE STOCKHOLM DECLARATION AND LAW OF THE MARINE ENVIRONMENT 3, 3-4 (Myron H. Nordquist et al., eds. 2003) ("The Stockholm Conference and the declaration that the participating States adopted at the end of the conference are generally considered as the starting point for what constitutes today the modern international law and policy for the environment."); id. at 3 ("The significance of the Stockholm Declaration lies in the fact that despite

all the obstacles and lack of genuine political will on the part of a great number of States, it succeeded in laying down a number of general principles that since then have constituted a framework and a source of reference whenever a step has been taken for the international protection of the environment."); id. at 4 ("Repeated references to the Stockholm Declaration in almost all major international environmental agreements show that the Declaration is indeed a milestone and the starting point for the body of laws and policies that today apply to the protection of the environment at the international level.").

123. Alexandre Kiss, The Destiny of the Principles of the Stockholm Declaration, in THE STOCKHOLM DECLARATION AND LAW OF THE MARINE ENVIRONMENT, supra note 122, at 53, 59 (noting that Stockholm Principles 1 and 21 "have been developed into customary rules").

124. Id.; see, e.g., infra text accompanying notes 137-39.

125. The Rio Declaration adopted this same concept in Rio Principle 2. See Rio Declaration, supra note 117, princ. 2. The only change made, in comparison to Stockholm Principle 21, was the addition of the words "and developmental" to then read, in relevant part, "the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies." Id. (emphasis added). This was added presumably because of the overall theme of development focused on by the Conference.

126. HUNTER ET AL., supra note 121, at 465.

127. Stockholm Declaration, supra note 116, princ. 21; see also INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 19.

er, is that this right to exploit comes with a major exception.128 Principle 21 requires that States "ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."129 Principle 14 of the Stockholm Declaration provides guidance by stating that to "reconcil[e] any conflict between the needs of development and the need to protect and improve the environment,"130 States must use the "essential tool" of "[r]ational planning."131 According to Stockholm Principle 13, to "ensure that development is compatible with the need to protect and improve the human environment for the benefit of [a State's] population," "States should adopt an integrated and coordinated approach to [its] development planning."132

The Corfu Channel133 case also demonstrates the general notion that States are not entitled to use their territories in ways that will ultimately harm other States.134 Specifically, the case provides that States may not use their territory in ways that they know will damage other States.135 If States do act with such knowledge, they must compensate the harmed State for the damage caused.136

(b) Environmental Preservation

The Precautionary Principle or Approach also receives widespread usage in international law, and it may be considered international environmental law.137 Since at least the 1960s, the Precautionary Principle has been used in international issues, but at least since the 1980s, it has been frequently used in international environmental law—through both multilateral and bilateral treaties.138 While the usage of the Precautionary Approach as an international rule has not been without challenge, "[a]t a minimum . . . there is sufficient evidence of state practice to justify the conclusion that the principle, as elaborated in the Rio Declaration, reflects a broadly accepted basis

128. See Stockholm Declaration, supra note 116, princ. 21.

129. Id.

130. Presumably, this language addresses the environment of a State's own territory as well as the territory of other States.

131. Stockholm Declaration, supra note 116, princ. 14.

132. Id. princ. 13.

133. The Corfu Channel Case (U.K. v. Alb.), 1949 I.C.J. 4 (Apr. 9).

134. INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 13.

135. Id.

136. Id. Note that few international cases have addressed the issue of damages owed to a State that has been harmed. Id. at 20.

137. Id. at 21.

138. Id. at 20-21; see also Int'l Law Ass'n (ILA), Berlin Conference: Water Resources Law, art. 23 cmt. (2004) [hereinafter Berlin Rules], available at http://www.internationalwaterlaw.org/documents/intldocs/ILA_Berlin_Rules-2004.pdf ("[T]he precautionary principle appears in almost all international environmental instruments adopted since 1990.").

for international action."139 In the Rio Declaration, the inclusion of a precautionary approach was "unanimously endorsed."140

Quite generally, the Precautionary Principle is the concept that States have a duty to protect the environment by considering the effects that development will cause.141 The Precautionary Principle, however, does not serve to completely halt and forbid all action that will harm the environment.142 Although the Precautionary Principle "indeed may impose a 'no-go' or a 'go-slow' on certain directions of innovation and scientific progress . . . , [it] is not based on 'zero risks' but aims to achieve lower or more acceptable risks or hazards." 143

Many people fear that such a precautionary approach "may stifle innovation or hamper scientific progress."144 In reality, however, an increase in the use of the Precautionary Principle "can help stimulate both innovation and science, replacing [outdated] technologies . . . with the clean technologies and systems science of a new industrial revolution."145 The result is likely to be an effective balance between innovation and the associated harm.146

Further, Rio Principle 15 also states that "[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."147 The International Court of Justice (ICJ) recognized this duty in the 1997

139. INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 22. For a critique of whether the Precautionary Principle is indeed customary international law, see Jutta Brunnée, The Stockholm Declaration and the Structure and Processes of Internation-

al Environmental Law, in THE STOCKHOLM DECLARATION AND LAW OF THE MARINE ENVIRONMENT, supra note 122, at 67, 77, which notes that "doubts linger" as to whether the Precautionary Principle is truly customary international law and noting that while "an increasing number of observers conclude that the principle is binding custom," some are skeptical and some states claim that there is no legally binding effect to the Precautionary Principle.

140. INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 21.

141. See Rio Declaration, supra note 117, princ. 15.

142. See id.

143. WORLD COMM'N ON THE ETHICS OF SCIENTIFIC KNOWLEDGE AND TECH., THE PRECAUTIONARY PRINCIPLE 16 (2005), available at http://unesdoc.unesco.org/images/0013/001395/139578e.pdf. The precautionary approach differs from the traditional view of "scientific findings" in that the traditional view may have ultimately resulted in the abandonment of a project where it was not certain that the project would not result in environmental harm. See INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 21.

144. WORLD COMM'N ON THE ETHICS OF SCIENTIFIC KNOWLEDGE AND TECH., supra note 143, at 15.

145. Id. at 15-16.

146. See id. ("While the [Precautionary Principle] indeed may impose a 'no-go' or a 'go-slow' on certain directions of innovation and scientific progress, the [Precautionary Principle] at the same time acts as a stimulant for other innovations and clean technological progress.").

147. Rio Declaration, supra note 117, princ. 15.

GabÃíkovo-Nagymaros Project Case.148 Though the ICJ shows great respect for the environment,149 at the same time it held that a State must fulfill its obligations where there is no proof that such activity will cause significant harm.150

The Precautionary Principle does take into consideration the different economic circumstances of States, and thus its application is not static.151 Specifically, Rio Principle 15152 provides that "[i]n order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities."153 This attempts to prevent exploitation of the developing States because they are not held to the same standards as thriving developed States.154

The Principle of Sustainable Development155 is also an important international environmental law concept.156 Generally, this principle stands for the proposition that States have an obligation to develop in a way so as to preserve resources for future generations.157 Specifically, Rio Principle 3 provides that "[t]he right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations."158 Rio Principle 4 details how to fulfill this obligation by stating that "to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation

148. Case Concerning the GabÃíkovo-Nagymaros Project (Hung. v. Slovk.), 1997 I.C.J. 7, 42 (Sept. 25).

149. Id. at 41 (emphasizing "the great significance that [the ICJ] attaches to respect for the environment, not only for States but also for the whole of mankind").

150. See id. at 42 (noting that to fulfill its obligations, Hungary must have "at least proven that a real, 'grave' and 'imminent' 'peril' existed . . . and that the measures taken by Hungary were the only possible response to it").

151. See Rio Declaration, supra note 117, princ. 15.

152. Although the themes of the Rio Declaration are quite similar to the themes previously addressed by the Stockholm Declaration, the Stockholm Declaration did not address the Precautionary Principle.

153. Rio Declaration, supra note 117, princ. 15.

154. While many sources of international environmental law account for the inability of developing countries to comply with certain standards to the same extent of developed countries, these are not within the scope of this Comment.

155. Rio Declaration, supra note 117, princ. 4.

156. See HUNTER ET AL., supra note 121, at 200 (noting that since the Rio Declaration, the Principle of Sustainable Development "has received nearly universal acceptance . . . among every sector of international society" and that the concept has been included in many international environmental declarations and treaties).

157. See id.

158. Rio Declaration, supra note 117, princ. 3.

from it."159 This principle does not prevent development; rather it requires that each State approach development in a certain way.160

Conjunctively, the Precautionary Principle and Principle of Sustainable Development show that States have an obligation to use environmental effects as a consideration, not as a determinative factor, in whether to move forward with construction and development projects (including hydroelectric dam projects, among others). Where a State has knowledge that extreme environmental consequences are certain to result from a considered development, then both principles would likely say to not move forward.

Yet, where such environmental consequences are not certain to result—even if only because the scientific evidence is not determinative or complete—the Precautionary Principle advises to continue but at a slower, more careful pace. This slowed continuation would also be in conformance with the Principle of Sustainable Development because moving at a slower rate would contribute to preservation of environmental resources for future generations. Because of this relationship, when a State formulates its development approach in compliance with the Precautionary Principle, it is much more likely to also comply with the requirements of the Principle of Sustainable Development.161

Neither the Precautionary Principle nor the Principle of Sustainable Development gives mention to territorial boundaries.162 Thus, arguably, the two principles obligate a State to consider the effect of projects generally, including the impacts on other States, as opposed to only the impact on its own current environment.163 Likewise, neither the Precautionary Principle nor the Principle of Sustainable Development applies solely to one resource or issue within the context of international environmental law,164 and thus both principles are applicable to a State's construction and use of hydroelectric dams.

159. Id. princ. 4. The Rio Declaration also recognized that developing and developed countries should not be held to the same standards, stating that "[t]he developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command." Id. princ. 7.
160. See id. princ. 3.
161. Another view of the relationship between these principles is that the Principle of Sustainable Development is a balance between the well-established Right to Develop and the Precautionary Principle. Brian Trevor Hodges, Where the Grass Is Always Greener: Foreign Investor Actions Against Environmental Regulations Under NAFTA's Chapter 11, S.D. Myers, Inc. v. Canada, 14 GEO. INT'L ENVTL. L. REV. 367, 393-94 (2002).
162. See, e.g., Rio Declaration, supra note 117, princs. 3, 4, 15.
163. See generally id.
164. See id. princs. 3, 15.

(c) States' Duty to Cooperate

General sources of international environmental law also provide that States have a duty to cooperate with each other; such cooperation is paramount to the adherence to other broad themes of international environmental law.165 This duty is considered customary international law.166 Principle 25 of the Rio Declaration provides a clear and concise statement of this duty. Specifically, the principle provides that "[p]eace, development and environmental protection are interdependent and indivisible."167 Without peace between States, there can be no successful movement toward environmental preservation; peace itself cannot result unless States are willing to cooperate. For example, Stockholm Principle 24 provides that "[i]nternational matters concerning the protection and improvement of the environment should be handled in a co-operative spirit by all countries, big or small, on an equal footing."168

Rio Principle 12 further provides that States should make all efforts to achieve international consensus for environmental concerns by stating that "[u]nilateral actions to deal with environmental challenges outside the jurisdiction of the importing country should be avoided. Environmental measures addressing transboundary or global environmental problems should, as far as possible, be based on an international consensus."169 Less abstract, and more direct, is Stockholm Principle 24, which stresses the duty of governments to cooperate "through multilateral or bilateral arrangements, or other appropriate means" for the purpose of controlling, reducing, or otherwise eliminating adverse environmental effects.170

In 1957, even before the Stockholm Declaration set forth this principle, the Lake Lanoux Arbitration stressed notice.171 The panel in Lake Lanoux "held that as a matter of customary international law, a State that is engaging in behavior likely to significantly im-

165. See, e.g., id. princ. 25; see also Kiss, supra note 123, at 55 (noting that the Stockholm Declaration's philosophy is expressed in large part in Principles 24 and 25, "inviting States to cooperate in international matters concerning the protection and improvement of the environment").
166. See PHILIPPE SANDS, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 461 (2d. ed. 2003).
167. Rio Declaration, supra note 117, princ. 25. Likewise, Rio Principle 26 holds that "environmental disputes" should be handled "peacefully and by appropriate means in accordance with the Charter of the United Nations." Id. princ. 26.
168. Stockholm Declaration, supra note 116, princ. 24 (emphasis added).
169. Rio Declaration, supra note 117, princ. 12. Rio Principle 12 further ties in the Principle of Sustainable Development by stating the following: "States should cooperate to promote a supportive and open international economic system that would lead to economic growth and sustainable development in all countries, to better address the problems of environmental degradation." Id.
170. Stockholm Declaration, supra note 116, princ. 24.
171. See generally Lake Lanoux Arbitration, 12 INT'L ARB. AWARDS 281, 315-16 (1957).

pact the environment of another State is obliged to involve the affected State in discussions regarding these activities."172

B. Sources of Transboundary Water Law

Sources of international law specifically addressing transboundary watercourses did not appear until approximately the 1950s.173 Prior to that, some sources did exist, such as nongovernmental resolutions, and sources specific to particular regions had not yet received international application.174 Multiple theories addressing the relationship between riparian States with regard to transboundary water rights have prevailed, depending on the particular time period.175 However, after a brief overview of the relevant sources of law, this Section will focus primarily on the equitable utilization theory, as it has become the "cornerstone" of international water law. The available sources of international law, at least in part, adhere to this theory.176

1. Relevant Sources

The Helsinki Rules on the Uses of the Waters of International Rivers were adopted by the International Law Association (ILA) in 1967 after the ILA's fifty-second conference, which was held in Helsinki, Finland in 1966.177 While these rules provide valuable information specifically applicable to international rivers, one major downfall

172. Hodges, supra note 161, at 393-94 (citation omitted).
173. Surya P. Subedi, Regulation of Shared Water Resources in International Law: The Challenge of Balancing Competing Demands, in INTERNATIONAL WATERCOURSES LAW FOR THE 21ST CENTURY: THE CASE OF THE RIVER GANGES BASIN 7, 8 (Surya P. Subedi ed., 2005).
174. Id. at 8-9.

175. See id. at 9.
176. See, e.g., Convention on the Law of the Non-navigational Uses of International Watercourses (1997) [hereinafter UN Convention], available at http://untreaty.un.org/ilc/texts/instruments/english/conventions/8_3_1997.pdf (adopted by General Assembly Resolution Convention on the Law of Non-navigational Uses of International Watercourses, G.A. Res. 51/229, art. 5, U.N. GAOR, 51st Sess., 99th plen. mtg., U.N. Doc. A/RES/51/229 (May 21, 1997)).
177. Int'l Law Ass'n [ILA], Fifty-Second Conference, Helsinki Fin., Aug. 14-20, 1966, The Helsinki Rules on the Uses of the Waters of International Rivers (Aug. 1966) [hereinafter Helsinki Rules], available at http://www.internationalwaterlaw.org/documents/intldocs/helsinki_rules.html. After the Helsinki Rules were adopted in 1966, the ILA then drafted multiple sets of rules to different water-related activities that were not specifically addressed in the Helsinki Rules. Joseph W. Dellapenna, The Berlin Rules on Water Resources: The New Paradigm for International Water Law, in WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2006: EXAMINING THE CONFLUENCE OF ENVIRONMENTAL AND WATER CONCERNS (American Society of Civil Engineers CD-ROM) (Randall Graham ed., 2006) [hereinafter Dellapenna, The Berlin Rules], available at http://www.ualg.pt/5cigpa/comunicacoes/Berlin Rules Summary.doc. These included: "flood control (1972), pollution (1972, 1982), navigability (1974), the protection of water installations during armed conflicts (1976), joint administration (1976, 1986), flowage regulation (1980), general environmental management concerns (1980), groundwater (1986), cross-media pollution (1996), and remedies (1996)." Id. at 4.

is that these rules were not endorsed by the United Nations—the ILA is a nongovernmental body that is not affiliated with the UN.178 Also important is that while the Helsinki Rules are relevant to the issue of hydroelectric dams, they were not created as a multilateral treaty, and thus the rules are not binding on any States.179

In 1997, the International Law Commission (ILC) of the United Nations incorporated themes from the Helsinki Rules into its Convention on the Law of the Non-navigational Uses of International Watercourses.180 The UN Convention was approved by 103 States at the Convention, but has still not come into force.181 Article 36 of the UN Convention requires that thirty-five States ratify, accept, approve, or accede, and when the thirty-fifth instrument does this, the UN Convention will come into force.182 As of May 2009, only sixteen States had become signatories and seventeen states had ratified, accepted, approved, or acceded.183 While the allotted time for ratification expired in May 2000, some States that did accede did so after the May 2000 deadline;184 States are thus still presumably permitted to accede.185 Therefore, the UN Convention may at some point come into force.186

Before the UN Convention's adoption in 1997, "the international community did not have at its disposal a set of written rules and principles endorsed by a political arena. Up until this time, the Helsinki Rules . . . were the only set of written rules to be referred to,"187

178. Laurence Boisson de Chazournes, The UN Convention on International Watercourses: Prospects for an Unfinished Agenda for Co-Management, http://gurukul.ucc.american.edu/maksoud/water98/present7.htm#Chazournes (last visited June 1, 2009). Although not affiliated with the United Nations, the ILA is well known for "the articulation of cogent and compelling statements of the customary international law relating to fresh water resources." Berlin Rules, supra note 138, at 2 ("Working over a span of nearly 50 years, the Association has produced a series of rules addressing various topics relating to the overall field of international water law.").
179. See generally Helsinki Rules, supra note 177.
180. UN Convention, supra note 176.
181. STEPHEN C. MCCAFFREY, THE LAW OF INTERNATIONAL WATERCOURSES: NON-NAVIGATIONAL USES 315 (2001); Press Release, United Nations, General Assembly Adopts Convention on Law of Non-Navigational Uses of International Watercourses, GA/9248 (May 21, 1997), available at http://www.un.org/News/Press/docs/1997/19970521.ga9248.html.
182. UN Convention, supra note 176, art. 36.
183. United Nations, Multilateral Treaties Deposited with the Secretary-General, Status as of 13 May 2009, Convention on the Law of the Non-Navigational Uses of International Watercourses, http://treaties.un.org/doc/Publication/MTDSG/Volume II/Chapter XXVII/XXVII-12.en.pdf (last visited June 1, 2009) [hereinafter Multilateral Treaties Deposited with the Secretary-General]. Ratifying, accepting, acceding, and approving States include: Finland, Germany, Hungary, Iraq, Jordan, Lebanon, Libyan Arab Jamahiriya, Namibia, Netherlands, Norway, Portugal, Qatar, South Africa, Sweden, Syrian Arab Republic, Tunisia, and Uzbekistan. Id.
184. Id.
185. See id.
186. See id; see also MCCAFFREY, supra note 181, at 315.
187. de Chazournes, supra note 178.

and it was debatable as to whether the Helsinki Rules actually "constituted customary law."188 Note, however, that the Helsinki Rules seem to, overall, be considered customary international law.189 In 1997, the very same year in which the UN Convention was adopted, the International Court of Justice in the GabÃíkovo-Nagymoros Project Case190 referred to the Convention "as expressing, at least in part, contemporary customary international law governing internationally shared waters."191 Even though the UN Convention has not been ratified, one argument is that "the success of the Convention does not depend on whether it enters into force. Its influence is more likely to derive from its status as the most authoritative statement of general principles and rules governing the non-navigational uses of international watercourses."192 Further, the UN Convention is likely to "remain highly influential and persuasive as a statement of current customary and general international law on watercourses as it is the culmination of over 20 years of in-depth research by the International Law Commission into the state of international watercourse law and practice."193

Recognition is also due to the Berlin Rules, the ILA's 2004 revision of the Helsinki Rules.194 Arguably, "[t]he Berlin Rules set forth a clear, cogent, and coherent summary of the relevant customary international law, incorporating the experience of the nearly four decades since the Helsinki Rules were adopted."195

There are a couple of important differences in the scope of the

Berlin Rules in comparison to both the Helsinki Rules and the UN Convention. One significant difference is that the Berlin Rules do not

188. Id. Widely accepted, however, is the claim that the Helsinki Rules are customary international law. See, e.g., Dellapenna, The Berlin Rules, supra note 177, at 1 (arguing that "[t]he Helsinki Rules quickly came to be seen as the authoritative summary of the customary international law on transboundary or internationally shared waters"). But see Lisa M. Jacobs, Sharing the Gifts of the Nile: Establishment of a Legal Régime for Nile Waters Management, 7 TEMP. INT'L & COMP. L.J. 95, 101 (1993) ("The Helsinki Rules are not an international convention. Nor are they a treaty, since they do not represent particular states' agreement among themselves to the principles expressed. The Helsinki Rules are not customary law. Insufficient state practice exists to show the Rules' widespread acceptance, and no evidence indicates that states feel bound to follow these Rules.").

189. Joseph W. Dellapenna, International Law's Lessons for the Law of the Lakes, 40 U. MICH. J.L. REFORM 747, 762 (2007).

190. See Case Concerning the GabÃíkovo-Nagymaros Project (Hung. v. Slovk.), 1997 I.C.J. 7, 42 (Sept. 25).

191. Berlin Rules, supra note 138, at 3.

192. Stephen McCaffrey, The Contribution of the UN Convention on the Law of the Non-Navigational Uses of International Watercourses, 1 INT'L J. GLOBAL ENVTL. ISSUES 250, 250 (2001).

193. Owen McIntyre, The Role of Customary Rules and Principles of International Environmental Law in the Protection of Shared International Freshwater Resources, 46 NAT. RESOURCES J. 157, 160 n.2 (2006).

194. See generally Berlin Rules, supra note 138.

195. Dellapenna, The Berlin Rules, supra note 177, at 6.

solely focus on international waters.196 Instead, their focus includes national waters "to the extent that customary international law speaks to those waters."197 Likewise, the Berlin Rules focus on ground waters in addition to surface waters.198 Rapporteur for the Berlin Rules, Joseph W. Dellapenna, stated in reference to these rules that the inclusion of these matters within this single set of rules allows

> a lawyer, a jurist, a water manager, a water policy maker, or anyone else concerned by the rules of customary international [law] pertaining to water [to], for the first time, find all the relevant rules in one place, with attention to the interrelationships of the rules as well as to their clear statement.199

The next subsection will emphasize discrepancies between the Helsinki Rules, the UN Convention, and the Berlin Rules. Additionally, this Section will occasionally offer the author's opinion regarding the language and importance of the contents of each of these sources.

2. Relevant Themes

(a) Equitable Utilization

Currently, the theory of equitable utilization is at the "cornerstone" of international law regarding transboundary watercourses,200 and "[t]here is little contention that equitable utilisation is a well-established principle of customary international water law."201

Equitable utilization202 can be viewed as an integration and compromise between two previous theories, the doctrine of absolute sovereignty and the doctrine of territorial integrity.203 Briefly, the doctrine of absolute sovereignty would allow an upper riparian State to do as it wishes with the transboundary watercourse flowing through its country regardless of the harm caused to the lower riparian

196. See id.

197. Id.

198. Id. at 5-6.

199. Id. at 6-7.

200. Subedi, supra note 173, at 9.

201. Simon Nicholson, Water Scarcity, Conflict, and International Water Law: An Examination of the Regime Established by the UN Convention on International Watercourses, 5 N.Z. J. ENVTL. L. 91, 113 (2001).

202. "Equitability has been understood . . . to mean not division into equal portions, but the equality of right to use the water for beneficial purposes." Sharif S. Elmusa, Harmonizing Equitable Utilization and Significant Harm: Comments on the 1997 ILC Convention, Conference on "Water, Dispute Prevention and Development: South Perspectives," Presented at the Center for the Global South, American Univ. (Oct. 12-13, 1998), http://gurukul.ucc.american.edu/maksoud/water98/present7.htm#El-Musa.

203. See Dellapenna, The Berlin Rules, supra note 177, at 3.

State.204 Conversely, the doctrine of territorial integrity may be used by a lower riparian State to claim that it has a right to a "fair share" of the water within the transboundary watercourse to "meet its existing and potential use."205

The Helsinki Rules "crystallized and codified" the well-established use of equitable utilization, albeit by using slightly different phraseology.206 Specifically, Article IV of the Helsinki Rules states that "[e]ach basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin."207

The UN Convention addresses equitable utilization in Articles 5 and 6.208 Importantly, notice that compared to the Helsinki Rules, the UN Convention's language is substantially longer and includes a new focus. In particular, Article 5.2 includes for the first time (other than individual treaties created between States) the idea of participation in achieving equitable and reasonable use:

> 1. Watercourse States shall in their respective territories utilize an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse.

> 2. Watercourse States shall participate in the use, development and protection of an international watercourse in an equitable and reasonable manner. Such participation includes both the right to utilize the watercourse and the duty to cooperate in the protection and development thereof, as provided in the present Convention.209

Both the Helsinki Rules Article V and the UN Convention Article 6 provide ways to determine what is meant by equitable and reasonable use.210 Each of these sections includes a list of factors and provides that States must consider all relevant sources equally and "on the basis of the whole."211 While this flexibility is beneficial in the sense that it leaves room to account for States' particular circumstances and the uniqueness of particular regions and watercourses, it may, for practical purposes, prove to be quite a complication. In practice, an analyst applying these factors may find this flexibility burdensome and lacking of sufficient guidance to determine whether a

204. Id.; see also Subedi, supra note 173, at 9.
205. Subedi, supra note 173, at 9 (citation omitted).
206. Dellapenna, The Berlin Rules, supra note 177, at 3.
207. Helsinki Rules, supra note 177, art. IV (emphasis added).
208. UN Convention, supra note 176, arts. 5, 6.
209. Id. art. 5.
210. UN Convention, supra note 176, art. 6; Helsinki Rules, supra note 177, art. V.
211. UN Convention, supra note 176, art. 6; Helsinki Rules, supra note 177, art. V.

use, such as hydroelectric dam construction, is actually an equitable and reasonable use of a particular transboundary watercourse.212 Article 9 offers some help to analysts through its requirement that States provide each other, on a regular basis, with relevant information.213 This requirement at least ensures that States have current, relevant information on hand when making a determination.214

Recognizing the necessity for overall protection of the watercourse, Article 8 provides that "[w]atercourse States shall cooperate on the basis of sovereign equality, territorial integrity, mutual benefit and good faith in order to attain optimal utilization and adequate protection of an international watercourse."215 Arguably, the use of the word "optimal" combined with the specification of "watercourse" makes clear that an equitable and reasonable use is based on what is equitable and reasonable for the watercourse as a whole rather than simply a State's equitable and reasonable use of that portion of the watercourse flowing through its territory.

(i) UN Convention Article 5 and General Principles of International Environmental Law

Article 5 of the UN Convention can be viewed as incorporating several important customary international law principles. Similar to Stockholm Principle 21, a State is permitted to use transboundary watercourses within its territories, but is precluded from doing so in a way that harms another State.216

Additionally, "to be equitable and reasonable, the use must also be consistent with adequate protection of the watercourse."217 This can be viewed as representing the broad themes of both the Precautionary Principle and Principle of Sustainable Development. Specifically, in order to protect the watercourse, a precautionary approach will be necessary. For example, a State would not know for certain that it is adhering to this protection requirement unless it moves more slowly in order to further investigate the effects of the dam, thereby adhering to a precautionary approach. Further, by taking such a precautionary approach, the State is much more likely to be in compliance with the overall Principle of Sustainable Development, as such protection will preserve the watercourse for future generations.

212. Elmusa, supra note 202 (claiming that such an analyst will face difficulties "for two reasons: one is that individual factors lack specificity as to meaning and, the second, is that multiplicity of the factors and lack of assigning weights to each diminish their value as a practical tool").
213. McCaffrey, supra note 192, at 253.
214. Id.
215. UN Convention, supra note 176, art. 8 (emphasis added).
216. See id. art. 5.
217. McCaffrey, supra note 192, at 253.

(b) No Significant Harm

It is well established in international law and specifically set forth in Stockholm Principle 21 (and Rio Principle 2) that States may not exploit their own resources to such a point so as to cause damage to other States.218 This concept is included in the doctrine of no significant harm.219 While the Helsinki Rules principally focused on equitable utilization with no focus on the idea of no significant harm, the UN Convention focuses on both.220 The concept of no significant harm is codified in Article 7 of the UN Convention:

> 1. Watercourse States shall, in utilizing an international watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other watercourse States.
> 2. Where significant harm nevertheless is caused to another watercourse State, the States whose use causes such harm shall, in the absence of agreement to such use, take all appropriate measures, having due regard for the provisions of articles 5 and 6, in consultation with the affected State, to eliminate or mitigate such harm and, where appropriate, to discuss the question of compensation.221

(c) Competing Doctrines Within the UN Convention?: Equitable Utilization Versus No Significant Harm

A major difficulty with the UN Convention is the "clash" between equitable utilization (Article 5) and no significant harm (Article 7).222 This clash resulted in debate both during and after drafting regarding whether equitable utilization or no significant harm holds precedence.223 This determination is crucial because, on one hand, if "equitable utilization" is deemed to take precedence, then so long as an upstream riparian State's actions are equitable and reasonable, significant harm may eventually still be caused to the downstream riparian State.224 On the other hand, if "no significant harm" is deemed to take precedence, then an upstream riparian State is not permitted to even an equitable and reasonable use of the transboundary watercourse, if that will cause significant harm to the downstream riparian State.225 For these reasons, upstream riparian States

218. See Stockholm Declaration, supra note 116, princ. 21.
219. See UN Convention, supra note 176, art. 7.
220. See id. arts. 5, 7.
221. Id. art. 7.
222. Nicholson, supra note 201, at 116-17.
223. Id.
224. Id. at 117.
225. Id.

are in favor of the equitable utilization principle and downstream riparian owners are in favor of the no significant harm principle.226

Negotiations during drafting eventually resulted in a compromise; however, "the balance reached between articles 5 and 7 can best be described as 'tantalisingly obscure.' "227 Unfortunately, the adopted draft, even after extensive negotiations, still presents problems between whether equitable utilization or no significant harm prevails.228

Although some may view the issue as unresolved by the UN Convention, careful inspection of the phrasing of the UN Convention strongly suggests that equitable utilization is favored over no substantial harm. Article 7 addresses a State's responsibility to cause no significant harm to another State.229 However, Article 7.1 includes the language "take all appropriate measures," and 7.2 includes the statement "having due regard for the provisions of articles 5 and 6," which are the very articles addressing equal utilization.230 Furthermore, Article 10 provides that "[i]n the event of a conflict," the conflict "shall be resolved with reference to articles 5 to 7."231 Based on these statements, one can easily conclude that no significant harm certainly does not prevail over equitable utilization. Supporting this conclusion is a relevant example used by McCaffrey regarding the inclusion of these statements:

> This would presumably mean that if State A's hydroelectric use conflicts with State B's agricultural use, the conflict is not to be resolved solely by applying the 'no-harm' rule of Article 7, but rather through reference to the 'package' of articles setting forth the principles of both equitable utilisation and 'no-harm.'232

The Berlin Rules attempt to eliminate controversy between equitable utilization and no significant harm by adopting the following language in Article 12:

> 1. Basin States shall in their respective territories manage the waters of an international drainage basin in an equitable and reasonable manner having due regard for the obligation not to cause significant harm to other basin States.
> 2. In particular, basin States shall develop and use the waters of the basin in order to attain the optimal and sustainable use thereof and benefits therefrom, taking into account the interests

226. Id. at 116-17.
227. Id. at 117 (citation omitted).
228. See id.
229. UN Convention, supra note 176, art. 7.
230. Id.
231. Id. art. 10.
232. McCaffrey, supra note 192, at 255.

> of other basin States, consistent with adequate protection of the waters.233

This phrasing "emphasizes that the right to an equitable and reasonable share of the waters of an international drainage basin carries with it certain duties in the use of those waters."234 Similar to both the Helsinki Rules and the UN Convention, the Berlin Rules include factors to determine whether a use, such as the construction and use of a hydroelectric dam, is an equitable and reasonable use of a transboundary watercourse.235 However, the Berlin Rules emphasize sustainability and prevention of environmental harm by adding two additional factors.236

(d) States' Duty to Cooperate

It is widely recognized that "[t]he duty of cooperation is the most basic principle underlying international water law."237 Without State cooperation, it would ultimately prove impossible for States to fulfill obligations prescribed to them through the many sources of international law.238 Article 6 of the UN Convention provides that "watercourse States concerned shall, when the need arises, enter into consultations in a spirit of cooperation."239

Article 8 further provides that in States' determinations regarding the manner of cooperation, "watercourse States may consider the establishment of joint mechanisms or commissions."240 While this is merely a suggestion, as it uses the word "consider," many scholars deem this ideal.241 This proposition is the best approach because use of a joint mechanism will assist when two riparian states disagree as to what activities will provide " 'optimal utilisation and adequate protection.' "242 Such a joint mechanism will allow individuals from

233. Berlin Rules, supra note 138, art. 12.
234. Id. art. 12 cmt.
235. See id. art. 13.
236. Id. (adding "[t]he sustainability of proposed or existing uses" and "[t]he minimization of environmental harm" to its list of factors).
237. Id. art. 11 cmts. (noting that in addition to the Berlin Rules, the Helsinki Rules and other international environmental law documents recognize this rule).
238. See id.
239. UN Convention, supra note 176, art. 6. The UN Convention furthers its emphasis on participation by including this statement within the same article (Article 5) in which it lists the elements. Id. art. 5.
240. Id. art. 8. Indeed, a paragraph was added to Article 8 of the UN Convention regarding the use of joint mechanisms or commissions because "delegations negotiating the Convention attached such a significance to cooperation through joint mechanisms." McCaffrey, supra note 192, at 253; see, e.g., infra Part VI.A. (explaining the creation of the International Joint Commission between the United States and Canada).
241. See, e.g., McCaffrey, supra note 192, at 253.
242. Id. (quoting UN Convention, supra note 176, art. 8).

each State to mutually determine whether the States should permit certain uses of the transboundary watercourse.

Article 9 also states that "watercourse States shall on a regular basis exchange readily available data and information on the condition of the watercourse."243 This contributes to the requirement for State cooperation because without cooperation, it would be impossible to provide each other with this required information. Additionally, Article 10's statement that "no use of an international watercourse enjoys inherent priority over other uses," except where agreement or custom specifies otherwise, also shows that States must work together to determine the equitable and reasonable uses of a watercourse, rather than one State assuming and declaring that its use has priority.244

(e) Dispute Avoidance and Settlement

The Helsinki Rules, the UN Convention, and the Berlin Rules all provide information regarding prevention of disputes, and since disputes are many times inevitable, these sources also provide dispute resolution information for use when disputes actually occur.245 Because all three sources provide relatively similar provisions, dispute resolution information is not a main focus of this Comment. It should be noted, however, that the inclusion of this information in agreements regarding transboundary watercourses and hydroelectric dams is especially important as it ensures that a harmed party will have a mechanism for legal enforcement.

243. UN Convention, supra note 176, art. 9.
244. Id. art. 10.
245. See generally UN Convention, supra note 176, arts. 11-19, 30, 33, annex arts. 1-14; Berlin Rules, supra note 138, arts. 56-73; Helsinki Rules, supra note 177, arts. XXVI-XXXVII. UN Convention Part III, entitled Planned Measures, sets forth a framework for avoiding and handling disputes between watercourse States. See UN Convention, supra note 176, arts. 11-18, 33. Article 12, requiring notice, provides that before implementing "planned measures which may have a significant adverse effect upon other watercourse States," the State is required to give those States "timely notification." Id. art. 12. This notification should include technical data and results from environmental impact statements. Id. This information should be given "in order to enable the notified States to evaluate the possible effects of the planned measures." Id. The UN Convention Article 13 then specifies a time period for reply to notification, obligations of the notifying state during the reply period, information regarding the reply to the notification, and information regarding an absence of reply to notification. Id. art. 13. Article 17 addresses consultations and negotiations, further showing the importance of State cooperation. See id. art. 17.

For those situations in which one State fails to give notice to another affected State, Article 18 provides procedures for the absence of notification. Id. art. 18. It states that where one "watercourse State has reasonable grounds to believe that another watercourse State is planning measures that may have a significant adverse effect upon it," the affected State may request the planning State to comply with Article 12, by giving such notification of harm. Id. Article 33 specifically addresses settlement of inevitable disputes. See id. art. 33.

(f) Additional Relevant Articles of the UN Convention

(i) Ecosystems and Marine Environment

As discussed previously, the effects of hydroelectric dam construction can affect rivers and the supported ecosystems immensely. The UN Convention includes specific language addressing ecosystems that is directly relevant to hydroelectric dams.246 Article 20 provides that "[w]atercourse States shall, individually and, where appropriate, jointly, protect and preserve the ecosystems of international watercourses."247 Likewise, Article 23 of the UN Convention specifically addresses the duty of watercourse States to "take all measures with respect to an international watercourse that are necessary to protect and preserve the marine environment, including estuaries, taking into account generally accepted international rules and standards."248 In a sense, these UN Convention articles enhance the widely accepted Principle of Sustainable Development but on a more focused issue directly applicable to transboundary watercourses.

(ii) Hydraulic Works

The UN Convention also incorporated language specifically applicable to "regulation" of the natural flows of transboundary watercourses by stating in Article 25 that "[w]atercourse States shall cooperate, where appropriate, to respond to needs or opportunities for regulation" and that "[u]nless otherwise agreed, watercourse States shall participate on an equitable basis in the construction and maintenance or defrayal of the costs of such regulation works."249

In addition to general consultation requirements set forth for transboundary watercourses in Article 24,250 Article 26 includes consultations directly applying to one State being harmed by the installations of another State. Article 26.2 provides the following:

> Watercourse States shall, at the request of any of them which has reasonable grounds to believe that it may suffer significant adverse effects, enter into consultations with regard to:

246. See UN Convention, supra note 176, art. 20.
247. Id.
248. Id. art. 23.
249. Id. art 25. Article 25 defines "regulation" as "the use of hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of an international watercourse." Id.
250. Id. art. 24. Article 24.1 provides that "[w]atercourse States shall, at the request of any of them, enter into consultations concerning the management of an international watercourse, which may include the establishment of a joint management mechanism." Id. Article 24.2 further provides that " 'management' refers, in particular, to: (a) Planning the sustainable development of an international watercourse and providing for the implementation of any plans adopted; and (b) Otherwise promoting the rational and optimal utilization, protection and control of the watercourse." Id.

> (a) The safe operation and maintenance of installations, facilities or other works related to an international watercourse; and
> (b) The protection of installations, facilities or other works from wilful or negligent acts or the forces of nature.[251]

V. ENFORCEMENT AND ITS COMPLICATIONS

A. Legal Enforcement

While various mechanisms exist to address problems and disputes, a major impediment is enforcement.[252] This Section will focus on several enforcement deficiencies with regard to the sources of international environmental law relevant to the construction and use of hydroelectric dams.

1. Relevant Law Is Nonbinding

One common enforcement problem is that often the relevant international law is simply not binding, and where the law is nonbinding, a harmed State has no mechanism to force the harming State to comply.[253] This may arise either because the relevant international law is a nonbinding source that is not considered to be customary international law and thus binding on no States or because the relevant binding sources are not binding on the particular State causing the harm.[254]

While the Helsinki Rules and the UN Convention provide enforcement provisions specifically relevant to disputes resulting from hydroelectric dam construction and use,[255] these sources are not necessarily binding. The Helsinki Rules are likely widely considered customary international law, in which case they are binding.[256] However, the UN Convention, while continuously gaining acceptance and

251. Id. art. 26.
252. See, e.g., INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 14.
253. See id. at 14-15.
254. See id.
255. See supra Part IV.B.1.
256. See supra notes 188-89 and accompanying text. Article XXX of the Helsinki Rules provides that "[i]n case of a dispute between States as to their legal rights or other interests," negotiation should be sought. Helsinki Rules, supra note 177, art. XXX. If both states consider the problem to be "incapable of resolution," then Article XXXII "recommend[s] that they seek the good offices, or jointly request the mediation of a third State, of a qualified international organization or of a qualified person." Id. art. XXXII. One such example is the creation of the International Joint Commission by the United States and Canada to handle such disputes. See infra Part VI.A. Further, where such states are still unsuccessful at resolving their problems, then Article XXXIII "recommend[s] that they form a commission of inquiry or an ad hoc conciliation commission," which will try to "find a solution, likely to be accepted by the States concerned, of any dispute as to their legal rights." Helsinki Rules, supra note 177, art. XXXIII. As a last resort, Article XXXIV "recommend[s] that the States concerned agree to submit their legal disputes to an ad hoc arbitral tribunal, to a permanent arbitral tribunal or to the International Court of Justice." Id. art. XXXIV.

having the UN's endorsement, has not come into force and is not yet considered customary international law and thus binds no State to its framework of enforcement mechanisms.[257]

Should the UN Convention eventually come into force, assuming it would not yet be widely accepted as customary international law, it will only bind those States that ratify it.[258] Additionally, the UN Convention is meant to solely be a framework—used as a starting point for States with such transboundary watercourse issues to build upon when generating their own agreements.[259]

2. No Attached Enforcement Mechanism

A second major impediment to enforcement—presuming that relevant international law is binding upon the harming State—is that there is not always an enforcement mechanism attached to the applicable law, and if there is, there is not always a way to force the harming party to submit to that mechanism. This is the classic problem with customary international law principles, as they do not typically define "required behavior."[260] Instead,

> these rules state international duties that are too vague to provide any guidance about what behavior is acceptable or to facilitate ready application of these rules to specific disputes. When publicists endow these abstract duties with substantive content and attempt to generate determinate outcomes for future disputes, they inevitably privilege the interests of some states over others.[261]

Further, many States, especially developing nations, "refuse to consider themselves bound by rules of customary international law, however determinate the rules may be."[262] Thus, while Stockholm Principle 21,[263] the duty of States to cooperate,[264] and likely the Precautionary Principle[265] are customary international law and are therefore binding, a harmed State may have no authority to force the harming State to a particular, or any, enforcement mechanism.

Even the International Court of Justice does not have the power to force a State to submit to its jurisdiction.266 Thus, in order to es-

257. See supra notes 181-86 and accompanying text.
258. Scott Barrett, International Cooperation and the International Commons, 10 DUKE ENVTL. L. & POL'Y F. 131, 139 ("A country only needs to comply with a treaty to which it is a party.").
259. See generally UN Convention, supra note 176.
260. INTERNATIONAL ENVIRONMENTAL LAW ANTHOLOGY, supra note 114, at 15.
261. Id.
262. Id.
263. See supra notes 125-32 and accompanying text.
264. See supra notes 165-66 and accompanying text.
265. See supra notes 137-39 and accompanying text.
266. See Aloysius P. Llamzon, Jurisdiction and Compliance in Recent Decisions of the International Court of Justice, 18 EUR. J. INT'L L. 815, 815 (2007).

tablish ICJ jurisdiction over a State, the State must either have voluntarily submitted to the ICJ's compulsory jurisdiction or have agreed in a treaty that in the event of dispute the parties would submit the case to the ICJ.267

To minimize the problem of no available mechanism to force a harming State to submit to a particular mechanism, many treaties, both multilateral and bilateral, provide enforcement mechanisms that are binding on the party States.268 Ideally, transboundary States will choose to create treaties for transboundary waters and, more specifically, when a hydroelectric dam project is proposed for that river. These treaties prove beneficial, when drafted properly, because they can incorporate—and essentially codify—general principles, such as the Precautionary Principle, and relevant international watercourse law, such as the UN Convention. Use of such incorporation to address the construction and use of hydroelectric dams will ideally include enforcement mechanisms. When these enforcement mechanisms are incorporated into a treaty, in times of dispute, party States are then required to submit to that mechanism and consider the rendered decision binding.

3. Rendered Decision May Not Mean that the Problem Is Solved

A third enforcement problem is that even when States adhere to their duties of cooperation during a dispute and thus submit their case to the mechanism they previously designated through agreement, the eventual rendered decision may not always resolve the dispute.269

B. Nonlegal Forms of Enforcement

Realistically, because of these enforcement deficiencies, many times a harming State may halt or change its activities not based on the enforcement of an international environmental law, but through other nonlegal mechanisms. One general principle is the idea of reciprocity.270 A harming State may determine that although a certain action would be a good economic decision for the State, taking such an action will then leave open the door, and in a sense encourage, other States to take the same action.271 Thus, a State may determine

267. See id. at 844; see also infra Part VI.C. (demonstrating the difficulty of enforcement when a State is in noncompliance with customary international law).
268. See, e.g., infra Part VI.A.
269. See, e.g., infra Part VI.B (discussing an ICJ decision that did not resolve Hungary and Slovakia's dispute regarding a set of locks on the Danube River).
270. Barrett, supra note 258, at 133 n.6 (stating that "[c]ooperation may be sustained . . . by using a strategy of reciprocity").
271. See id. at 132-35.

that although a project would currently benefit the State, when other neighboring States take the same action, the State will be harmed.272

Additionally, a harming State may be forced into compliance with the applicable laws or forced to abort or alter a harmful project not because of international environmental law itself, but because of international pressure.273 International groups and leaders are likely to contact the State to show disfavor and lack of support. Additionally, a harming State is likely to receive hostile opinion and disruption from both its own citizens and the affected citizens of other States, and, possibly, even citizens internationally.

Damage to a State's reputation from noncompliance is injurious; such noncompliance may deter other States from entering into future agreements with the deviant State. A State's deviation from the law is problematic because "even a single deviation carries the risk of precipitating general erosion in law abidance, to the detriment of all states."274

VI. APPLICATION TO HYDROELECTRIC DAMS

Even though many States attempt to maintain good relations and exert effort to manage transboundary watercourses, ultimately, in times of need, each State will presumably still act according to what is best for its own State. Thus, many times when one upstream State envisions an economic benefit from the construction of a hydroelectric dam, that State may simply choose to take action regardless of the expense and harm the project will cause to other States which have rights to the same transboundary watercourse. Therefore, a sad reality is that many times States are harmed, and although there are relevant international environmental laws, the harmed State may still not be able to receive justice.

As noted, many multilateral and bilateral treaties contain specific enforcement mechanisms that the parties agree to follow in the event of later dispute, which do help avoid the problem of relying solely on the other State to abide by customary international law.275 As Principle 24 of the Stockholm Declaration provides, many times such bilateral agreements should be and are created specifically to deal with the watercourse issues that the neighboring States may be facing.276 Such bilateral agreements for actions like hydroelectric dam con-

272. See id.

273. See, e.g., infra notes 338-44 and accompanying text (discussing a letter to the Brazilian government signed by multiple organizations and individuals to show disapproval of the government's actions).

274. Barrett, supra note 258, at 139.

275. For an example of a bilateral treaty containing specific enforcement mechanisms, see Part VI.A.

276. See Stockholm Declaration, supra note 116, princ. 24.

struction and management will not necessarily prevent disputes from arising, but will ideally contain, with detail, enforcement mechanisms that the parties will use in case of dispute as well as contain an agreement to treat such decisions as binding.

Several relevant agreements (and lack of agreements) regarding hydroelectric dams and transboundary watercourses are identified in the following discussion. These situations exemplify the importance of bilateral agreements, yet show the enforcement deficiencies of relevant international environmental law—even when bilateral agreements exist.

A. United States and Canada

The United States and Canada have recognized for many years the necessity for joint specifications and a specific joint body to address transboundary water issues.277 The Boundary Waters Treaty was created in 1909 to "prevent disputes regarding the use of boundary waters and to settle all questions which [were then] pending between the United States and . . . Canada."278

In Article II of the Boundary Waters Treaty, the United States and Canada agreed that while either State has "the exclusive jurisdiction and control over the use and diversion, whether temporary or permanent, of all waters on its own side of the line which in their natural channels would flow across the boundary or into boundary waters," any such diversion "resulting in any injury on the other side of the boundary . . . shall give rise to the same rights and entitle the injured parties to the same legal remedies as if such injury took place in the Country where such diversion or interference occurs."279 This recognition shows the States' regard for Principle 21, the basic customary international law principle of the right of a State to develop and exploit its own resources, but only to the extent that it does not harm other States.

The Boundary Waters Treaty additionally creates the requirement in Article IV that neither party will create "any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters" where it results in raising the waters on one side of the boundary "unless the construction or maintenance thereof is approved by the . . . International Joint Commission."280 This ar-

277. See generally Treaty Between the United States and Great Britain Relating to Boundary Waters Between the United States and Canada, U.S.-Gr. Brit., Jan. 11, 1909, 36 Stat. 2448 [hereinafter Boundary Waters Treaty].

278. Id. When the treaty was initially created in 1909, the parties were the United States and "His Majesty the King of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, [and the] Emperor of India." Id.

279. Id. art. II.

280. Id. art. IV.

ticle creates a legally binding formulation of the general principle of cooperation; without this "codification," the duty to cooperate may otherwise be unenforceable.281 Additionally, harming States are obligated to consult with those States which are negatively impacted; this concept was later codified in relevant sources of law.282

The International Joint Commission (IJC) was created in Article VII of the treaty.283 Through its creation, both the United States and Canada recognized that each State's action regarding the "lake and river systems along the border" affect the other.284 Through the IJC, "[t]he two countries cooperate to manage these waters wisely and to protect them for the benefit of today's citizens and future generations."285 While the Boundary Waters Treaty was created long before the creation of either the Helsinki Rules or the UN Convention, the treaty's creation of the IJC shows a valuable concept, which was codified and emphasized in these later sources.286

The Columbia River Treaty, also between the United States and Canada, specifically addresses the Columbia River basin rather than all transboundary waterways between the two States as did the Boundary Waters Treaty.287 The existence of the Columbia River Treaty itself helps prove the overall effectiveness of the Boundary Waters Treaty, and specifically the IJC:

> Canada and the United States, in the years since the [Boundary Waters Treaty], often with the assistance of the International Joint Commission created by the [Treaty], have concluded several river agreements, the most important of which is the 1964 Columbia River Treaty. This accord resolved one of the most acrimonious boundary water conflicts between the two countries.288

281. See supra Part IV.A.2(c).

282. See UN Convention, supra note 176, arts. 7-8; Berlin Rules, supra note 138, art. 11; Helsinki Rules, supra note 177, art. XXIX.

283. Boundary Waters Treaty, supra note 277, art. VII.

284. International Joint Commission, Who We Are, http://www.ijc.org/en/background/ijc_cmi_nature.htm (last visited June 1, 2009).

285. Id. Note, however, that while many of the same themes were agreed to through the creation of these treaties, neither the United States nor Canada ratified the UN Convention. See Multilateral Treaties Deposited with the Secretary-General, supra note 183.

286. The creation of the IJC shows yet another application of including general prin-

ciples in a bilateral treaty, which ultimately makes those otherwise unenforceable principles legally binding, Specifically, the IJC clearly recognizes the overall themes of the Precautionary Principle and the Principle of Sustainable Development. This is clear based on the Treaty's focus on the States working together to preserve the water for today's use (presumably by doing careful analyses of impacts on the environment of each State) and by doing this in such a way so as to preserve for future generations. See generally Boundary Waters Treaty, supra note 277.

287. See generally Treaty Relating to Cooperative Development of the Water Resources of the Columbia River Basin, U.S.-Can., Jan. 17, 1961, 15 U.S.T. 1555 [hereinafter Columbia River Treaty].

288. Patricia Wouters, Foreword to INTERNATIONAL WATER LAW: SELECTED WRITINGS OF PROFESSOR CHARLES B. BOURNE, at xv (Patricia Wouters ed., 1997) (citations omitted).

The Columbia River Treaty specifically sets out development requirements for both the United States and Canada and arrangements for implementation.289 Article XV establishes a Permanent Engineering Board that, among other things, ensures that the Treaty's objectives are being met.290 Article XVI then specifies that those differences arising under the Treaty that cannot be resolved may be referred to the IJC by either State.291 If the IJC does not make a determination within three months, either party may then "submit the difference to arbitration by written notice to the other."292 The Treaty then provides details about the arbitrational tribunal.293

Although these treaties and the creation of the IJC have not completely prevented disagreement between the United States and Canada,294 they provide procedures and mechanisms that, overall, have assisted the States in working through their differences and ultimately reach agreements regarding shared water basins.295 Additionally, the very existence of the IJC is an important attribute, as many States have no joint mechanism to deal with transboundary watercourse decisions and disputes.296

289. Columbia River Treaty, supra note 287, art. II (development by Canada); id. art. III (development by United States); id. art. XIV (arrangements for implementation).

290. Id. art. XV, § 2. The Permanent Engineering Board is also required to "assemble records" of the river flows of the boundary between the United States and Canada, report to the countries when there is "substantial deviation from the hydroelectric and flood control operating plans," "assist in reconciling differences" between the countries regarding "technical or operational matters," periodically inspect to "ensur[e] that the objectives of the Treaty are being met," report to the United States and Canada "at least once a year of the results being achieved under the Treaty," and "investigate and report" on other matters that arise "within the scope of the Treaty" when either country requests. Id.

291. Id. art. XVI, § 1.

292. Id. art. XVI, § 2.

293. Id. art. XVI, § 3.

294. Specifically, the existence of the Boundary Waters Treaty did not prevent dispute regarding the Columbia River; thus the Columbia River Treaty was created. See supra note 287 and accompanying text. Likewise, the Columbia River Treaty did not completely deter dispute. For example, "when the term of the sale of downstream benefits under [the Columbia River Treaty] expired, a new agreement . . . was reached only after considerable controversy and disagreement." Wouters, supra note 288, at xv (emphasis added).

295. INST. FOR U.S. POLICY RESEARCH, UNIV. OF CALGARY, CONFERENCE REPORT, TRANSBOUNDARY WATER POLICY ISSUES: THE WESTERN NORTH AMERICAN REGION 1 (2007) (noting that while transboundary water "is very much under dispute, . . . Canada and the United States have been relatively successful in negotiating transboundary water where others have been less successful"); Stephen J. Randall, Executive Summary, in 2 INST. FOR U.S. POLICY RESEARCH, TRANS-BOUNDARY WATER POLICY ISSUES: THE WESTERN NORTH AMERICAN REGION, OCCASIONAL PAPER SERIES SPECIAL ED. 1, 1 (2008) ("[I]n spite of the cross border disputes that have arisen between Canada and the United States the two countries actually have an envious record in resolving disputes, as for instance in the case of the Columbia Basin Treaty and the longstanding work of the International Joint Commission (IJC)."); see also text accompanying supra note 288.

296. See INST. FOR U.S. POLICY RESEARCH, supra note 295, at 1; Randall, supra note 295, at 1 (emphasizing that much of the successful negotiating between the United States and Canada is a result of the IJC's effectiveness, and that fifty-five of the fifty-six disputes submitted to the IJC were resolved unanimously).

B. Hungary and Slovakia

An examination of the highly publicized dispute between Hungary and Slovakia demonstrates that even when a final decision of the ICJ is rendered, the dispute may still not be resolved.297 Hungary and Slovakia signed a bilateral treaty in September 16, 1977, which entered into force on June 30, 1978, regarding construction and operation of the GabÃíkovo-Nagymaros System of Locks in the Danube River, which included a hydroelectric power plant.298 The 1977 Treaty also set forth specific procedures for dispute resolution.299

Hungary never began part of the construction that the agreement mandated.300 Hungary claimed that there was not "adequate knowledge of the consequences of environmental risks" and that more studies were necessary.301 In response, Slovakia diverted the Danube River and implemented a "provisional solution," aiming to provide the benefits that it had anticipated receiving from the system of locks.302

Hungary and Slovakia each claimed that the other violated the 1977 Treaty, based on different theories of violation.303 All attempts to use the designated enforcement procedures set forth in the 1977 Treaty failed, and eventually the case was submitted to the ICJ, which had been agreed upon in the 1977 Treaty as the court of last resort.304 The ICJ held that both parties had violated international law but, ultimately, without giving specific instructions on what each State was then to do, said that the Treaty as agreed upon was still in force.305 The ICJ provided that Hungary and Slovakia had a duty to negotiate and, while doing so, to take into account the principles of environmental law.306

Ultimately, although the ICJ rendered a decision, the dispute was not completely resolved.307 There has been at least one appeal to the ICJ for an additional judgment,308 and there have been multiple negation attempts between Hungary and Slovakia.309 Specifically, after the ICJ's decision, Hungary and Slovakia entered into negotiations,

297. Case Concerning the GabÃíkovo-Nagymaros Project (Hung. v. Slovk.), 1997 I.C.J. 7, 42 (Sept. 25).
298. Id. at 14, 20.
299. Id. at 23.
300. Id. at 31-33.
301. Id.
302. Wouters, supra note 288, at xviii.
303. GabÃíkovo-Nagymaros Project, 1997 I.C.J. 7 at 15-16, 35-38; Wouters, supra note 288, at xviii.
304. GabÃíkovo-Nagymaros Project, 1997 I.C.J. 7 at 11.
305. Id. at 54-56; see also Llamzon, supra note 266, at 833.
306. Llamzon, supra note 266, at 833.
307. See id. at 833-34.
308. Id. at 833.
309. Id.

which "broke down" in 1998.310 After negotiations failed, Slovakia requested the ICJ give another judgment because of Hungary's alleged unwillingness to negotiate in good faith.311 In 2002 and 2003, there was "some talk" that Slovakia would return to the ICJ.312 In 2004, following a two-year period of no negotiation, Hungary and Slovakia each announced that they were willing to continue negotiations for implementation of the original ICJ decision.313 These negotiations, however, apparently accomplished very little.314

C. Brazil and Bolivia

Yet another unfortunate example of the difficulty of enforcement is the present dispute between Brazil and Bolivia. "The eternal tension between Brazil's need for economic growth and the damage that [it] can cause to the environment are nowhere more visible than here in this corner of the western Amazon region."315 This dispute not only demonstrates a State's internal struggle between its need for efficient energy and its efforts toward environmental preservation, but it also shows the direct application, or rather the lack thereof, of international environmental laws and their enforcement.

Brazil, one of the world's leading dam-building nations,316 is currently demonstrating the extent of international dispute resulting from a State's lack of regard for the environment, transboundary States, and the relevant law. In 2007, the Brazilian government approved other hydroelectric dam projects, including the Santo Antonio and Jirau dams, which will be constructed on the Madeira River.317 According to Glenn Switkes, Director of International Rivers Network's Latin America office, these projects "[will] dam the Amazon's principal tributary, causing dramatic changes to the riverine ecology and affect[] thousands of families who depend on the river for income, nutrition, and agriculture."318

Before the project's approval, and even since its approval, the project has stirred ongoing controversy both within Brazil and internationally, based largely on the environmental impacts on neighbor-

310. Id.
311. Id.
312. Id.
313. Id. at 834.
314. Id.
315. Rohter, supra note 48.
316. Press Release, World Commission on Dams, Brazil: A Major Hydro Power (Aug. 11, 1999), http://www.dams.org/news_events/press309.htm ("Brazil is one of the [countries] most dependent on hydroelectricity, with 96.9 per cent of power generated coming from its 600 dams.").
317. Gary Duffy, Brazil Gives Amazon Dams Go-Ahead, BBC NEWS, July 10, 2007, http://news.bbc.co.uk/2/hi/americas/6286804.stm; Switkes, supra note 80.
318. Switkes, supra note 80, at 1.

ing Bolivia.319 Proponents of the Santo Antonio and Jirau dams claim that without the dams, serious blackouts will result in Brazil, and they assert that construction of the dams will create many new jobs.320 However, "[a]s environmentalists see it, the dams, one of which is to be barely 20 miles from Brazil's border with Bolivia, will not only add to the strains on the Amazon, but also generate tensions within the country and between Brazil and its neighbors."321

Independent studies prepared by the state public attorney's office in Rôndonia, Brazil and by IBAMA, the Brazilian government's environmental agency (under the previous executive board),

> confirm what environmentalists and social movements have feared—that the Madeira project would cause enormous impacts. These would be felt over thousands of kilometers, from the mouth of the mighty Amazon and up the Madeira into neighboring Bolivia and Peru. A principal factor is the Madeira's extremely high sediment load—the river carries millions of tons of clay, sand, and silt from the Andean slopes where it is born to the Amazon River, where it accounts for half of all the sediments along the lower Amazon. Studies have shown that when the dams begin operation, the upstream Jirau reservoir would fill up with sediments, extending the flooded area into rainforests in neighboring Bolivia. The retention of these sediments behind the walls of the dams would also rob downstream floodplains of the precious nutrients that fertilize agricultural lands and help sustain the Madeira's incredible biodiversity 322

Additionally, critics claim that the dams will put thirty-three endangered mammal species at risk of extinction, including the spotted jaguar, giant anteater, giant armadillo, and giant otter.323

319. See generally id.
320. Rohter, supra note 48.
321. Id. "[T]he dispute . . . appears to have more to do with politics and economics than science and nature." Id. The political debate regarding the hydroelectric dams is further complicated by the countries' animosity regarding other current issues. Ivo Cassol, gover-

nor of the Brazilian state of Rôndonia stated that " 'Bolivia has no reason to meddle in this matter,' '[t]hey've already given us enough problems.' " Id.

322. Switkes, supra note 80, at 2; see also Michael Kepp, Brazil-Bolivia Joint Work Group to Study Environment Impacts of Amazon Dam, INT'L ENV'T DAILY, Dec. 28, 2006. In November 2006, Rondonia's own public prosecutor who was personally concerned about the

> thoroughness of the [environmental impact study] and its supplementary studies, asked an independent group of researchers to do its own studies on the dams, which it passed on to IBAMA in December [2006] . . . . The researchers' studies showed that, because of the Madeira River's high sediment load, the dams could block sediment passage, thus denying the organic material to the downstream food chain in the dam's reservoirs and that the dams could block the migration of spawning fish.

Id.

323. Int'l Rivers Network, The Amazon Under Threat: Damming the Madeira 1-2, http://www.internationalrivers.org/files/MadeiraFact.pdf (last visited June 1, 2009).

On July 9, 2007, IBAMA granted the preliminary license for the construction of the project.324 IBAMA eventually released the final report in November 2007.325 It took IBAMA approximately two years to approve the project, and even with passage, IBAMA included thirty-three conditions with which the winning consortium must comply.326

On December 10, 2007, despite the ongoing controversy, the Brazilian government auctioned off the construction contract for the Santo Antonio dam.327 A few days earlier, on December 6, 2007, Friends of the Earth-Brazilian Amazon filed an injunction to suspend the December 10th auction and argued that "the IBAMA technical team recommended through its impact assessment that neither Madeira River dam should receive a preliminary environmental license."328 On the morning of the auction, dissatisfied Brazilian groups delayed the start of the auction and disrupted the bidding process, claiming that the project would "displace thousands and harm the environment"; protesters were ultimately forced to stop by Brazilian police officers.329

In August 2008, the Brazilian government officially granted the consortium a license for the Santo Antonio Dam project.330 Additionally, Brazil sent eviction notices to 3,000 indigenous people living in the area of the dam construction, requiring that they "abandon their lands" by August 30, 2008.331 Construction on the Santo Antonio dam

324. FRIENDS OF THE EARTH BRAZIL ET AL., THE AMAZON RIVER'S LARGEST TRIBUTARY IS UNDER THREAT 11 (2007); see also Duffy, supra note 317.

325. Bank Info. Ctr., Environmentalists Go to Court to Suspend the Auction of Rio Madeira Dam Project (Dec. 6, 2007), http://www.bicusa.org/en/Article.10602.aspx.

326. Duffy, supra note 317.

327. Alan Clendenning, Brazilian Consortium to Build Amazon Dam (Dec. 10, 2007), http://www.internationalrivers.org/en/latin-america/brazilian-dams/brazilian-consortium-build-amazon-dam.

328. Michael Kepp, Brazil Auctions Madeira Dam Concession Despite Protests over Environmental Issues, INT'L ENV'T DAILY, Dec. 11, 2007.

> "Our injunction request was based on IBAMA ignoring its own in-house technical team's recommendation not to license the dams, firing the head of its licensing department, and hiring outside consultants who gave the dam complex a more favorable recommendation, one which allowed IBAMA in July to give both dams the preliminary licenses needed to auction them," [Gustavo Pimentel, Friends of the Earth-Brazilian Amazon's eco-finance manager] told BNA.

Id.

329. Clendenning, supra note 327.

330. Press Release, Glenn Switkes, Gustavo Pimentel & Iremar Ferreira, Environmentalists Blast Construction License for Amazon Dam (Aug. 14, 2008), http://www.internationalrivers.org/en/node/3226.

331. Intercontinental Cry, Indigenous Bolivians Declare Emergency over Brazil Dams, July 14, 2008, http://intercontinentalcry.org/indigenous-bolivians-declare-emergency-over-brazil-dams.

began in September 2008,332 and the dam is expected to be functioning in 2012.333 Most recently, on December 23, 2008, IBAMA fined the consortium constructing the Santo Antonio dam the equivalent of over $3 million for killing eleven tons of fish, including catfish, during the dam's initial construction phases.334 Also in December 2008, the Brazilian National Development Bank (BNDES) announced that it would fund sixty percent of the project, an amount less than it had initially promised.335 This decrease was "apparently because even BNDES is scared about the project's risks and wants to share them with other investors."336 The "mass killing" of fish337 along with the decrease in funding demonstrates that critics' concerns about the dam project are likely very accurate.

Glenn Switkes commented in 2007 that "[a]round the world, people are appalled by the cynical and dishonest manner in which the Brazilian government has side-stepped due process and pushed through the Madeira Dams, despite evidence that they will have massive impacts on the Amazon Basin ecology."338

Global dissatisfaction is apparent through a September 21, 2007, Coalition letter written to Brazilian Foreign Relations Minister Celso Amorim and Brazilian Presidential Chief-of-Staff Dilma Rousseff.339 Although it is not apparent (or at least not yet) in this particular controversy, this letter shows how a State may be pressured into complying with international environmental laws even where it is initially willing to violate.340 The Coalition letter contains an extensive list of individuals and organizations that support "the formation of binational working groups [between Brazil and Bolivia] to assess the potential impacts on Bolivia of the Santo Antonio and Jirau dams on the Madeira River, the Amazon's principal tributary."341

332. Dead Catfish May Be the Least of Lula's Worries (Dec. 23, 2008), http://www.internationalrivers.org/en/blog/aviva-imhof/dead-catfish-may-be-least-lulas-worries.

333. Clendenning, supra note 327.

334. Brazilian Agency Fines Dam Consortium for Fish Kill, 32 INTL. ENV'T REP.

30 (2009).

335. Dead Catfish May Be the Least of Lula's Worries, supra note 332.

336. Id. (reporting that the riskiness of the project seems to be the culmination of concerns about both environmental risks and the "global financial implosion").

337. Id.

338. Press Release, International Rivers, Auctioning off the Amazon: Brazil's Madeira River Auction Sparks Anger, Protests, Lawsuits (Dec. 10, 2007), http://www.internationalrivers.org/node/2347. At the international level, to show opposition "activists barraged Brazilian embassies and consulates in the United States, Argentina, Holland, Belgium, and other countries with phone calls, and faxes, and e-mailed President Lula." Id.

339. Letter from Associãçao Terra Laranjeiras et al., to Celso Amorim, Braz. Foreign Relations Minister, and Dilma Roussef, Braz. Presidential Chief-of-Staff (Sept. 21, 2007), http://www.amazonwatch.org/newsroom/view_news.php?id=1464 [hereinafter Coalition Letter]; see also Press Release, Switkes, Pimentel & Ferreira, supra note 330.

340. Coalition Letter, supra note 339.

341. Id.

The letter addresses the relevant harm by stating that "[o]fficial project studies and independent expert opinions indicate that there is a distinct probability that Bolivia could suffer flooding of territories . . . ; loss of fish species and serious impacts on some of the most important fish currently populating the upper Madeira; and health impacts."342

Further, the coalition addresses Brazil's legal duty by stating that

> [t]he need for prior assessment of the possibility of negative impacts of this significance using the "precautionary principle" is affirmed in international treaties, including the Montreal Protocol (1987) and the Rio de Janeiro Declaration on Environment and Development (1992). The Convention on Biological Diversity (1992), which both Bolivia and Brazil have subscribed to, holds that sovereign states have "the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."343

The letter concludes by emphasizing that the Coalition "trust[s] that representatives of civil society organizations (CSOs) and independent technical experts will be guaranteed participation in [the] process, and that the working group meetings will be conducted in a transparent manner."344

Although Brazilian supporters have circumvented this necessity and moved forward with the preparation and actual construction of these dams, by law, Brazil is obligated to consider the potential impact to the entire river basin.345 Thus, in its determination to construct the Santo Antonio and Jirau dams, Brazil should have considered (and should continue to consider) the effects to Peru and Bolivia, both of which are in the same river basin.346

342. Id.

343. Id. This letter specifically shows how although the listed treaties are not binding on every country worldwide, in this instance, the Convention on Biological Diversity, is binding on both Bolivia and Brazil because they have each signed the treaty. Thus, Brazil is legally obligated to ensure that its activities do not damage Bolivia's environment. While the Convention on Biological Diversity is outside the scope of this Comment, because Brazil is legally bound to its enforcement mechanisms, it may be an enforcement route by which Bolivia could take action.

344. Id.

345. Rohter, supra note 48.

346. See id. As an aside, note that in December 2006, Brazil and Bolivia did actually agree to establish a bilateral work group after Bolivia "expressed concerns about the environmental impact" of Brazil's planned dam construction. Kepp, supra note 322. In requesting this joint work group, Bolivia cited to a 2002 agreement between the two countries which required a " 'rational use' of hydro resources along their common border." Id. Unfortunately, however, the work group "ha[d] no power to effect the project or its licensing," and based on Brazil's actions since early 2007, it appears that Bolivia was unsuccessful with any attempts to prevent Brazil from moving forward. Id.

VII. CONCLUSION

A. Regarding Environmental Harm

While on the surface each State seems interested in preserving international watercourses, it can be presumed that, naturally, each State's ultimate concern is the effect on its own territory. Assuming this is true, each State is only secondarily concerned with the eventual effects of its actions on other States.

While there is much opposition regarding hydroelectric dams, most of these opponents "do not believe that [any] dam should ever be constructed."347 Rather, they simply believe that development projects, including dams, "should only be built after all relevant project information has been made public; the claims of project promoters of the economic, environmental, and social benefits and costs of projects are verified by independent experts; and when affected people agree that the project should be built."348

This position is justified. Hydroelectric dam construction should not be eliminated, as there indeed are advantages to these dams, especially as a source of reliable energy production. But each State clearly has an obligation, and should fulfill that obligation, to thoroughly plan and analyze the likely effects of a proposed hydroelectric dam before construction begins, even where a State considers the construction to be hugely profitable and a necessity for energy purposes. This would ensure compliance with such concepts as equitable utilization, by ensuring that the construction is truly the optimal equitable and reasonable use of the watercourse itself, rather than simply an equitable and reasonable use for the particular State. A State's concern regarding the condition of its environment would also be in line with general principles of international law, namely the Precautionary Principle and Principle of Sustainable Development.

B. Regarding Brazil and Bolivia Specifically

Because customary international law is binding on all States, with regard to Brazil and Bolivia, Stockholm Principle 21 is definitely binding,349 the duty to cooperate is definitely binding,350 and the Precautionary Principle is likely binding (depending upon which argument prevails regarding whether the principle truly is customary international law).351 Further, while the Principle of Sustainable Development is not clearly customary international law, it still receives

347. Frequently Asked Questions About Dams, supra note 26.
348. Id.
349. See supra note 126 and accompanying text.
350. See supra notes 166, 171-72 and accompanying text.
351. See supra notes 137-39 and accompanying text.

widespread use throughout the international community,352 and thus it would not be unreasonable for one of those countries to presume that the other should adhere to the principle. Unfortunately, however, these principles lack any definite enforcement mechanisms and thus it is in essence impossible for Bolivia to force Brazil to comply based on these principles alone.

Additionally, even assuming that the Helsinki Rules are customary international law, there still are no definite enforcement mechanisms within, but rather there is a framework as to how bilateral agreements should be arranged. Likewise, even if the UN Convention were actually in force, neither Brazil nor Bolivia has ratified it. Further, even if both parties had ratified it, because it is also a framework convention, without a bilateral treaty specifying enforcement mechanisms, Bolivia may still have no route for enforcement.

One hope for Bolivia, however, flows from the fact that both Brazil and Bolivia are parties to the Convention on Biological Diversity.353 Because both are parties, it is binding on each country, and thus Bolivia may be entitled to proceed upon any specified enforcement procedures in the treaty.

C. Regarding Transboundary Water Law

An ideal situation would be one where a straightforward and well-established set of laws and an intact precedent—similar to that of domestic law of the United States and many other countries—currently existed on the international level. It would further be ideal if when ambiguities or enforcement problems arise, like those that exist as a result of the increased use of hydroelectric dams, a legislative body could mandate rules and compliance by a simple enactment of a relevant statute. While international environmental law sources relevant to hydroelectric dams, both general and international water law specific, do exist, an obvious deficiency is that these are not mandatory; realistically, no such international body has authority to force every State worldwide to comply.

Although there is no mandatory body, and thus no binding procedure specifically addressing how and when a State may construct and maintain a hydroelectric dam on a transboundary watercourse, the sources we do have on the international level, namely the Helsinki Rules and the UN Convention, are a definite start. The Helsinki Rules, in existence since 1966, while never binding, eventually and for the most part, became customary international law.354

352. See supra notes 155-56.
353. See supra note 343 and accompanying text.
354. See supra note 179 and accompanying text.

Over thirty years later, in 1997, the United Nations finally adopted the UN Convention to address and expand upon those themes that the ILA had addressed in the Helsinki Rules. As noted by the UN Convention itself, it is a framework, intended to be expanded upon by States, with consideration to those States' particular situations and the transboundary watercourses affected. Although the UN Convention has not come into force, and although it is not widely considered customary international law at least at this point, it is a step toward uniformity in State treatment of international fresh water issues, namely hydroelectric dams and the effect on other States. Additionally, the ILA's adoption of the Berlin Rules in 2004 further demonstrates that this is a body of international law that is likely evolving, thus (ideally) eventually resulting in a clearer acceptance of these recurring themes.

Important, however, is that while such transboundary watercourse specific sources of law are not clearly binding, there are some general principles of international environmental law that are binding, such as Stockholm Principle 21, the overall duty to cooperate, and likely the Precautionary Principle. And, there are other principles not (at least yet) considered customary international law, such as the Principle of Sustainable Development, that are still important to international environmental law and adhered to by many States. Adherence to these recurring themes of international environmental law requires compliance efforts with an eye toward the effects on each State's own environment and economy, as well as an eye toward the effects on other States.

Although such a scenario is ideal, realistically, it is not likely that worldwide each State will immediately begin to comply with all sources of international environmental law by taking into account both the effects to its own State and to others. This is the case not only because much of the law is not binding, but also because even where the law is binding, many States will, with little consequence, refuse to comply because, particularly with customary international law, there are no mandated enforcement procedures.

On a more plausible scale, however, is a goal for greater acceptance of the use of bilateral treaties between transboundary States for hydroelectric dam projects. Such use of bilateral treaties would be consistent with relevant sources of international water law and would allow consideration to the unique characteristics of the particular States and transboundary waters involved. Additionally, these bilateral treaties would allow the parties to include provisions important to unique local and regional issues.

The creation of bilateral treaties is certainly not a final resolution to these transboundary watercourse disputes and enforcement mechanism deficiencies, as bilateral treaties certainly do not guarantee

that no future disputes will arise. However, even though not perfect, bilateral treaties do provide binding enforcement mechanisms for certain principles of customary international law, which otherwise a country would be unable to enforce.

Even more specific—and in a continued attempt to resolve disputes between States who have negotiated a bilateral treaty—is the creation of some type of commission, such as the IJC created by the United States and Canada. These commissions provide a body comprised of individuals from each country that can decide difficult questions, such as those that may evolve through construction and use of hydroelectric dams on transboundary watercourses.

Overall, in addressing hydroelectric dams, there are, in the author's opinion, two related, yet distinct, issues: (1) the actual environmental harm caused by dam construction and use; and (2) the lack of adherence to relevant international environmental law. Of the two, it is more realistic and more effective to address the deficiencies of the law itself and aim for international efforts toward both overall compliance and additional development of the law. By focusing primarily on the law, as opposed to the actual environmental harm, States will inevitably cause less harm to the environment of their own territory and the territory of other States.

A Study of Hydroelectric Power - e-News | Penn State ...

A Study of Hydroelectric Power:
From a Global Perspective to a Local Application

Prepared by:
Duane Castaldi
Eric Chastain
Morgan Windram
Lauren Ziatyk

Prepared for the
2003 Center for Advanced Undergraduate Studies and Experience
From Industrial Revolution to Industrial Ecology: Energy and Society

College of Earth and Mineral Sciences
The Pennsylvania State University

ABSTRACT

As energy becomes the current catchphrase in business, industry, and society, energy alternatives are becoming increasingly popular. Hydroelectricity exists as one option to meet the growing demand for energy and is discussed in this paper. Numerous consideration factors exist when building hydropower plants; whether the concerns are global or local, each has been measured when discussing this renewable energy source. From environmental and economic costs of constructing such plants to proposing the addition of hydropower generating capabilities in Pennsylvania, the authors have used personal experience from field studies and intensive research to cover the topic of hydroelecticity.

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INTRODUCTION

Hydroelectric power captures the energy released from falling water. In the most simplistic terms, water falls due to gravity, which causes kinetic energy to be converted into mechanical energy, which in turn can be converted into a useable form of electrical energy. Ancient Greeks used wooden water wheels to convert kinetic energy into mechanical energy as far back as 2,000 years ago. In 1882 the first hydroelectric power plant was built in the United States using a fast flowing river. Humans in time began creating dams to store water at the most convenient locations in order to best utilize power capacity (Australia Renewable Energy). Additional engineering and structural changes have followed, providing for a much more complicated process in designing a hydroelectric power plant.

Hydroelectric power plants are categorized according to size. They fit into one of four different size ranges: Micro, Mini, Small, and Large. A Micro sized plant is one that generates less than 100 kW of electricity and would typically be used to power 1-2 houses. A Mini facility can serve an isolated community or a small factory by generating 100kW-1MW of electricity. A Small plant generates 1MW-30MW and can serve an area while supplying electricity to the regional grid. Lastly, a Large facility generates more than 30MW of power. Hydroelectric power accounts for about 10% of the total energy produced in the United States. The United States has the hydroelectric power potential to create 30,000MW of electricity by utilizing 5,677 undeveloped sites. This figure is based on environmental, legal, and institutional constraints. In Pennsylvania, we could potentially produce 5,525,646 MWhr of electricity annually; however, this would still only account for 3% of total electricity generation in the commonwealth.

According to the US Hydropower Resource Assessment Final Report, there are a total of 104 projects that have a nameplate capacity of 2,218MW. One of these sites is the Flat Rock Dam in Manayunk, PA and this will be the site of our proposed hydroelectric power plant. It is

located in Philadelphia County in the Delaware River Basin on the Schuylkill River and has a nameplate capacity of 2500kW. The canal and dam were first built in 1819 and rebuilt in 1977 after the dam collapsed. It is built on top of a naturally existing fall. The canal served to provide transportation for anthracite coal in the region by allowing boats to avoid the rapids; the water was also used to power mills on Venice Island, the island created by the canal. Boaters today use the “slack water” for recreation.

Research Expedition Sites

Irafoss Power Station

On the trip to Iceland and the Untied Kingdom we saw two hydroelectric power plants – Irafoss and the Dinorwig Electric Mountain. Irafoss is located in Iceland and is one of three power stations on the River Sog. The power plants were designed to provide electricity to the capital city of Reykjavik. The Irafoss station harnesses power from two falls, the Irafoss and Kistufuss, located on the lower Sog. The combined head of the two falls is 38 meters. When it went online in 1953 it utilized 2 turbines that each generated 15.5 MW. In 1963 an expansion of the plant added a third turbine, which has a generating capacity of 16.7 MW. Interestingly, one of the brands of generators they use is Westinghouse Electric, International Co. of the United States.

The Electric Mountain and Dinorwig Power Station in Wales in the United Kingdom is a pump-storage facility. The basic mechanics of a pump-storage facility is the use of two reservoirs at different altitudes. When water from the upper reservoir is released energy is generated. During non-peak hours when there is excess energy, the water is pumped from the lower reservoir back to the upper reservoir in order to fulfill peak demand once more. The picture on this page is a schematic of the inner workings of the plant. It can generate 1320MW of power and the pumps and turbines can reach maximum capacity in less than 16 seconds.

Electric Mountain

Scope of Project

While these are effective plants in their respective geographical areas, we wanted to research the effectiveness of building a hydroelectric power plant in a more local region of Pennsylvania. As mentioned earlier, we will take a look at the power potential of Flat Rock Dam in Manayunk, PA. We chose to address economic and environmental considerations and then propose a site in which to build a power plant and/or make modifications to the existing area. First, we wanted to address the general environmental concerns of any hydroelectric power plant. We decided to weigh the benefits and drawbacks to the flora and fauna affected by the construction of a plant. We

Flat Rock Dam on the Schuylkill River

then considered what economic impacts would be placed on the immediate area surrounding the plant, and also examined the historical and contemporary economics of the region. Finally, we studied the engineering specifications to satisfy as many environmental and economic concerns as is possible while building an efficient plant with the correct amount of power generation.

ENVIRONMENTAL EFFECTS

The implications of a hydroelectric power plant are quite varied and have significant effects on the physical, biological, and human environment in and near the site area. Complicating the matter even further, hydroelectric power generation is usually not the single reason why a dam is constructed along a river. A coal power station is not built for any other reason but power generation, whereas a hydroelectric dam may be constructed for other reasons such as flood control. Since hydropower is generated from the dam, however, some of the environmental implications should still be attributed back to the production of hydropower. As we have chosen a site with a pre-existing dam not all of the implications will directly apply. However, it is important to understand all the consequences of hydroelectric power and the existence of dams on rivers.

Physical

The physical environment is affected rather significantly by the construction of a hydroelectric power station. Both the river and ecosystem of the surrounding land area will be altered as soon as dam construction begins. Once the barrier is put in place, the free flow of water stops and water will begin to accumulate behind the dam in the new reservoir. This land may have been used for other things such as agriculture, forestry, and even residences, but it is now unusable. The loss of habitat may not seem severe but if this area was home to a threatened

or endangered species, the dam construction could further threaten that species risk of extinction (Biswat, 1981).

The reservoir that has been rapidly filling up with water immediately begins filling up with sediment as well. Obviously the use of the reservoir is inhibited by sedimentation, so less water can be stored when more sediments fill in the bottom of the reservoir. The engineering problem with sedimentation is that less power is generated as the reservoir's capacity shrinks. Clean water stripped of its sediment load is now flowing downstream of the dam. This clean water has more force and velocity then water carrying a high sediment load and thus erosion of the riverbed and banks becomes problematic. Since this is unnatural and a form of "forced erosion" it occurs at a much faster rate then natural river process erosion to which the local ecosystem would be able to adapt. Environmentalists must work to slow down the water by creating barrages, although the effectiveness of these techniques is not exactly known (Thorndike, 1976).

An additional problem the sedimentation of the dam creates is erosion of the delta at the mouth of the river. All the sediments that are now trapped in the reservoir previously ended up in the delta. The Aswan Dam on the Nile River is a perfect example; the delta that is 1,000 km away is heavily eroded by winter waves. Sediments carried downstream during flood season would build the delta back up again before the dam was constructed. However, lacking sediments during flood season now, the delta is eroded nearly year round.

Oftentimes some of the most severe environmental implications of a project occur during the construction phase. The case of building a dam is no exception. Many new roads are built which requires the removal of vegetation and topsoil since dams tend to be built in undeveloped regions. The fill used for the dam often comes from the local area, in an effort to reduce

transportation costs. The local impact becomes quite severe because of combining quarries with new roads and dam construction. Usually, environmental protection guidelines are followed during the construction phase to limit damage to the environment, even though damage cannot be completely avoided.

Another often-ignored environmental effect of dam construction is the impact on the microclimate level. Recent research has suggested that man-made lakes in tropical climates tend to reduce convection and thus limit cloud cover. Temperate regions are also impacted with "steam-fog" in the time period before freezing. In addition, depending on the size of the dam created, a moderating effect may be noticed on the local climate. Since water cools and warms slower then land, coastal regions tend to be much more moderate then land-locked regions in terms of temperature. Research has found in Hubei, China, that the Danjiankau Reservoir has increased winter temperatures by about one degree Celsius and decreased summer temperatures by the same amount (Biswat, 1981).

Finally, one of the least studied and most disputed physical impacts of dam construction is the possibility of inducing earthquakes. Some scientists believe that seismic activity can be attributed to the creation of dams and their adjacent storage reservoirs. The theory is that added forces of the dam along inactive faults seem to free much stronger orogenic tensions. Early research indicates that the depth of the water column may be more important to inducing earthquakes rather then total volume of water in the reservoir. While more research is needed on this subject several disasters such as the Koyna Dam in India seem to provide some truth to this theory (Biswat, 1981). While these impacts can be quite severe often they do not receive the attention of the biological impacts that people tend to associate more with animals like fish.

Biological

Animal and plant life are impacted significantly by the dam construction. As mentioned earlier the large scale flooding destroys a large area of habitat for animals and destroys an equally large number of plants. If the region was forested prior to the construction of the dam the timber is harvested before the flooding begins. Reservoirs that in the future will be used for recreation such as boating or fishing tend to be completely cleared of trees. In addition, in very cold climates such as Canada, deterioration of fully submerged trees occurs very slowly – increasing the likelihood that the trees must be removed first (Biswat, 1981). The impact of tree removal is more logging equipment around the dam site which of course increases roads and pollutants into the region.

Flora

Another negative biological impact of dams is the growth of aquatic weeds. Tropical and semi-tropical regions seem to have the largest problem with weed growth. In Surinam, Lake Brokopondo has become inundated with Eichhornia crassipes, which is commonly referred to as water hyacinth. In just four years the water hyacinth has covered more then fifty percent of the reservoirs surface. The impacts of weeds can be significant to water loss. More weeds growing in the reservoir result in a higher rate of evapotranspiration. Also, more water must be released for irrigation purposes to ensure that an adequate supply makes it to the lower reaches of the irrigation channel if there are weeds growing in the channel as well. The weeds will compete with fish for space and nutrients that are already under stress living in an unnatural setting.

Some disease rates such as malaria and schistosomasis tend to increase as weeds provide a very favorable habitat for mosquitoes and other invertebrates that spread these diseases. How do we contain these problems? The weeds can be controlled, although the task is often very

difficult and expensive. In shallow water mechanical or manual clearing is by far the most effective. However, in deeper waters this is not an option and either chemical or biological means must be used to remove the weeds. Chemical herbicides work very well but bring about a whole new set of environmental hazards to organisms, humans and the ecosystem in general. The scariest part about using chemical herbicides is that their overall effect is generally not known until they have caused a problem. Finally, biological controls can be used to combat the weed problem. This involves using fish or other aquatic organisms to eat the weeds (Biswat, 1981). The process of weed control often works best when mixing the three techniques described above. While biological impacts receive a great deal of press and publicity so do the human-environmental impacts of hydroelectric power.

Fauna

Animals tend to get the most attention from the press and public in general when dam projects are proposed. In Africa, before the construction of the Volta Dam, rescue operations began to catch and transport as many animals as possible to safer areas. Some animals such as elephants, giraffes, and rhinoceroses are so large that this process is quite difficult and expensive. Environmental laws are not international; therefore when unique or rare habitats are involved the hope is that design or location changes can be made to save these habitats, but this does not always occur. The creation of the dam does however create a new larger habitat for some species of fish. For example when the Lake Nasser dam was created fish production increased nearly four- fold (Biswat, 1981). The news for fish during dam construction is far from all good, though.

For some kinds of fish the building of a dam makes completing their life cycle nearly impossible. Anadromous fish, such as salmon, are hatched upstream in a freshwater

environment but spend their adult lives at sea in the salt water. The eel, a kind of fish classified as catadromous, is hatched at sea but spends much of its adult life in freshwater streams (Biswas 1981). Since these fish rely on streams and rivers to get to and from different environments, creating a dam makes a large roadblock for these animals to overcome. This is especially true in the Pacific Northwest in the United States. Without features such as fish ladders these fish would die off. However, even the fish ladders do not work perfectly and many fish die due to the dams.

There are a number of measures that can be taken to help minimize fish mortality at hydroelectric power plants. The most obvious step is to lower the number of fish that pass through the turbine. This can be accomplished by using better screens to capture the fish or establishing diversion passageways. A more complicated and emerging technology involves making “fish-friendly” turbines.

It is thought that gap sizes, runner-blade angles, wicket gate openings, overhang, and flow patterns are the components that most lead to fish injury. Pelton turbines, which are small turbines designed for high head installations cause nearly complete mortality of fish passing through. Kaplan, Francis, and Bulb turbines tend to be safer for small fish with mortality rates of only about thirty percent. These types of turbines have much larger areas of water passage. Kaplan turbines are thought to be the most fish-friendly of the conventional turbines. These turbines are used on the Columbia and Snake Rivers in the Northwestern United States and have a low mortality rate of just twelve percent. Scientists and engineers hope to work together to make changes to the design of turbines to ensure fish safety. Research is showing that reducing gaps might help fish pass through turbines safely. By reducing the gaps there should be less shear stress and grinding. However, it should be noted that all of this research is too preliminary

to be positively sure. Scientists are researching whether the route of passage through a turbine has any impact on survival rates. However, at this point the data is mixed and no definite conclusions can be reached (Cada, 2001).

Humans

Often the most discussed topic of building a new hydroelectric power plant is the dislocation of large numbers of people. In China, for example, the Three Gorges Dam Project will force the dislocation of over one million Chinese people (China Online, 2000). While relocating may not seem problematic, consider the fact that many of these people come from small villages where different cultural values and beliefs are held and all of the sudden these villages are merged together in a new setting. Residents are forced to leave behind all their ancestral roots. This is especially troublesome in Africa where people have to leave behind gods, shrines, and graves of their ancestors, all of which are very important to the local culture (Biswat, 1981).

The human-environment is also positively impacted by such large-scale projects with flood control. A significant reason why the Three Gorges Dam was not stopped despite the environmental hazards was the benefits to those living downstream. The Chinese government claimed that over 15 million lives would be saved downstream with flood control measures being put in place (China Online, 2000). Some proponents of hydroelectricity have pushed the issue of increased recreation as a benefit to society. It is true that by turning a river into a lake a park can be built around the dam for campers, boaters and whoever else wants to use the lake. However, this may not be as beneficial as it seems in the United States. The United States already has a plentiful supply of lakes to use for recreational purposes but has few remaining rivers free of obstruction and still able to flow freely (Thorndike, 1976). Therefore, the recreational argument

in favor of hydroelectric power is not very useful as many nearby residents will not want to see a free flowing river stopped in favor of a large reservoir.

While most of the environmental benefits to hydroelectric power are disputed, one is not. Hydroelectric power emits no air pollutants. A combined two billion tons of carbon dioxide are not emitted by burning fossil fuels thanks to hydroelectric power plants across the world.(Understanding Energy, 2003) While the environmental impacts of hydroelectric power are very far reaching and in some cases severe, they do not always receive the same amount of attention as the economic impacts. In the end, economics more often then not is the reason for the success or failure of a proposed project.

ECONOMIC ASPECTS OF HYDROPOWER

Economics is a branch of science concerning the distribution, production, and consumption of services and goods. Economics focuses on the financial aspects of a society on local, regional, and global scales. We need to learn about the economic structure and its function in order to fully understand (on a global scale) trade relations between countries, why and how (on a regional scale) a society works, and why (on a local scale) a business or factory fails or succeeds.

Thus when considering the construction of a hydropower plant in Pennsylvania it is necessary to have a basic understanding of the economics involved in building such a plant and how it would affect a local community economically. We also must consider the global economics of such a renewable energy source as hydroelectric. The global and local economics of hydropower will be explained throughout this analysis. The figures and statistics included in several surveys analyzed are too exhaustive and detailed to include in a regional economic

analysis; thus we will examine the areas in which costs are high or low, without providing too many monetary examples.

Global Hydropower Economics

On a global scale, the majority of consumed energy is derived from oil. All forms of (other) energy sources are affected by oil prices; when oil prices are low, the demand for alternative energy is low. When oil prices are high, people turn towards alternative energy sources and are more likely to decrease their consumption of oil. This thesis was tested in the 1970s when the oil embargo was in place. Such energy forms as solar, wind, hydro, and nuclear increased in use; more plants were built, and a greater demand was placed on these renewables. This is a very important factor in considering globalization and the relations of countries. When the United States has a large dependence upon oil producing countries such as Venezuela, Kuwait, and Iraq, we are at the mercy of these countries' roller-coaster economies that fluctuate from day to day and remain unstable. The more dependent we are on a sole country the more vulnerable we become. Now, not only are we concerned with deriving energy resources from these countries, we are fully invested in assuring the stability of the economies, which requires enormous financial contributions on our part.

A national/regional economic factor which must be considered in the proposal of a hydroelectric plant is the effect on the Gross Domestic Product (GDP) of a country with consideration to the years of plant operation. The U.S. Commerce Department calculates GDP as a measure of total output of goods and services within the country based on the following items:

- Personal consumption
- Government expenditures

- Private investment
- Inventory growth
- Trade balance

The GDP is calculated using a "chain-weighted" method. As deregulation increases business activity, relative prices for goods change quickly and dramatically. The "chain" system also recognizes that output for computers, telecommunications equipment and health services is growing much faster than other parts of the economy. The "chain" method forces the government to recalibrate the relative prices of these goods - and their relative importance to the economy - every year (USA Today).

A current thorough economic analysis of nationwide hydroelectric plant potential in the United States is available through a joint program between the U.S. DOE Office of Energy Efficiency & Renewable Energy, the Energy Information Administration, and The Idaho National Engineering and Environmental Laboratory. Using data across the United States, power plant sites were analyzed and assessed for economic cost and input to an area.

Local Hydropower Economics

When contemplating the local economics of a hydro plant, several things must be kept in mind: development, operating, and maintenance costs, and electricity generation. When evaluating a site, one must first consider whether it is already developed or not. If a dam does not exist, several imperative things to consider are: land/land rights, structures and improvements, equipment, reservoirs, dams, waterways, roads, railroads, and bridges. In an already developed area the only developmental costs that require consideration are structures, improvements, and equipment. Development costs may include factors for creating recreation, preserving historical and archeological sites, maintaining water quality, and lastly (but certainly

not least) protecting fish and wildlife. Several graphical representations are available to demonstrate the increased costs associated with undeveloped sites. Operation and maintenance costs are considerably more exhaustive. They include water for power, hydraulic expenses, electric expenses, and rents.

Flat Rock Dam Economics

Flat Rock Dam

The site chosen for our current project is the Flat Rock Dam located in Philadelphia County Pennsylvania on the Schuylkill River, shown at right. This site is complete with a pre-existing dam; however, no electric generating power is present at the moment. In order to update the design and make amendments, we must understand the environment surrounding the area, as well as the economics of the process of maintaining the dam, distributing power, and providing employment opportunities. It is of interest to note that the town of Manayunk where the Flat Rock Dam is located was previously called “Flat Rock,” coined in 1810 because of an area of flat rocks in the Schuylkill River. Since its birth, the town has maintained its livelihood around the River as a means of travel and trade. By 1819, the completion of the Flat Rock Dam, had aided much in Manayunk’s prosperity and communication. Flat Rock Dam facilitated a difficult section of the Schuylkill River where "Rummell's Falls" was and had previously only been navigable when waters were high. It was in 1819 when the mills of Manayunk really started being built in large numbers and immigrants (mostly from England) began operating the mills. From an early time, the dam was a major leader in contributing to prosperity in Manayunk. Obviously jobs in conjunction or related to the dam were plentiful during the height of river travel and commerce. Lock operators, millers, and canalsmen were important occupations within the community.

In order to evaluate this site for a hydroelectric power plant, we must consider the fact that there is a pre-existing dam, the ownership of the dam (land use rights) and how much it will cost to modify and maintain the dam (covered in the site construction analysis). BAMR (The Pennsylvania Department of Environmental Protection’s Bureau of Abandoned Mines Reclamation) has full ownership to the Flat Rock Dam. However, Lower Merion Township maintains a boat launch and picnic area that provides recreational access to the pool and dam. There is currently some controversy surrounding the use of powerboats in the pool area.

The debate surrounding the economics and environment of the dam provides us with the question of “Should the dam be used for maximum potential, or be maintained as is?” The dam has historically provided a means of livelihood; however, what is its future potential? The Flat Rock Dam was destroyed previously in a flood and rebuilt; the costs that accrued with rebuilding were substantial. Were they unnecessary? The dam is currently not providing any means of power to the residents of Manayunk. Historically it proved to be an invaluable asset to the community. When considering extensive technological improvements, the provision of power would not be of high interest to the citizens of Manayunk who now receive their power from Philadelphia based electric providers. Though the Flat Rock Dam is a historically important site, many environmental problems mentioned above have contributed to the idea that it should be removed. Alternatively, if the dam was not removed but rather upgraded and built upon as an energy provider for the community, what would it look like and what would the details involve? We will turn to these questions in the remaining section.

BUILDING A HYDROPOWER PLANT

The task for this project now turns to developing a site for a proposed hydropower plant. With the environmental and economic knowledge gained above, a suitable location was found that will satisfy the numerous variables in designing a power plant. Now we will review our choice of the Flat Rock Dam site for engineering considerations. One factor that must be kept in mind is that the location will need to be geologically sound; the underlying rock formations must have the capability to hold the weight of a dam.

The surrounding area must also be able to hold the water behind the dam in a manner that will not extensively damage the surrounding area scenically or physically. This is a major concern that must be addressed since most of Pennsylvania's rivers have been developed.

The daily routines of the general public require a fluctuating need for power, with the most electricity used during 'peak demand' times. Meeting peak demand is one issue that has been addressed by electricity providers with generally the same response. Most producers of electricity in the United States use natural gas-fired power plants to quickly meet the surge; however, combustion of natural gas produces numerous gasses that pollute the environment. Using water instead of natural gas to meet this demand decreases reliance on non-renewable fuel and does not produce volatile organic compounds, SOx or NOx emissions.

The United States Department of Energy subcontracts the Idaho National Engineering and Environmental Laboratory (INEEL) to study hydropower throughout the country. Information on all possible sites in each state has been compiled and listed with numerous site variables taken into consideration when determining available power at each location. In Pennsylvania, major rivers available for damming include the Allegheny, Beaver, Delaware,

Monongahela, Ohio, and Susquehanna. Figure 1, below, summarizes the power available in each river.

Figure 1: Potential power in Pennsylvania rivers (Conner, 1997)

INEEL provides a detailed listing of sites on each river available for power generation. The Flat Rock Dam in Manayunk, PA proved to be a solid match with the environmental factors described below. (Flat Rock Dam Information).

Consideration Factors

The Flat Rock Dam site was chosen based on the characteristics from the INEEL database. These nineteen points are detailed in Table 1, below, and provide a solid argument for developing hydropower in Manayunk. Sustainability Factors range from a low of 0.1 to 0.9, with 0.9 having the least impact on land and being the most likely for development.

Table 1: INEEL PESF (INEEL)

Project Environmental Sustainability Factors	
Wild/Scenic Protection	0.9
Wild/Scenic Tributary or Upstream/ Downstream Wild/Senic Location	0.9
Threatened/Endangered Fish	0.9
Cultural Value	0.9
Fish Presence Value	0.9
Geologic Value	0.9
Historic Value	0.9
Other Value	0.9
Recreation Value	0.75
Scenic Value	0.9
Wildlife Value	0.9
Threatened/Endangered Wildlife	0.9
Federal Land Code 103	0.9
Federal Land Code 104	0.9

Federal Land Code 105	0.9
Federal Land Code 106	0.9
Federal Land Code 107	0.9
Federal Land Code 108	0.9
Federal Land Code 198	0.9

The Manayunk location in Southeastern PA remains an ideal candidate for construction of a hydropower dam. Effects of building the generating station near the dam are minimal; environmental impacts are especially low. Actually constructing this facility will require precise knowledge of the site and dam dimensions.

Construction

When designing a hydroelectric power plant a number of elements and equipment need to be taken into consideration. Dam size, retention basin size and depth, inlet valves, weir and control gates, penstock length and diameter, turbines, generators, transformers and excitation equipment, and efficiency all have to be examined. Elevation or head and stream flow have to be established as well. In our case we can achieve a maximum drop of 21 feet or 6.4 meters and have an average stream flow of 9070 cubic feet per second or 256.83 cubic meters per second. According to the INEEL hydropower resource database we can achieve 2500kW of electric

power. Using this information we can find out how much of the flow we need to achieve 2500kW. The following is the calculation:

Power equation: P=eHQg	Solve for Q:
P=electric power output in KW	2500=(0.81*6.4*Q*9.81)
e=efficiency (.81 for small scale hydroplants)	Q=49.15 m^3/s
H=Head in meters	%of flow used: 49.15/256.83=19%
Q=design flow, m^3/s	
g=gravitational constant, 9.81m/s^2	

According to the calculation we will only need to divert 19% of the stream flow to create the needed amount of electricity. We will not divert much more than the needed 19% as to not take away from the aesthetics of the dam and the rushing water. As this is a highly recreational area, we do not want to greatly disturb the environment.

Plant Specifications

The next task is actually choosing the specifications for the plant. The main dam is already in place, as we chose a site with a pre-existing dam. However, in the spot where our power plant will sit, there will be a head of 21 feet. The dam is an integral part of the power plant. It is what controls the water; by damming up the water, the amount of water used to create power can be determined. When building a power plant from the ground up, the building of the dam would be the first step. Building a dam requires much research, approval, time, and money. The geology of the area must be taken into account (as was mentioned previously) so to avoid collapse due to geologic activity such as earthquakes. The size of the retention basin, or where the water sits behind the dam, must also be considered. Flow rate of the river and sediment load

must also be determined in order to establish an estimate on the dam lifetime. If the river carries a large sediment load, sediment will build up behind the dam more quickly than if there is less of a load. There are also mitigation techniques for removing sediment that can be considered for the project to lengthen lifetime. The dam also must go through an extensive approval and permit process. The Federal Energy Regulatory Commission is the main government body that provides the license for such a project as a hydroelectric power plant. Building dams and power plants takes a lot of time and money as well. There is always the chance of holdups and delays and sometimes projects can even run out of money. By choosing a site with an existing dam, all that needs to be done is some modifications – a choice that will require a lot less time and money

(Woodward).

Upon approval and completion of the dam the actual power plant needs to be built and each component fashioned. The following picture is a schematic of a power plant and all of its component parts.

Intake

The intake is the entrance to the system for the water. The inlet valves and control gate control how much water is going to enter the system. There are a number of different inlet valve designs. Three types that TOSHIBA Company of Japan offers are spherical or rotary, butterfly, and thruflow. GE Power Systems offers butterfly and rotary designs, as well as 6 others. We chose a thruflow (pictured left) as it has less head loss and leakage than the butterfly and rotary (pictured right) designs (GE Power Systems and TOSHIBA).

The next step is the intake weir and where the water will enter the power plant. The weir also is responsible for diverting the water. It also must help keep solid material from entering the system. Three examples of intakes are the side intake without weir, side intake with weir, and bottom intake. A side intake without a weir is relatively cheap requiring no complex machinery, but asks for regular maintenance and repairs. At low flows very little water will be diverted so this type of intake is not suitable for rivers with great fluctuations in flow. The side intake with weir is a set-up in which the weir can be partially or completely submerged in the water. This design requires little maintenance but low flow cannot be diverted properly. The weir is completely submerged in the third design, the bottom intake. It is very useful with fluctuating flows and allows excess water to pass over the weir. With our location and dam we would use the side intake with weir design. It allows us the most flexibility and will be the most effective and economic (Micro Hydropower Basics).

Penstock

The Penstock is a tunnel that caries the water from the intake to the turbines. There are a number of factors to consider when deciding which material to use in the building of the penstock. They are: surface roughness, design pressure, method of jointing, weight and ease of installation, accessibility of the site, terrain, soil type, design life and maintenance, weather conditions, availability, relative cost, and likelihood of structural damage. When considering soil type, you have to choose a material that will not be degraded or eroded by the surrounding soil. Economically speaking, the penstock can account for up to 40% of total cost of the plant. This is why efficient planning is critical (Micro Hydropower Basics).

Turbines

Once the water flows down the penstock, it passes and turns the turbines. There are a number of different models of turbines depending on which company the turbine is purchased from. However, there are common designs. Two different types of turbines are impulse and reaction turbines. Impulse turbines include Pelton, Turgo, cross-flow, and multi jet Pelton designs. Reaction turbines include the Francis, propeller, and Kaplan turbines. There are different designs specified for different head values. High head requires either a Pelton or Turgo, medium head calls for cross-flow, multi-jet, or Francis, and low head requires cross-flow, propeller, or Kaplan. In our situation, we have medium head so the cross-flow is going to be the best design for us. Also, the cross-flow has to be horizontal and that will work the best with our set up. “Also called a Michell-Banki turbine a cross-flow turbine has a drum-shaped runner consisting of two parallel discs connected together near their rims by a series of curved blades. A crossflow turbine always has its runner shaft horizontal (unlike Pelton and Turgo turbines which can have either horizontal or vertical shaft orientation)" (Micro Hydropower). A specific type of cross-flow turbine is the Ossberger. It has an efficiency of up to 86%. It can operate in head ranges of 1-200m and with water flows of 0.025-13 cubic meters per second.

Ossberger Horizontal Turbine

Due to these specifications, we will need to use four turbines at our location to generate the maximum amount of power. Ossberger turbines are relatively slow moving at 20-80 revolutions per minute. "The Ossberger turbine is a radial and partial admission free stream turbine. From its specific speed it is classified as a slow speed turbine. The guide vanes impart a rectangular cross-section to the water jet. It flows through the blade ring of the cylindrical rotor, first from the outside inward, then after passing through the inside of the rotor from the inside outward. Where the water supply requires, the Ossberger is built as a multi-cell turbine. The normal division in this case is 1:2. The small cell utilizes small and the big cell medium water flow. With this breakdown, any water flow from 1/6 to 1/1 admission is processed with optimum efficiency. This explains why Ossberger turbines utilize greatly fluctuating water supplies with particular efficiency" (Ossberger).

Generators, Transformers, and Electricity Production

Water flows through the turbine to turn it and its shaft to create mechanical energy that is transformed into electrical energy by the generators and transformers. Depending on the company purchased from, there are a number of different models of generators. Two main designs are the vertical or horizontal arrangements (TOSHIBA). There are four major

components to the generator; they are the shaft, exciter, rotor, and stator. The water turns the turbine, which turns the shaft and causes the exciter to send an electrical current to the rotor. The rotor is comprised of a series of large electromagnets that spin inside the stator, which is a tightly wound coil of copper wire. This process creates a magnetic field, which creates an alternating current, AC, by the moving of electrons. The transformer then converts the AC to a higher voltage current. The generator and transformer sit in what is known as the powerhouse. This is the main building of the hydropower plant. From the powerhouse there are four main wires that leave. There are three for the three phases of produced power and a ground wire common to the other three. These power lines are connected to the regional power grid (How Stuff Works, inc). The last component to the system is the tailrace. The tailrace is simply the pipelines that carry the water back out to the river.

Development Configuration

The diagram on the right shows some development configurations that the river and canal with the powerhouse can have. Based on how the dam and canal look in our scheme, design b, the extended fall canal, looks to be the best option. This design allows us to best utilize our given area.

CONCLUSION

After investigating the various impacts of a hydroelectric plant, we were able to determine the feasibility of implementing a hydroelectric plant at the Flat Rock Dam. Since most environmental concerns stem from construction of the dam, this location would not be greatly affected by the installation of a hydropower generating facility. Also, taking into the consideration that this is a highly scenic site of recreational value, we will only partially disrupt the volume of water over the dam, using about 19 percent of the flow. Most environmental concerns are mitigated by the fact that the area is already partially developed for a project such as this.

Economically speaking, this project would benefit the community by providing energy as well as employment opportunities. Construction costs are relatively low, especially when compared to the high price of building a new dam. Because the residents of Manayunk will benefit, any economic costs incurred by the building of a hydropower plant are justified.

Based on the environmental and economic considerations discussed, Flat Rock Dam would be a promising potential site for a hydropower plant. It would be classified as a small hydro project generating 2.5 MW of electricity. All materials involved in the construction would be readily available. There are many companies that service small hydropower plant projects and component parts would be easily accessible. Overall, the Flat Rock Dam site appears to be a good candidate for a hydropower plant due to its environmental, economical, and engineering feasibility. Through our research we have seen numerous applications of hydroelectric power from large scale projects to those on a smaller scale. From international power generating stations to a potential local opportunity, we have realized the vast opportunities of this natural resource.

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Environmental Impacts of Dams

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Low flows below dams killed thousands of salmon on the Klamath in 2002The environmental consequences of large dams are numerous and var

The environmental consequences of large dams are numerous and varied, and includes direct impacts to the biological, chemical and physical properties of rivers and riparian (or "stream-side") environments.

The dam wall itself blocks fish migrations, which in some cases and with some species completely separate spawning habitats from rearing habitats. The dam also traps sediments, which are critical for maintaining physical processes and habitats downstream of the dam (include the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands).

Another significant and obvious impact is the transformation upstream of the dam from a free-flowing river ecosystem to an artificial slack-water reservoir habitat. Changes in temperature, chemical composition, dissolved oxygen levels and the physical properties of a reservoir are often not suitable to the aquatic plants and animals that evolved with a given river system. Indeed, reservoirs often host non-native and invasive species (e.g. snails, algae, predatory fish) that further undermine the river's natural communities of plants and animals.

The alteration of a river's flow and sediment transport downstream of a dam often causes the greatest sustained environmental impacts. Life in and around a river evolves and is conditioned on the timing and quantities of river flow. Disrupted and altered water flows can be as severe as completely de-watering river reaches and the life they contain. Yet even subtle changes in the quantity and timing of water flows impact aquatic and riparian life, which can unravel the ecological web of a river system.

A dam also holds back sediments that would naturally replenish downstream ecosystems. When a river is deprived of its sediment load, it seeks to recapture it by eroding the downstream river bed and banks (which can undermine bridges and other riverbank structures, as well as riverside woodlands). Riverbeds downstream of dams are typically eroded by several meters within the decade of first closing a dam; the damage can extend for tens or even hundreds of kilometers below a dam.

Riverbed deepening (or "incising") will also lower groundwater tables along a river, lowering the water table accessible to plant roots (and to human communities drawing water from wells) . Altering the riverbed also reduces habitat for fish that spawn in river bottoms, and for invertebrates.

In aggregate, dammed rivers have also impacted processes in the broader biosphere. Most reservoirs, especially those in the tropics, are significant contributors to greenhouse gas emissions (a recent study pegged global greenhouse gas emissions from reservoirs on par with that of the aviation industry, about 4% of human-caused GHG emissions). Recent studies on the Congo River have demonstrated that the sediment and nutrient flow from the Congo drives biological processes far into the Atlantic Ocean, including serving as a carbon sink for atmospheric greenhouse gases.

Large dams have led to the extinction of many fish and other aquatic species, the disappearance of birds in floodplains, huge losses of forest, wetland and farmland, erosion of coastal deltas, and many other unmitigable impacts.

Environmental Impacts of Large Dams: African examples

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Environmental Impacts of Large Dams: African examples. By: Lori Pottinger. Date: Tuesday, October 1, 1996 Latin America Africa South Asia China Southeast Asia Policy ...

Land and water are ecologically linked in a natural system called a watershed. From the smallest droplet to the mightiest river, water works to shape the land, taking with it sediment and dissolved materials that drain to watercourses and, in most cases, eventually to the sea. So, too, is the river a product of the land it inhabits—the type of rock and soil, the shape of the land, and the amount of vegetation are some of the factors that determine the river’s shape, size and flow.

When these ties between the land and the river are broken by a large dam, the consequences are felt throughout the watershed, as well as by the web of life it supports. Of all the ways to tamper with or harm a river, a large dam usually has the most immediate and far–reaching effects because of the huge changes it causes to river hydrology—its very circulation system.

Some 40,000 large dams, most of which were built in the past 50 years, now obstruct the world’s rivers. More than 400,000 square kilometers—an area larger than Zimbabwe, and 13 times the size of Lesotho—have been inundated by reservoirs worldwide. The world’s largest impoundment, the 8,500 sq.km. Volta Reservoir behind Ghana’s Akasombo Dam, flooded 4% of that nation’s land area. In the United States, whose 5,500 large dams make it the second most dammed country in the world, we have stopped building large dams, and are now spending great amounts of money trying to fix the problems created by existing dams.

Although the impacts of large dams have been well documented for some time now, in case after case, new ones are proposed whose environmental impacts are downplayed or even ignored. A 1990 internal survey of World Bank hydroelectric dam projects showed that 58% were planned and built without any consideration of downstream impacts, even when these impacts could be predicted to cause massive coastal erosion, pollution and other problems.

The following are some of the more serious environmental impacts of dams on rivers and the life they support. I have concentrated on the kinds of impacts that might affect the Orange River watershed, leaving out other major dam–caused problems that have affected rivers under different ecological circumstances.

Reducing the flow of water from a river changes the landscape it flows through, which in turn can affect the ecosystem’s flora and fauna. A dam holds back sediments, especially the heavy gravel and cobbles. The river, deprived of its sediment load, seeks to recapture it by eroding the downstream channel and banks, undermining bridges and other riverbank structures. Riverbeds are typically eroded by several meters within a decade of first closing a dam; the damage can extend for tens or even hundreds of kilometers below a dam. Within nine years of closing Hoover Dam in the US, the riverbed below the dam had lowered by more than 4 meters. Riverbed deepening will also lower the groundwater table along a river, threatening vegetation and local wells in the floodplain and requiring crop irrigation in places where there was previously no need. The depletion of riverbed gravels reduces habitat for many fish that spawn in the gravelly river bottom, and for invertebrates such as insects, molluscs and crustaceans. Changes in the physical habitat and hydrology of rivers are implicated in 93% of freshwater fauna declines in North America.

Before the Aswan High Dam, the Nile River carried about 124 million tons of sediment to the sea each year, depositing nearly 10 million tons on the floodplain and delta. Today, 98% of that sediment remains behind the dam. The result has been a drop in soil productivity and depth, among other serious changes to Egypt’s floodplain agriculture. The Aswan Dam has also led to serious coastal erosion, another problem stemming from the loss of sediments in a dammed river. Another example of this problem is along the mouth of the Volta River in Ghana. Akosombo Dam has cut off the supply of sediment to the Volta Estuary, affecting also neighboring Togo and Benin, whose coasts are now being eaten away at a rate of 10–15 meters per year. A project to strengthen the Togo coast has cost US$3.5 million for each kilometer protected. The story is the same on coastline after coastline where dams have stopped a river's sediments.

Dams also change the pattern of the flow of a river, both reducing its overall volume and changing its seasonal variations. The nature of the impacts depends on the design, purpose and operation of the dam, among other things. All parts of a river's ecology can be impacted by changes to its flow.

A river's estuary, where fresh water meets the sea, is a particularly rich ecosystem. Some 80% of the world's fish catch comes from these habitats, which depend on the volume and timing of nutrients and fresh water. The alteration of the flows reaching estuaries because of dams and diversions is a major cause of the precipitous decline of sea fisheries in the Gulf of Mexico, the Black and Caspian Seas, California's San Francisco Bay, the Eastern Mediterranean and others. The regulation of the Volta River in Ghana by the Akasombo and Kpong dams has led to the disappearance of the once–thriving clam industry at the river's estuary, as well as the serious decline of barracuda and other sport fish.

The storage of water in dams delays and reduces floods downstream. River and floodplain ecosystems are closely adapted to a river's flooding cycle. The native plants and animals depend on its variations for reproduction, hatching, migration and other important lifecycle stages. Annual floods deposit nutrients on the land, flush out backwater channels, and replenish wetlands. It is generally recognized by biologists that dams are the most destructive of the many abuses causing the rapid disappearance of riverine species. About 20% of the world's recognized 8,000 freshwater species are threatened with extinction.

The floodplain itself is also affected by dams. Studies on the floodplain of the Pongolo River in South Africa has shown a reduction in diversity of forest species after it was dammed. And forests along Kenya's Tana River appear to be slowly dying out because of the reduction in high floods due to a series of dams.

Fifty years ago, the United States rushed into a water development program with little understanding of the negative impacts it would have on its rivers and all who depend on them. Today, we are beginning to "pay the piper" in depleted fisheries, damaged ecosystems, receding coastlines and many other problems linked to the damming of our rivers. We are now being forced to manage our dams differently, allocating more flow to the environment in an effort to stop further dam–related destruction of ecosystems and taking other costly steps to save valuable fisheries. We are even preparing to take down some particularly bad dams, at enormous expense. And we no longer build big dams.

Although it has now become very difficult to build destructive river projects in the US and many other highly dammed countries, our hydro industry and financial institutions continue to export this obsolete technology, much in the same way the chemical industry continued to export pesticides long after they had been banned in the country of origin. At dam conferences, the talk these days always centers around finding "fresh markets" to exploit and new ways to sell dams to a skeptical public.

The new South Africa has the opportunity to devise a water policy that builds on what the world has learned in the past fifty years of unchecked river development, and that involves civil society in the decision–making process. In the longterm, such an approach is the only one that doesn't diminish one of Africa's most treasured resources—its rivers.

What are the environmental impacts of Hydroelectric power plants

http://www.answers.com/Q/What_are_the_environmental_impacts_of_Hydroelectric_power_plants December 07, 2014

The major impacts are associated with dams and reservoirs related to the power plants. Reservoirs cover land which was previously in vegetation or forests,.

es through the year, the larger a reservoir needed to maintain a minimum level during dry months.If deforestation occurs in a basin that supplies water for an existing hydro plant, seasonal variations may start to be observed (i.e., too much water during rainy months and not enough during dry months). Excess water will overflow the reservoir and is useless for power production. Eventually, power production will start to decrease and fuel plants will have to be used to produce the extra power during demand peaks as follows:If the water level was ever allowed to go below the intake pipe, the turbines can no longer operate. Before that happens, the plant operators would selectively shut down turbines to reduce the rate of depletion of the reservoir, and during demand peaks the power that is not produced by the idle turbines would need to be produced by alternative sources, typically thermoelectric (fuel) plants.

A basin covered with dense vegetation will show 1) less evaporation and 2) less seasonal variability in the rivers flowing to the reservoir. The more the water supply fluctuat

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The Environmental and Socio-Economic Impacts of Hydroelectric Dams in Turkish Kurdistan.
By Thomas Moran

Abstract:
Through an interdisciplinary approach based on natural and social science this project aims to define some important issues concerning the sustainable development of hydroelectric dams through the specific case of the proposed Ilisu hydroelectric dam, located on the Tigris river in the south eastern region of Turkey. Specific emphasis will be placed on the environmental and socio-economic impacts of the dam affecting the indigenous population of the region, most of which are Kurds. The findings of this project are aimed at improving the acknowledgement of the vulnerability of host indigenous populations that are faced with the problems associated with large-scale dam construction.
The Ilisu Dam is part of one of the largest dam projects in the world, the Southeastern Anatolia Project. When eventually completed, it will include over 20 dams on the Tigris and Euphrates rivers. The Government led scheme aims to bring desperately needed development to the region through the use of water resources. The much-needed development of the region is due to number of different reasons cited in the project. The findings of this project point to a number of socio-economic problems that dam development has created. These findings have prompted the investigation into the socio-economic problems associated with the region prior the dam development. The understanding of such socio-economic problems and how they are affecting the given goals of the GAP project have helped to underline the inadequate planning procedures of the GAP authorities. This has also exposed the open neglect and marginalization of the Kurdish population in the region by the Turkish authorities, strongly suggesting change of approach in the way Turkish authorities manage development projects in the region.

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Chapter I: Introduction

The increasing global demand for energy combined with the ongoing quest for clean, renewable energy has been a topic of perceived interest amongst countries of developed and developing status worldwide. The level of interest and intent on using renewable technologies in energy has increased massively over the past 20 years or so, as has the realisation of the importance of minimising damage caused to the environment through the more classical, environmentally hazardous modes of energy production. During this same frame of time, various forms of energy production have been discovered, developed and put forward, of which some have been successfully implemented whilst others have been shunned. Many factors depend on whether the technologies developed are successful.

It is not necessarily the case where the most environmentally or financially sound technologies are the ones that are chosen as solutions to our global, increasing need for energy provision. Energy provision is a complicated matter. Some energy production technologies suit certain environments more than others, despite the fact that the energy production technology in question might not be as environmentally friendly as others. The best solution might not necessarily mean it is the cleanest one, but overall it might be the best solution all round. What I mean by this is that all factors that are directly or indirectly affected by energy production have to be considered so that the most suitable form can be identified and used. This means that although certain technologies might have a minimal impact on the natural environment, i.e., they might not be polluting the natural environment although they might have undesirable impacts in terms of the social or economical environment. If this is the case, then a technology that has more undesirable impacts on the natural environment but suits the socio-economic environment more might be a better choice. The choice of the less environmentally friendly technology would there for be a better choice in terms of sustainable development due to the fact that it is the better solution in terms of long-term prospects and that it might convene all concerned stockholders on the whole.

As far as the project that I have decided to undertake is concerned, I will be looking at renewable energy production technology that is generally perceived as one of

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the technologies that will bring many developing countries in the world up to date in terms of energy provision and help them gain developed status. Notably, it concerns the large-scale hydroelectric dams that are being planned and constructed in the developing world, notably focusing on a Turkish case study, the Ilisu Dam, located on the Tigris River. The actual construction of such large dams is today of the one of the hottest subjects of debate in the quest for sustainable development. In our day and age of increasing environmental awareness, the apparentness of environmentally sustainable generation of electricity is becoming more crucial, where many nation states worldwide, in both the developed and undeveloped parts of the world are striving for environmentally friendly ways of energy production. Hydroelectric power is seen by many as one of the cleaner modes of electricity generation, which is true in terms of electricity production but if we examine secondary effects as well as externalities, it becomes more obvious in the context of the overall environment that these dams are potentially damaging and in some cases dangerous for the local environment.

Large-scale dam construction is not a recent phenomenon, as dams similar to the size of the proposed Ilisu Dam have been erected worldwide over the past 50 years. Nevertheless, there has been a general downsizing of hydroelectric and irrigational dams in the developed world due to the many reasons, most of which can relate to the increasingly problematic impacts that are seen after the dams have been completed.

These impacts are generally not contemplated during the planning stages of the projects, thus are only identified through years of experience in the dam construction industry. So many unforeseeable impacts have to be taken into consideration, as well as their variable amplitudes all depending on the unique characteristics of the dam itself and of its host environment.

Many critics in the developed world have generally labelled the actual construction of large-scale hydroelectric dams as environmentally and socio-economically unviable. With most of the large scale dams being developed in the developing parts of the world for reasons of much needed irrigational purposes as well as the increasing demand for energy supply, I find it very worrying as in so many of these countries there is also a severe need of improvement in general economic and social policies. The planning and implementation of hydroelectric dams is a long and

complicated process that requires a specific economic and social conditions to be in existence so that the dam itself can serve its initial purpose without causing more problems than the case of not building one.

It is often the case with many of these countries that crucial considerations in the planning stages are ignored; where by the consequences of such actions are felt by the 'lesser' and more vulnerable groups in society. Such groups would constitute those marginalised from the mainstream society, such as indigenous populations. These groups in society are often those who will benefit least from the dams due to the fact that they don't conform to the perceived norms of society and therefore do not conform to the mainstream needs of the society.

As we shall see from the case study that I have chosen for this project, there are many underlying issues concerning socio-economic conditions that apply to the indigenous populations that have to be accounted for during the planning stages of a dam. If these conditions are ignored, there could be relentless consequences for the indigenous populations concerned and would present the government responsible for ignoring such conditions with a social and economical crisis on a scale beyond their capacity of control.

Chapter II: Problem Formulation

2.1. Problem-orientated Research Question:

"How does hydroelectric dam development, in terms of environmental and socio-economical impacts, affect the local indigenous populations of Turkish Kurdistan?"

2.2. Aims

My aims of this project are to research and analyse the impacts, both direct and indirect, that a large dam might have on its local environment and population in a developing region. I shall be assessing the dam development in the context of sustainable development. The impacts that I shall be investigating are environmental impacts and socio-economic impacts. By researching these impacts, I shall be looking at how these impacts are affecting the development of the local communities, both through how the environmental and socio-economic impacts affect the local inhabitants of the area in which the dam and reservoir will be constructed.

I find it crucial to set the criteria for the direct and indirect impacts. Direct impacts can be described as those impacts that arise directly from the development of the dam. That is to say that the direct causes of such impacts are related to the dam. Impacts that would be defined as 'direct' could be seen as the submerging of a valley as the reservoir is being filled. The flooding of a valley where by it becomes permanently submerged would constitute a direct impact from the dam development. Another direct impact would be the inability of aquatic organisms, such as fish, to migrate up-stream due to the dam-barrage.

Indirect impacts are harder to predict than direct impacts as they involve more than on process. Unlike direct impacts whose causes can be traced back to the dam, there are intermediate actors that bring on the impacts. Also, indirect impacts are harder to predict as they involve multiple stage processes, often specific to the environment of the location of the dam. So where by it might be possible to develop mitigation measures to deal with direct impacts in general, it is often much harder to create a mitigation model to deal with many of the indirect impacts as different conditions apply for each specific

dam. A good example of an indirect impact would be the rise of unemployment in a city after it has received a large number of unskilled farm workers displaced by the flooding of their homes to make way for a reservoir dam. In this case, the rise in unemployment would be caused by the overload of the city's capacity in providing employment to its newly acquired inhabitants. The reason for the displacement of these people into the city would be the filling of the dam reservoir. Here we see the increases in levels of unemployment are caused indirectly by the population displacement.

During my investigation of the various impacts of the Ilisu Dam, I shall be directing my main focus on the various environmental and socio-economic impacts that are affecting the indigenous Kurdish population within the vicinity of the dam. In doing so, it will be important to assess which impacts are affecting the wellbeing of the affected population and to identify which impacts that will degrade their wellbeing. After having identified such impacts, I will see if the planning authorities of the dam are implementing adequate mitigation measures to counteract the negative impacts sustained by the Kurdish population.

The case study that I have chosen to work with is located in the southeastern region of Turkey. Two Turkish dams will be covered through such case studies. The Ilisu Dam that is currently under construction. These two dams are similar to each other in the way that they are both under the same project: the Southeastern Anatolia Project. The Ilisu dam is located in the Kurdistan portion of Turkey, an area, which is predominantly inhabited by the Kurds and has been the focus of a lot of political controversy of the past 20 years or so. The area has been and still is subjected to civil conflict between the ruling government of Turkey and a large proportion of the local Kurdish population who have been striving for independence from the Turkish State. When Ilisu is completed, it will be amongst one of the largest (third largest to be precise) of its kind in Turkey.

Being fully aware of the differing nature of the environmental impacts and the socio-economic impacts that dams might have, I will attempt to establish links between the two. The links that I want to establish are those linking the indirect socio-economic impacts to direct environmental impacts of the dam. In doing so, I will try and prove that these indirect socio-economic have arisen due to the direct environmental impacts combining with unfavourable socio-economic conditions resulting in the indirect socio-

economic impacts. Having established this, I will prove how the environmental and socio-economic impacts are not mutually exclusive of each other, but rather complimentary of each other in the given circumstances. In doing so, I hope to strengthen the argument that the planning of large hydroelectric dams is more multi-dimensional and requires more angles of approach than the methods currently being used in Turkey today.

In doing so, I will attempt to prove through this project that the link between the two are strong enough so that people will realise that hydroelectric power is a technology that is complex and requires specific levels of environmental, economic and social conditions in order for it to function as a sustainable energy-producing technology.

Furthermore, I will attempt to show that countries still in the midst of development such as Turkey are not quite ready for such a step.

2.3. Criteria for choosing case studies

During the process of finding a case study to use for the scope of this project, I wanted to find a region that was in some way in the midst of transition between developing and developed status. Turkey fits the criteria perfectly as it is a country that is split into two worlds. Part of it is developed to ‘western norms’; where by part of it (that is the region I shall focus on) is severe need of social and economical development. The development of hydropower in this region of the country is to cater Turkey’s increasing power demands into the 21st Century, although how this will benefit the predominantly local indigenous Kurdish population still remains questionable.

The primary reason for Turkey’s increase in energy demand is to cater Turkey’s increasing industrial capacity, which is mainly located in the more developed western side of the country. Through researching the case studies, I will attempt to assess whether the dam projects will aid the regional development by improving the wellbeing of the local Kurdish communities or whether it will worsen it.

2.4. Limitations of Study

During the past few months spent researching ideas for the project, I decided to use two case studies for this project. In choosing 2 case studies, I initially decided to use 2 dams in the same region, under the same national project (the GAP project). It was my

original intention to have a dam that had been recently completed (Berke) and a dam that was in the stages of construction (Ilisu). In doing so, I wanted to compare data from the two dams and see what lessons the planning authorities had learnt from the completed dam and whether or not these were implemented into the planning of the dam in construction.

Unfortunately I have not had the possibility in travelling to the region for research purposes and hence have had to use mostly secondary sources data from various sources such as books, journals and the Internet.

One thing that I have realised is the extreme difficulty in obtaining data from government sources. The official EIA for the Berke Dam I managed to obtain although it dates back to 1991. Therefore, I have decided to focus my attention on the Ilisu Dam. There seemed to be a lot more information available for this case study as it has produced much interest from various NGO’s both in and outside Turkey. I decided to drop the case study of Berke dam due to the fact there was not enough reliable data available on this case study and therefore did not want to risk ending up with insufficient data to analyse. Several credible NGO’s have documented the developments of the Ilisu Dam, especially as far environmental and socio-economic aspects are concerned. Despite the failure by the planning authorities to release the EIA on the Ilisu Dam, several companies that were part of the consortium to develop the Ilisu Dam have abandoned the project, giving useful indications of the results within this EIA.

Chapter III: Methodology

The approach that I shall use is a qualitative approach; by using an interdisciplinary frame of analysis in examining the impacts given by the case study and the significant effects these impacts have on the Kurdish population in the region affected by Ilisu dam.

All of the data that I shall be examining will come from secondary sources, as the acquirement of first hand data was not possible

This project will provide a deeper insight into the workings and effectiveness of current national (Turkish) policies and regulations concerning the construction of large-scale hydroelectric dams. I shall be regarding these as planning tools and shall be closely assessing their effectiveness in balancing Turkey’s increasing energy demands whilst maintaining the regional development of the local needs.

In investigating these assessments, I shall attempt to determine which criteria have been deemed as priorities by the planning authorities, seeking to determine the extent of public participation that has taken place, as well as to which perceived environmental and socio-economic factors have been deemed as expendable. In this case, it will be how the indigenous Kurds are being displaced off their land and relocated to other areas in favour of national interests, in this case, energy provision. The impacts affecting the Kurds will be scrutinized by assessing the ways in which the Kurds will be affected on the long run.

Specific energy policies in Turkey will be looked at, in order to assess the level of priority that the Turkish government is assigning to the various forms of energy production available for Turkey to develop, including any alternatives to hydroelectricity that may have been considered. The implementation of domestic and foreign EIA directives from leading NGO's such as the World Commission on Dams and the World Commission on Environment and Development will be investigated too. Turkey whilst planning or constructing dams can see examples of this as directives draw up by NGO's such as the WCD and WCED that might or might not be taken into consideration. The directives such as those put out by the WCD are purely directives and are not bound by international law. The extent to which Turkey's dams in development are abiding by such

directives will prove to be one of the key factors in assessing the extent to which the government is serving the interests of the Kurds.

Establishing links between the various impacts as discussed in the Problem Formulation chapter will help me assess the extent to which the planning authorities are dealing with the impacts affecting the Kurds and whether or not sufficient efforts are being made in order to deal with those impacts.

Finally, I shall be able to establish the effect these policies and plans have both directly and indirectly on the local environment, both in terms of physical and socio-economic nature.

The project will highlight specific energy policies and hydro dam construction in Turkey both in the present and the past, affect the local area and population both through various environmental impacts as well as socio-economic impacts. Such impacts could be seen as population displacement where by whole communities are displaced by the location of a dam reservoir dividing them to certain extents. Other impacts such as the possibility of employment in sectors associated with the construction of the dam and reservoir can also be experienced. With the data obtained from the case studies, I will be able to see the extent and likelihood to which the Kurds will benefit from the dams.

Some of the impacts will be deemed as positive, some as negative. With the data available, I shall be attempting to show how the negative impacts heavily outweigh the positive, in the context of sustainable development and in what is best in the interests of the local population. Furthermore, I will be exploring the possibilities on how indigenous populations in both Turkey are being severely affected by dam construction, despite contradictive governmental claims stating that these populations stand to benefit from such development projects.

Chapter IV: Hydroelectric dams

Chapter 4 will be dealt with in 2 parts. In the first part I will be explaining the concepts of hydroelectricity and how this technology came about. Furthermore I shall be giving a descriptive and detailed account of what hydroelectric dams are and how they work. In doing so I will give a brief explanation of the origins of hydrological structures, highlighting the major turning points for dam construction.

The second part of this chapter will be deal with the various types of impacts that dam construction can have on its host environment.

4.1 History of Hydroelectricity

Hydroelectricity is a form of hydropower. Hydropower harnesses the power from moving water, under the influence of gravity, transforming it into mechanical or electrical power. In the case of hydroelectricity, the mechanical power created by the moving water is used to create electricity by 'feeding' the mechanical power through a generator, which in turn will produce the electricity.

The history of hydroelectricity does not stretch that far back. This is obviously due to the fact that electricity itself has only been around as a form of energy used by man for a couple of hundred years or so. Hydroelectricity was discovered or invented by an American carpenter and millwright Lester Pelton. Pelton invented the first water turbine called the Pelton Wheel or Pelton Turbine.

Pelton was inspired as result of a waterwheel going wrong. It was sometime during the 1870's as he was observing a waterwheel in action that the waterwheel slipped and became unhinged, forcing the wheel to become misaligned. Pelton noticed during this incident that the water was still able to flow, only now that it was being slightly deflected, and that the wheel was being turned at a faster velocity. It was at this point that Pelton made his great discovery, noticing that the water in normal turbines would hit the panels or cups on a wheel creating a splash. This splash for Pelton constituted wasted energy causing him to focus on how the energy in water could be harnessed instead of being wasted.

By 1880, Pelton obtained his first patent for a water turbine. Of course the first few designs that Pelton produced were not that good and kept improving with each amendment made, and it was not until 9 years later that Pelton was able to have a patent issued for an improved water wheel in 1889. The patent drawing can be viewed in the figure below.

1

The first industrial water turbine intended for generating electricity was developed in 1880 in Grand Rapids, Michigan. The only problem with early forms of hydroelectric power generation were that they were used to serve purposes in the direct vicinity of the turbines as transporting live electricity was a problem. It was only until this problem was overcome in the late 1890's that hydropower became widely used. The US was one of the pioneering countries in this field, becoming the first country to seriously use this alternative to fossil fuel electricity generating technologies. By the early 1900's, hydroelectric power was accounting for almost 40 percent of the total electricity produced in the US. As the technology was becoming more widely used it became

increasingly developed with increasing numbers and varieties of hydroelectric power stations being built. As a result of the increase in hydropower development in the first 20 years of the 20th Century, many more designs and varieties of hydropower stations were developed.

So we should consider the first quarter of the 20th Century as the pivotal point in the history of the developing hydroelectric power age.

4.2 History of Dams:

It's important to remember that this project is all about hydroelectric dams. The hydroelectric part of the dam is the part that concerns this project the least. This is due to the fact that the hydropower generated through a hydroelectric dam is done so through a turbine, a mere working part to the dam which does not make much difference towards the damaging nature of a dam itself.

It is only over the past 125 years that hydroelectric dams have been in use. Traditionally, dams have always been associated with irrigational uses. Dams built today are done so for two main reasons: for irrigational uses and/or for generating electricity. Many dams built now, are dual-purpose damns whereby the dam serves both interests. Dams themselves are one of the manmade structures that have been around for almost as long as civilisation itself. Of course the complexity and technology of dams has changed over time as has man's general knowledge and scientific endeavour over hydraulic technology.

Hydrological structures have been around for thousands of years and it is still not certain when the first ever hydrological structure was built. Although it is not clear when the first dam was built, much evidence according to Fred Perch, author of the 'The Dammed', point out that the one of the earliest structures that can be traced back in time is that of the Sumerians, constructed around 7,500 years ago, outside the ancient city of Ur of the Chaldees. The Chaldees refers to the Chaldeans, whom settled in the area around 900 BC, which was also named Mesopotamia by the Ancient Greeks2. The ancient city of Ur is actually situated in what is now known as Iraq. This ancient city is

1 Patent drawing of Pelton's water turbine;
http://inventors.about.com/library/inventors/bl_lestor_pelton.htm

now mostly buried by land although remnants can still be found site. What is now dessert used to be the most populated part of the world in ancient times. It is situated on a plain that is situated in-between the Euphrates and Tigris Rivers. The city of Ur was unique for its time due to the much advanced irrigation network that it had constructed, taking water from the two rivers and distributing it to the nearby fields. The irrigational network was itself primitive, as expected for that time, but effective. Simple holes were dug into the banks of the rivers enabling water to be channelled using crude mud channels to direct the water to its destination. Naturally, the water was not channeled a great distance so the fields that were irrigated were situated right by the banks of the rivers.

Over the following centuries, the fields intended for cultivation moved from the nearby river embankments in the shadows of the hills, further away, to the flat plains as the ability of the Samurians to channel water greater distances grew. It was not just mankind's ability to channel the river water that grew, but also to defend himself from flooding, as waters levels vary through the different times of the year, i.e. during the spring the water levels are high as snow on higher grounds such as the mountains is melting and hence feeding the streams that feed the rivers causing the river to rise and its banks to swell.

The ability of mankind to use and redirect water for his own needs constituted a big turn around for man in the sense that it enabled the Sumarians to develop as a culture, being able to use water to develop its own civilisation, as well as signifying the earliest beginnings of hydrological technology.

If we move on in time until around 500 AD, we would see the Persians using canals to channel water from the river Tigris to irrigate fields of distances up to 300 kilometres from the river banks. This constituted a massive improvement to the initial irrigational achievements of the Samurians, as the Persians actually maintained their waterways by using thousands of slaves to dredge the channels in order to keep the silt levels minimal. Minimising water flows and hence avoiding over-irrigation achieved lessening the salt intake in the fields. In addition to this, weeds were planted in order to lower the water table and keep the salt away from the roots of the crops.

2
Perch, '92; p.

Over time, man's knowledge of farming and irrigational techniques has improved. At first, it would take a long time to reach the next innovation, or realisation, but eventually through experience man has managed to improve and innovate his ability to manage water more efficiently. This meant that the world was being seen in a more scientific way, as hydrological civilisations became more and more advanced in their more rational approach to nature3.

Dams have come a long way since they first conceived on the most primitive and simple basis. As mentioned earlier in this section, small channels and other forms of irrigational structures such as the aqueducts built by the Romans have been around for a long time. What concerns us are the large dams that have been built over the last hundred years or so. Many could consider the actual dam building technology as a well-tested, safely established technology, having not seen any significant disasters arise from building large dams, yet this technology has only been around for around 100 years or so whereby man's experience with hydrological structures has been around for thousands of years and even today, we have not quite managed to perfect our skills in managing water. This is why I find it very naive to believe that a technology such as hydroelectricity has still got a lot to teach us, especially when taking environmental and socio-economic impacts into consideration. This will be explored in the next section of this chapter concerning the possible impacts of hydrological dams.

The mechanical workings of a dam are quite easy to understand. The actual mechanical workings of a dam are quite simple but of a high-technological standard, especially with mega-sized dams. The dam itself is like a wall that is built across a waterway like a river or a waterfall. This wall then stops the water from flowing through, creating a blockage. As a result of this, a reservoir builds up behind that dam, as the water is not passing through like it has been used to. The earliest forms of hydroelectric 'dams' did not have a reservoir to hold the stored water. This was because the early structures were not actually dams but simple hydroelectric systems that would use the natural flows over an existing waterfall or fast moving river. All that was needed was for the water to be deflected, passing through a slight diversion. These types of power stations were the earliest forms of 'alternating-current' electric power generation intended for commercial

3
Perch,'92; p.

use. One of the first examples of these was built by Niagara Falls (on the Canadian side) in 1893 and could be considered as the father of the modern electric power plant.4 This plant was small, generating 2,200 kilowatts and intended to power an electric railway. The same simple system is used throughout the world today.

Most hydroelectric power plants today are slightly more complex than this as they use a system that includes a reservoir behind it. With this system, the water is held back in the reservoir, being channelled through a gate that can be regulated according to water levels and also required output of power. As the water passes through the gate(s), it is channelled in a tunnel through to a turbine. The water passes makes the turbine turn as it passes through, spinning a generator that in turn generates electricity. The next illustration shows the simple workings of a hydroelectric dam.

5

One could imagine it being almost the same principle as dynamo powering a light on a bicycle, where by the water current passing through the turbine could be seen as the

4 http://americanhistory.si.edu/archives/d8047c.htm
5
Illustration showing the mechanical workings of a dam

bicycle wheel turning the dynamo to power its lights. Over time, the technology has improved where by the generators have been improved, becoming increasing in efficiency as technology improves.

The advantage with the system using a reservoir is that it has a storage capacity. This means that the water is stored in the reservoir, unlike the 'run-of-the-river' power stations as described in the previous paragraph that have virtually no storage capacity. The reservoirs all vary in size and proportions. Some reservoirs have a large surface area but are not deep, whilst other reservoirs have smaller surface areas but are very deep. The advantages with the smaller surface area reservoirs are that less water is lost in evaporation from the surface of the reservoir and that the reservoir takes up less land space. The more shallow reservoirs loss more water through evapotranspiration rates and takes up more land. The shorter and deeper reservoirs are seen in more mountainous, steep areas such as the mountains such as in Norway. In areas that are gentler, with not so sharp, mountainous terrain, the reservoirs are longer and shallower. There are two main disadvantages with such a reservoir. Firstly, evapotranspiration rates are higher seeing as there is a larger surface area, meaning that water is lost to the air and secondly, the reservoir is obviously going to take up more land, which means more land will have to be given up by any prior use to the construction of the dam. These problems will be addressed later in this chapter, in the sections dealing with various impacts that are associated the dams. In the next two diagrams, I have illustrated the differences in reservoirs as explained above.

6

7

6 Illustration representing short/deep reservoir
7 Illustration representing long/shallow reservoir

The last of the 2 diagrams, representing the longer, shallower type of reservoir is more typical in a landscape where the hills, if any, are more gradual. Such a reservoir will be seen in the proposed Ilisu Dam.

4.3 Impacts of Dams

As dams are built, the area in which the dam is constructed will see some very strong changes whereby the very physical character of the host location will be altered permanently as result of several key reasons.

Many environmentalists would argue that the environmental impacts that dams have as being the worst impact concerning large-scale dams. If one was to imagine the worst-case scenarios for a dam that has been poorly planned, then it is quite normal to contemplate some ecological nightmares concerning the potential impacts on the local environments of the dam. This classical view on the environmental sustainability of a technology is normal, as it is a natural instinct for an environmentalist to think of how something could be harmful towards the environment before considering anything else. The fact that hydroelectric dams without careful planning or management could mean a whole range of different impacts that might harm the environment is normal. But when thinking of the environment, one has to be very broad in ones scope of interpretation. It is no good merely considering physical impacts to the environment but a necessity to consider all forms of impacts: social, cultural and environmental impacts.

It is vitally important to equally consider these impacts as well as considering the other impacts such as the economic and social impacts that dams have. The reason for this is that even though they might have their own individual effects on the host environment, they also have specific impacts when combined with each other, depending on the characteristics of the host environment. Therefore, these impacts should be seen as interrelated, despite the fact that they don't seem to be initially, there are a lot of impacts that are understood to be related after dam construction has taken place. Many of these 'interrelated' impacts are not initially contemplated during the planning stages of a dam because planners responsible in predicting all potential impacts have not considered any reason to link or foresee such impacts related or linked to each other. Furthermore, those responsible for planning of dams see environmental impacts as mutually exclusive from

the socio-economic impacts and therefore seldom see any relation between the two. As we shall see from the various impacts of the Ilisu Dam, many of the social impacts experienced by the Kurds are interrelated with the environmental impacts, often as indirect impacts.

The various impacts caused by dams and reservoirs can be on different levels: local, regional, national or international. In most cases there are three main phases that impacts come in. These phases are usually the different stages in dam construction ranging from pre-construction to construction to post-construction phases and may continue in tropical and subtropical environments for 20 or 30 years before a steady state is reached, local people modify their habits or environmental change occurs[8].

Firstly, with the construction of a dam and its reservoir behind it, comes the noticeable change of the waterway that it is being built on. Previously, a river running undiverted through a valley will be subject to significant changes. The most obvious one would be the barrage built across the river that will stop the 'traditional' flow of water down it. This barrage will in effect slow down the flow of water after the barrage, causing the water levels below the barrage to change significantly. This in effect will alter many things that are related to the river downstream.

If we consider the changes occurring on the opposite side of the barrage, that is to say upstream of the barrage, we would see an opposing set of changes occurring. The water levels upstream of the barrage will also change, this time they will rise. This is because due to the 'blockage' forming at the point of the barrage, less water will be passing through. As this happens, an obvious volume of water will start building up behind that barrage, forming an artificial lake that we call a reservoir. This reservoir in effect covers an area that was formerly above the river that was dry ground, possibly serving as areas of agricultural cultivation or residential housing etc. The proportions (surface area and depth) of the reservoir all depend on the topographical nature of the area that the dam is built in. These proportions often are a decisive factor in the specific environmental impacts that the dam might have on its host environment.

Of the many impacts attributed to dams, I shall focus on the main impacts that are seen as the major impacts, i.e. the most important impacts. Many minor impacts might

8 Barrow, 1995;

come into play; unfortunately, assessing all possible impacts of large dams would be a thesis itself.

4.3.1 Environmental Impacts

The various environmental impacts of large dams are numerous and can be divided into two specific categories. These two categories are upstream impacts and downstream impacts. A further classification of these impacts can split them into to types of impacts: biological impacts and physical impacts.

First I shall deal with the upstream impacts. These are the impacts that occur on the side that is situated before the barrage. The upstream impacts are related to the reservoir of the dam, situated behind the barrage. The most common physical impact of large dams is the build up of sedimentation behind the barrage in the reservoir itself, otherwise known as 'reservoir siltation'. In the case of river that is unaltered by any human initiated activity such as dam construction, natural sediments are carried down the river stream and are deposited naturally along the riverbeds and banks. It also serves as a kind of fertiliser for the crops that irrigated downstream with water from the river. When the agricultural areas become deprived of their natural fertilisers, farmers tend to turn to additional chemical fertilisers, which in turn will pollute the groundwater of these areas constituting another problem in field of environmental issue.

What actually happens is that a lot of the sedimentation that is transported naturally down the river is caught by the dam and therefore does not pass through the dam. This in turn means that there is an unnatural build-up of sedimentation in the dam reservoir. As the dam reservoir is originally intended to serve as a storage capacity for the dam, the actual reservoir siltation will in effect reduce the reservoir's storage capacity. In more extreme cases, where in theory there was to be a large build up of sediment on the upstream side of the barrage, increasing pressure from the sedimentation could act on the barrage itself which could potentially put additional strain on the barrage. This in time could weaken the dam at the base and hence cause some concern in a foreseeable event of the dam collapsing due to this additional pressure.

Some regions in the world have higher sedimentation rates than others, so the rates of sedimentation would vary from region to region. According to the World

Commission on Dams, 25% of the world's existing fresh water storage capacity will be lost in the course of the following 25 to 50 years as a result of reservoir sedimentation9. These figures of course are cited taking into account that no measures to control sedimentation will be put in place. Additionally, the WCD predicts that most of the global loss of fresh water storage capacity will occur in the developing countries as well as those with higher sedimentation rates.

Another problem associated with the use of dam reservoirs is the stagnation of the water stored in the reservoir. Stagnation occurs, as the water is stored in the reservoir over long periods of time. There is minimal flow of water as it 'sits' in the reservoir waiting to be passed through the turbine and onwards downstream. As the water is stored in the reservoir, it becomes stagnant, as it is starved of oxygen. The stagnation of the reservoir water in effect reduces the number of organisms living and breading in the reservoir. Locals, who might depend on the river habitat to sustain a living such as fisherman, find it problematic doing so when the fish numbers up stream decline as a result of the waters decline in oxygen. A final note on reservoir stagnation is that due to the changes in the landscape, i.e., land becoming covered in water certain climatic changes will occur as the water reservoir will bring down the temperature in the areas that embank the reservoir. This would affect the organism living there, as well as the obvious areas, which can see the disappearance of colonies of wildlife etc.

This brings us to the downstream impacts. Due to the stagnation problem, the problems downstream that are caused by dam construction and planners often overlook the active altering of the river flow. This is quite obvious otherwise these impacts would not outweigh ones affecting the upstream side of the dam. Planners like to predict and safe guard the immediate areas around the dam and reservoir as much as possible, but rarely investigate probable impacts that arise further down the stream. I suppose this is because the problem is no longer directly concerned with the dam and hence not a main focal point during planning.

The water is often clear and unstratified due to the dams effect on silt deposits as explained earlier with reservoir siltation, and this often affects the fisheries and wildlife present downstream. Also, the loss of detritus deprives organisms of nutrients equally

9 Data given by the WCD in its 2000 report on Dams and Development.

affecting the ecosystem of the river. In the case of the water being clearer, certain fish or animals will find it increasingly difficult to conceal themselves rendering them more vulnerable against predators 10. Equally, organisms in the river such as fish will benefit from the clearer water conditions as fishing nets are rendered sufficiently visible that they no longer work which may mean many people lose their livelihoods11. But this is seen as a socio-cultural impact, which shall be highlighted in the following section.

The physical altering of the river flow by a dam will also cause changes such as thermal damage to the river downstream, as the water coming out of the dam risks being at a colder temperature due to the fact that is has been stored in a deep reservoir. Additional, stagnant water is heavier and hence colder the deeper that the canalization is towards the gate of the dam.

Another hazardous problem that risks becoming aggravated by dam construction is where the combination of detrimental impacts of river damming such as oxygen depletion (stagnation) and the discharge into the river downstream of solid waste and wastewater. The discharge of waste that was present before the construction of the dam was to a certain extent being purified by the natural flow of the river. The installation of a large dam can in effect reduce this positive effect that a river had in coping with waste charges which in effect worsens the pollution problems that the river might be experiencing. In many developing countries, there are problems concerning wastewater treatment before discharging into rivers, namely on the Tigris river in Turkey. This I shall elaborate more on in case studies chapter. The additional impact on this problem has on health I will detail in the next section. Below I have added a table to summarise the various environmental impacts that hydroelectric dams may have.

Advantageous Environmental Impacts	Disadvantageous Environmental Impacts
No atmospheric pollutants produced	Flooding of terrestrial habitat
Improves air quality	Modification of hydrological regimes
No waste produced	Modification of aquatic habitats
Lowers the general depletion of non-renewable energy sources such as coal and oil	The constant need to monitor and manage water quality.
New freshwater ecosystems with increased productivity can sometimes be created	Species activities and populations need to be monitored and managed
Enhances knowledge and improves management of valued species due to study results	Barriers for fish migration, fish entrainment
Helps reduce climate change	The need to monitor and manage sediment composition and transport
Does not pollute or consume the water it is using for electricity purposes	

10 Barrow,1995

11 Barrow1987b: 88 in Barrow,1995

4.3.2 Socio-Economic Impacts of Dams

According to the WCD, many people have benefited from the services large dams provide, such as irrigation and electricity generation. Their construction and operation can lead to many positive social and economic impacts. The actual construction of a dam can provide employment for the local communities and also provide incentives for businesses and enterprises setting up shop near the site of the dam. This would be the case where there is incentive to do so. When locals are able to work on the dam, it is only for a limited period of time as when the dam is completed, the use for labour will no longer be required. If there is no other investment around the construction sight, then those employment opportunities will diminish.

These are always very specific with each dam, especially in developing countries where all the various conditions combine to form unique and problematic social problems. This is why there is no concrete set of guidelines that can be applied in order to assure avoiding such social and human impacts. The WCD sets out guidelines, which are more vague in what they specify, as you will see in the chapter concerning the WCD. It sets out certain principles, that will ask to keep all stakeholders into consideration during dam planning but unfortunately, the perspective of planners, especially in cases with western built dams in developing countries, will always be radically different from those who are affected and live in the region. Planners will not often see the interests of the local population as they are 'blinded' by the vision of developing the dam. Obviously, in many cases where by large hydro-dams are being constructed, the need for energy is

12 Source of table: I.H.A, 2003; p.14

usually seen as an acceptable reason, but like in many issues for debate, alternatives will always be available, though rarely becoming attractive to developers who are determined to see their project become reality.

I would consider the most problematic social impact of dams as the displacement of people. This I find amongst the one of the worst impacts as I see it equally as bad as those who are displaced by war becoming refugees. In cases, people, whole families, communities even towns that have been subsiding next to each other for decades are forced to leave their homes are relocate somewhere else. In many cases today, whole communities are split up and resettled into new towns, even in other parts of the country. The level of compensation and resettlements depends from country to country.

Another point important to retain in relation to people displaced by dams is that there is a noticeable difference in the displacement of rural communities and urban communities. These two types of communities can vary the way that they cope with resettlement. It is often the case where urban communities are resettled; we are looking at a larger volume of people that can be moved together. In the case of a rural community is in not so easy and uniform. Often these people have no formal legal rights to the land as it is somewhere they have settled down, where by in many cases have no legal tenancy of the land. The more indigenous the displaced community might be, the more chance that they will be left with nothing. In the case of those with tenancy rights, who are moved and receive financial compensation, many of them are unable to manage the sums of money handed to them as compensation as they most probably have never previously handled such large sums before.

If we look at new possibilities for employment after relocation, we will see that a family moving from its home city to another one might not find so difficult in adjusting to their new environment compared to a rural family that has been relocated into a city. Such a family might only have skills needed in rural areas, such as farming skills where rendering it useless in the employment opportunities in the city. This also heavily depends on the level of isolation in rural areas prior to the move to the big city. The more 'indigenous' the community, the more difficult that it might find obtaining jobs after moving to the city from a rural setting due to the fact that they are expected to have certain skills that are no longer relative to the urban job market.

The social implications of displacement can be far reaching and are often signs of poor planning and management of large dams. Often rural communities with particular culture and traditionalistic ways of doing things become destroyed through displacement. Not only do villages and farms wiped off the map but also archaeological sights as well as churches and other heritage sights, clearing visible evidence of the existence of particular civilisations or communities. This is particular in cases of ethnic minorities that are facing displacement caused by the development of hydroelectric dams.

Another problem that arises are the new boundaries that form as a reservoir takes shape. The land which was is formerly linked by roads, paths and possibly railways becoming an uncrossable void, often separating families and communities, forcing people to travel much longer distances than prior to the construction of the dam. The formation of a reservoir could be seen as brick wall that has been set up by the planning authorities, in effect redefining the geographical boundaries of a region. Below I have made two drawings to illustrate this.

13

In the drawing above one can see the course of a river in its unaltered state. Notice the roads linking the village to town 'A' and town 'B' where by bridged roads across the river connect the towns.

13 Drawing showing a river before the dam

14

The last drawing shows the altered state of the river valley after the dam and its respective reservoir have been completed. Here one can see that some of the roads around the original course of the river have been submerged by the reservoir. Also one can see the village, has been replaced by the reservoir. Furthermore, the roads that linked the two towns through the village have been replaced by the reservoir. This means that without any tunnel or new bridges built in order to restore the direct link between the two towns, one has to make the long detour up stream to cross the river in order to access one town to the other.

In the guidelines that have been made up by the WCD; it states clearly that resettlement plans for displaced persons should be drawn up 'which reflect international accepted practice and includes international monitoring. In many cases, the locally displaced communities are left with no power. The guidelines state that local people have to be involved at the early stages of the project, all though with many dams today, especially in the developing world, such guidelines are largely ignored, as we shall see with the Ilisu dam in Turkey.

Another important focus point is the affects that dams might have on the general health of the local population. Many of the health problems associated with dams are generally linked to the physical attributes of the dam and reservoir, although many of the

14 Drawing depicting 'brick-wall' nature dams and reservoirs may have on host environment.

mental health problems can be harder to assess such as the stress or trauma experienced by becoming displaced by force.

In areas where by the impacts of reservoirs are climate change, certain warmer climates could see the increase in disease and germs where by the physical changes such as a dry area being turned into a reservoir experiencing heavy stagnation rates. In such cases an increase in malaria or leishmaniasis causing life-threatening conditions could theoretically take place, increasing the health risks on the local population. If a dam is disrupting the local environment is increasing the chance of disease or germs or unhealthy organism breading then it must be affecting local stakeholders unfavourably, hence strengthening reason not to build one.

In the previous section on environmental impacts, I mentioned how a dam can affect a river's purifying affect it may have on waste discharged into it. With the rivers reduced natural mechanism the waste in the rivers could potentially increase. An increase in waste levels will impact on general health. According to the WCD, these will be felt more significantly in developing countries and areas with poor wastewater disposal. An amplifying factor that could increase this would be the arrival of displaced communities of the dam that immigrate to urban areas situated downstream of the dam. A sharp increase in the urban population would in effect increase waste discharge levels, aggravating the problem even more.

Below I have added two tables summarising the various social and economical impacts dams might have.

Advantageous Economical Impacts	Disadvantageous Economical Impacts
May provide low operating and maintenance cost	High upfront investment
May provide long life-span (50 to 100 yrs)	Precipitation dependent
Provides reliable service	Storage capacity of reservoirs may become reduced due to sedimentation
Can instigate and foster regional development	Long-term planning required
High energy efficiency	Long-term agreements required
Can create job opportunities	Multidisciplinary involvement required
Saves non-renewable energy sources	Foreign contractors and funding often required (especially in the case of developing countries)
Provides energy independence through the exploitation of national resources	

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Advantageous Social impacts	Disadvantageous Social impacts
Water available for other uses	May involve resettlement
Flood protection provided	May restrict navigation
Can enhance navigation conditions	Local land use patterns will be modified
May enhance recreational facilities	Waterborne disease vectors may need to be checked
May enhance accessibility of territory and its resources	May reduce accessibility of territory and its resources
May provide opportunities for construction and operation with a high percentage of local manpower	Requires management of competing water issues
May improve local living conditions	Effects on impacted peoples' livelihoods need to be addressed
Sustains livelihoods (freshwater, food supply)	

In all we see that socio-economic impacts are largely variable as they depend on the extent and specific character of certain factors like the proportions of the dams and their reservoirs, as well as the geographical location, inhabitants and environment of the dam. There are so many detailed impacts that a dam may have, which is why the main aspects that will be needed to understand those I cite in this project in the relevant chapters concerning the various case studies are covered.

Chapter V: Sustainable Development

15
Source of tables: I.H.A, 2003; p.14

During the following chapter, I shall be dealing with the general theory of sustainable development and explaining the integration of the concepts of sustainable development in the context of the project. The issue of sustainable development lies at the forefront of the aims of this project. Seeing as the main scope of this project is to look at the environmental and socio-economic impacts that hydroelectric dams and their reservoirs might have on the indigenous Kurds of Turkey, it is therefore essential in being familiar with the concepts of sustainability as it will be up to me towards the end of the project to assess whether the dam that I will investigate as my case study is sustainable or not.

This chapter will be split into 2 sections. The first section will include the concepts of sustainable development, dealing with the basic definitions and advances in the theory of sustainable development. This section will deal will all the notions and everything else that is essential in the acquirement of sustainable development theory. It will also deal and explore the role of hydroelectricity in sustainable development looking at all requirements and conditions that are needed in order to obtain sustainability.

The Second section of this chapter will briefly cover the World Commission on Dams. In this section I will highlight the role of the WCD and give an account of how it helps countries around the world manage both water and energy resources by presenting an adequate and constant evolving framework for water and energy resources development. This section will highlight the importance for such a global public policy effort in the attempt to bring governments, the private sector and civil society together in one single process. At the same time, the main guidelines drawn up by this commission shall be highlighted, ensuring a framework of standards that in theory should pave the way for the improvement of dam construction and in theory provide a sustainable dimension for hydroelectric and irrigational dams.

5.1 Concepts of Sustainable Development:

"Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social

organisations on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organisation can be both managed and improved to make way for new era of economic growth. The Commission believes that widespread poverty is no longer inevitable. Poverty is not only an evil itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes."

Our Common Future, World Commission on Environment and Development, 1987, p.8

Over the last 30 years or so, since the Stockholm conference in 1972, the importance in minimising environmental change has become paramount to most of the world leaders today. The role of sustainable development has been pushed to the forefront of national issues to prioritise on. It has been formerly recognised through the world that development is not a straightforward issue and requires 'reading between the lines' or balancing certain needs that might not always seem compatible in the stride towards improving general human welfare. Whilst improving human welfare, one must at the same time keep environmental impacts to a minimal level, so that those improvements do not jeopardise the initial development intended.

"Sustainable development stresses the long-term compatibility of the economic, social and environmental dimensions of human well being, while acknowledging their possible competition in the short-term." (OECD, 2001)

From this quote taken from the OECD's 2001 publication on the critical issue on sustainable development are two main nations that arise from this assumption.

The first of the two notions maintains that in order to achieve development, there must be a balance of objectives that are seen to progress together otherwise some objectives might progress as others fail to materialise, signifying the initial progress of some the objectives as short-lived if simultaneous progress is not experienced in the other objectives. In other words, all objectives need to progress in order to obtain an overall improvement in all the stated objectives. If some objectives are fulfilled but others are

not, then the overall success will not be significant due to the fact that overall progress depends on the advance of all the stated objectives.

The second notion arising from the assumption states that development must be initiated with a long-term view of implications or uncertainties that might interfere with such development. This means that in the light of plans on a long-term scale, one must account for any events that might prevent initial aims. This is to say that when certain projects are planned and/or initiated, precautions and measures have to be implemented in view that the plans are in no way going to negatively affect the future prospects or generations. An example of this could be seen through the planning and construction of any hydroelectric dam and reservoir.

The development of hydroelectric dams and reservoirs is initially done through reasons of exploiting renewable resources and at the same time not sustaining any damage to the environment. It is one of the main reasons many developing countries turn to hydropower producing electricity without causing irreversible harm to the environment. Despite this, it is merely a theoretical assumption to hold and a very naive one to go by. The sustainability of hydroelectricity is a myth that many choose to adhere to. Like many so called environmentally friendly technologies, hydroelectricity has its limitations where by these limitations all vary depending on the exact nature and location of the dam and reservoir. Now if in the case of dam being constructed, limits of the dam need to be established before the first brick is laid. Limitations all depend on a number of factors that can range from the physical and geological attributes of the host environment to the type of use for the dam to the social and cultural aspects of the local populations. There are in fact so many things to take into account in the planning stages of dam, that there is never a dam built without the realisation afterwards of certain issues or problems that should maybe have been taken into account prior to its construction.

Now say in the hypothetical case of such a dam being built that after the dam has been finished and running for a period of 5 years, it has been noticed that some serious miscalculations have been made concerning the geological structure of the ground it has been built on. In such case, there would be a realisation that the dam is structurally unstable and it would signify a crisis for developers as well as local authorities and a case of poor planning. If this happens to be the case, then it can be seen that the "costs of one

generation's activities have compromised the opportunities of future generations, as some key features of the environmental and social system cannot be easily restored once damaged[16].

In today's day and age, it is no longer acceptable to think of sustainable development as an outside issue to be tackled on its own, but rather an issue that should be incorporated into everything in order to achieve its full definition as widely as possible. Many see economics as a separate issue to environment and that neither concern each other. This is in fact a direct contradiction the reality of the matter, where by economic policies and objectives play vital roles in the workings of day-to-day policy formulations and the priorities of many voters and of most policy makers[17]. It is for these reasons that sustainable development has become a front-running issue in government policy around the world.

In the past, economic growth and environmental standards were seen as separate if not opposing issues. This all started to change in the last 30 years or so, as the realisation that economic growth ensured the use and abuse of valuable natural resources became more apparent and widespread. As our ozone layer has become depleted and our rain forests cut back, it has become a common realisation that economic growth largely has a direct effect on environmental standards, causing the degradation of our environment and in turn the downward spiral of the general quality of life.

During the 1960's and 1970's more emphasis was placed on pollution related problems. The first real basic notions of environmental concern began to surface in those years, where by issues such as air and water pollution, toxic waste and waste management came to the forefront of concern. By the 1980's, more complex linkages were being established, recognising global problems that were affecting the world and no longer specific regions where such problems were seen to originate from. Such problems were things like acid rain, ozone depletion and climate change. After the 1980's, the world was well aware that something had to be done. In 1987, a report was published on the World Commission on Environment and Development was compiled, stressing the important influence that economic and policy decisions had on environmental issues. The

16
OECD, 2001, p.35
17
OECD, 2001, p.35

quote given at the start of this chapter comes from the report. The report itself started the first real wave of global environmental awareness bringing on the Rio Conference in 1992, from which Agenda 21 was compiled as well as increases in environmental policies that were drawn up in countries around the world. The United Nations Division for Sustainable Development and the Interagency Committee on Sustainable Development were formed so that some form of non-governmental organisation could keep leads on the implementation of environmental policies, keeping up the necessary pressure for the implementation of such policies.

Over the years since the Stockholm Convention, there have been countless attempts to modify and refine the meaning of sustainable development. The Brundtland Report compiled in 1987 still remains the concept that is mostly used throughout the world today. The definition is slightly shorter and stresses on the main part of the definition, which is meeting the needs of present without compromising the ability of future generations to meet their own needs[18].

If the word sustainability was to be defined individually, we could consider it meaning something that can be kept going on an indefinite basis. If we take hydropower into consideration and investigate it as far as sustainability is concerned, we would then see that it has masses of potential for the following reasons.

Hydropower with out a doubt can improve economic viability. Despite the fact that the actual planning and construction can be a long and laborious task, once the construction of dam has been completed and the initial financial loans used to finance the project have been paid off, the running costs of the dam usually equates to about 1 percent of the initial capital outlay[19]. With the adequate maintenance and providing that the necessary conditions in the host environment are there, the constant and reliable flow of electricity deriving from the hydropower plant can become the foundational support for industrial development and improve economic and social welfare.

The fact that hydropower plants can manage several uses of the water at the same time is an added bonus to its initial ability to produce electricity, pollution free. Other such uses as irrigational uses of the dam that provides a source for food production can be

18
Source: World Commission on Environment and Development, 1987; p.8

achieved at the same time. Another important factor is that in the case of a developing country turning to hydropower, it will then be able to rely less on importing electricity, hence become more self sufficient and less constrained by the import deficit in electricity that constrained the country in the first place. The revenue generated by the electricity produced by the dam can be used for other water uses.

Another reason advocating the potential for hydropower is the fact that it can help preserve ecosystems. Theoretically, hydropower uses the natural elements of the river, leaving the water unchanged as it passes through the turbines that generate electricity. This means that it in no way manages to deplete this valuable resource. Not all the responses of the ecosystems to dam development are favourable, as we can see in chapter 424. Nevertheless, most of the negative impacts on the ecosystem are related to poor planning of dams and also the nature of the water storage system used for the dams, i.e. the dam reservoirs. As most hydroelectric dams use reservoirs, the knowledge on how these impacts affect the ecosystem has improved over the years giving way to a field of knowledge and a broad range of avoidance and mitigation strategies concerning dam development. If we compare hydropower with other forms of electricity generation, we can see it has the least impacts of the environment. The only technology that is probably cleaner than hydropower is wind-power, which unfortunately is not as reliable and not as efficient which is due to the fact that a constant flow of electricity cannot be produced due to the variability of weather. In the case of dams, a constant flow is maintained through the adjusting of the floodgates according to the river level and flow. Nevertheless, wind power in comparison with hydropower is still in its infancy in terms of development, where by only time will give us a better indication of its true potentials.

The final reason that advocates the potential for hydropower in terms of sustainable development is for reasons of enhancing social justice. There are many ways that this can be brought on.

Firstly, the actual replacement of fossil fuel based electricity generation by hydropower will signify and positive change in the stabilisation of climatic conditions and hence a cleaner environment. Such fossil fuels are no longer being used and therefore

19
Source: IHA 2003, p.71
24
Please refer to section 4.3 on ‘Impacts of Dams’

no longer being depleted. Hydropower also requires less maintenance in comparison with most other electricity generating technologies and thus is ‘usually paid for by the same generation that built it25. By ensuring these simple objectives, hydropower plants can be passed on to future generations and minimise negative impacts their future and well being.

Secondly, the development of hydropower can in theory improve the equality between different groups of people in modern societies. This all depends on the conditions that are made for the project implementation, which usually depend on an open and fair approach to the planning of such projects. All options and mitigation processes need to be put into perspective. Also every single stakeholder has to be included in the discussing and planning of the project, regardless of his or her stake. This means that there has to be public participation at the highest levels. There has to be full transparency concerning all aspects of the project, where by nothing must be kept from the public eye.

Many of the processes that are needed to ensure equality between various groups of people are very much dependent on the willingness to cooperate from all sides. Usually there are always those who do not wish to grant equal opportunities say to opposing groups, which is why it is often sensible and beneficial to all stake holders to include social and development agencies in the negotiating of the project. This would be to ensure that neutral parties could give a fairer dimension to the planning process and therefore ensure equity between the groups. Only through such patient and complex processes handled through neutral development agencies can hydropower projects serve as ‘tools’ to enhance social justice.

When it comes to indigenous communities and other vulnerable groups of people that are affected by hydropower development, it is important to ensure that these people are treated equally. It is therefore necessary to ensure the above conditions. Furthermore, due to the special and vulnerable nature of these groups in society, often-extra care is needed to ensure their well being. First of all, they need to be brought to the negotiating table and have their perspectives taken seriously. Secondly, in the event of population displacement, they need be included in acceptable resettlement programs that they

25
IHA, 2003; p.73

themselves acknowledge, not something that is forced upon them. And finally, the populations that are to be displaced need to be adequately compensated in the way that there is an improvement in their well-being compared to their situation before the project has been implemented. The compensation or alternatives has to be recognised and accepted by the displaced populations, otherwise the action of bringing these people to the negotiation table will be seen as pointless20.

In order to get sustainable development in practice, it is vital for those responsible for project planning to take all the necessary conditions into consideration, such as those conditions mentioned above. We must also remember that sustainable development is not a fixed concept, although many of the definitions and explanations of what sustainable development is, such as the one arising from the Brundtland Report, should be the starting blocks for ourselves to continue developing. We have to take these initial ‘starting points’ as our foundation block and then move on from there, taking the necessary considerations that affect our individual situation into perspective. Each specific issue of development has its own set criteria; therefore no specific set framework that can be devised for sustainable development on the whole; it all depends on each specific case.

5.1 The World Commission on Dams:

The World Bank and the World Conservationists Union helped to set up the WCD in 1998. The main reasons for the setting up of the WCD was due to the increasing rift between various NGO’s, national and regional planning authorities, governments and international institutions such as the World Bank concerning the dam development. According to the WCD, it was realised that a solution to the general rift between the various stakeholders was impossible to mitigate through any of their own proposals. This is why it was decided that the WCD would be set up to take charge of such disagreements and attempt to get participants from governments, the private sector, international financial institutions, civil society organizations and affected people21together to discuss and review the development effectiveness of large-scale dams. This process lasted for

20
Source for conditions of sustainable hydropower development concerning indigenous communities; I.H.A, 2003; p.74-75

two and a half years where by at the end of it, the commission published a report in 2000 that provided a set framework of internationally acceptable criteria for guidelines and standards for large-scale dams. The title of this report is called 'Dams in Development: A New Framework for Decision Making'. Despite the fact that the guidelines and directives that have come out from the WCD are not reinforced by international law, organizations such as the World Bank use these directives as a framework on deciding whether dam projects are acceptable or not. In fact, this framework of directives could be considered as the modern day bible for large-scale dam development. The two main goals of the commission were stated as:

-To review the development effectiveness of dams and assess alternatives for water resources and energy development;

-To develop internationally accepted standards, guidelines and criteria for decision making in the planning, design, construction, monitoring, operation and decommissioning dams.22

Many different assertions were made by the WCD as to the general situation of the current large dams in the world. After the two and a half years of discussion between the various parties, the commission was able to identify five crucial stages that needed to be considered in the determination of the various options to be pursued and whether or not the construction of a dam should go ahead. These were of the following23:

1. Needs assessment: validating the needs for water and energy services.

This stage sees the initial assessment of the plans of water and energy development that reflect both local and national needs. A decentralised consultation process is required in order validate all the various needs.

2. Selecting alternatives: identifying the preferred development plan from among the full range of options.

During the second stage, all the necessary social, economical, environmental, technical and financial aspects to the project will be reviewed. This should be done through participatory multi-criteria24 that give equal consideration to the aspects

21
http://www.dams.org/commision/intro.htm
22
Goals as set by the WCD on their website: http://www.dams.org/commission/mandate.htm
23
The Five Key Decision Points of the WCD Criteria: WCD, 2000; p.262
24
WCD, 2000; p.262

mentioned above. During this stage various investigations and assessments should be made such as EIAs or feasibility studies.

After these two criteria have dealt with and the decision is to go ahead with the dam, the following three points concerning the preparation, implementation and operation of the dam would need to be considered:

3. Project preparation: verifying agreements are in place before tender of the construction contract.

During this stage, most of the detailed planning and design should be effectuated. Licenses and legal frameworks will be set up and made clear as well as the assignment of building contractors, signing of contracts, etc. Before this is finalized, specific mitigation mechanisms, compensation agreements and technical requirements should be made clear.

4. Project implementation: confirming compliance before commissioning.

This phase sees out the procurement and construction stages of the dam. Within this stage, the decision to grant a license to operate all depends on the implementation of various benefit sharing and mitigation measures at different stages of the project implementation.

5. Project operation: adapting to changing contexts.

The final stage oversees the reviewing of any necessary amendments that are deemed necessary in modifying the dam to changing contexts. This should be done through a participatory review of the performance and initial impacts of the project.

By using the five key points of the WCD criteria as a guide for the development of a dam project, decision makers and stakeholders can effectuate the development of a dam by minimizing risks to livelihoods of host communities, cost overruns as well as all other perceived unfavourable impacts that the dam is likely to have. According to the WCD, the short term will need financial resources to enable much of the various stages and decision-making processes function properly. This will in turn enable the operation and management of the dam on the long term beneficial to all stakeholders, saving costs as well as ensuring dam development at the most sustainable level.

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Chapter V: Case Study

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Flow chart representing the five key decision points of the WCD set criteria.

During the following chapter, the case study for this project will be presented. The case study that is going to be used is situated in Turkey. For this reason, I shall split the chapter into 4 sections. These sections will each cover the important and relative information needed to assess the problems that I have chosen to investigate for this project.

The first section will cover the general background information on Turkey and of its geographical details, its economic situation, population, government, electricity situation, environmental situation, and so on. This section will provide the necessary information needed in order to present the specific case study for this project.

The second section will also cover aspects of Turkey, setting particular focus on the Kurdish minority of Turkey. Specific emphasis will be laid on the political and cultural situation of the Kurds in Turkey, more importantly addressing the 'Kurd Question'. This is a key section, serving as the 'backbone' to understanding key background aspects to the Kurdish situation in Turkey. It will attempt to give a clearer picture of the complex situation Turkish Kurds are faced with both politically, socially and economically. This is that it provides a better understanding of the context and scope of this project, namely the detrimental effects that super dams might have on indigenous Kurdish communities of Turkey.

The penultimate section of the case study chapter will detail the National Energy policies of Turkey. This will be useful in assessing Turkey's energy situation, notably its future plans to supply the country with energy, more importantly, what technologies that will be considered and eventually used. The national energy policies will in addition provide clues on, if any, the alternatives to the technologies currently used. This section will also briefly explore any national energy policies or directives in relation to energy supply, especially hydroelectric power.

The final section of chapter 5 will present the case study used: the Ilisu Dam. This section will cover all relevant data concerning the case study of the project highlighting specific detailed impacts of both positive and negative kind. This is essential, in order to obtain a balanced outlook on the issue of hydroelectric dams in Turkey.

Each of the four respective sections of this chapter will have a set focus on the important aspects of the chosen country of the case study, the particular cultural and

social identity of the case study's environment and the case study itself. It is vital that these sections are complete and clear as they are key in the interpretation and analysis of the data that is used to assess the nature and extent of the negative impacts exerted on the Kurds through large-scale dam development.

6.1 Turkey

Turkey is a country that would serve as a great subject for debate, irrespective of the topic to debate. There are many fascinating issues concerning Turkey that would prove almost impossible to the most knowledgeable of academics to agree on. One only has to look at the most simple facts about the country to realise that many things just are not clear-cut enough to provide a clear and simple answer. Simple facts such as its geography or its actual level of development can be so ambiguous; that even the most acclaimed academics would have problems agreeing over. So for this section of the chapter, I shall put the facts straight and give the data concerning the Turkey that will be necessary so that the aims of this project can be achieved.

Physical Attributes

The geographical aspects of Turkey are of the following. Turkey is officially recognised as a middle-eastern country that is situated between the two continents of Asia and Europe. It is the transitional country where by European culture meets with Asian culture. Part of Turkey actually lies on the European continent, bolstering claims that it belongs to Europe. The portion that lies in Europe only accounts for 3% of the country's total surface area. Despite this, it manages to encompass Istanbul, which is the largest city in the country. Ankara, the capital, is Turkey's second largest city. This part of Turkey is called Thrace. Thrace is separated from mainland Turkey by narrow waterways that link the Aegean Sea with the Black sea. The illustration below shows simple map of Turkey, indicating its physical boarders and natural coastline.

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Turkey has a total surface area of 780.580 square kilometres, which roughly equates to the size of France or a little larger than the US state of Texas. Approximately 9.820 square kilometres of its total surface area is covered by water. This only corresponds to about 1,5% of its total surface area, although figures such as these will increase as the many hydroelectric dam projects are realised.

The actual land boundaries cover a total distance of 2.648 kilometres and border no less than 8 countries. These countries are the following: Greece and Bulgaria respectively situated towards the west and the north; Georgia, Armenia, Azerbaijan and Iran situated towards the east; and Iraq and Syria situated towards the west.

Turkey's coastline is extensive and is one of its remarkable cartographic features. The coastline covers a total of 7.200 kilometres, bordering three different seas: the Black Sea, the Aegean Sea and the Mediterranean Sea.

Turkey is covered by several saltwater lakes and has numerous rivers running through it. The Euphrates and Tigris rivers are two of the most important rivers in respect to the aims of this project. The Tigris river is directly concerned with the dam used for the project's case study. As far as the topography is concerned, Turkey as a whole range of different landscapes where by several mountain ranges are located within its boarders,

26 Map source: http://www.infoplease.com/atlas/country/turkey.html

giving the country a unique character. This is why Turkey can be subdivided into 8 different land regions. These regions are of the following:

The 'Northern Plains' covers the area of Thrace, as well as the Black Sea coastline of Anatolia. This area is characterised by rolling plains of long grass in the Thrace region, ideal for livestock grazing. The coastal region of the Northern Plains are suitable for farming crops such as corn, fruits, nuts, and tobacco.

The 'Western Valleys' are situated along the Aegean coastline. This region is one of the most fertile regions in the country, characterised by wide valleys with fertile soil giving rise to important agricultural usage. It is then no surprise that it has the highest values in terms of agricultural output.

The 'Southern Plains' is a thin region characterised by arable plains that have very fertile soils ideally situated along the Mediterranean coastline. Here, mostly citrus fruits, olive trees and cotton are exploited. A notable feature of this region is that it needs irrigation during the hot and dry summer months.

The 'Western Plateau' is an area of highlands and scattered river valleys that extends across the central Anatolian part of Turkey. This area is less fertile than the previous three. Most of the area is uncultivated due to the little rainfall that it receives, except for the portion of river valleys where limited farming of barley and wheat is possible. Otherwise, mostly grazing of livestock dominates over crops as far as agricultural activities are concerned.

The 'Northern Mountains' cover the Pontic mountain range to the north, linking the Black Sea to the Northern Plains.

The 'Southern Mountains' consist of the Taurus Mountains and several smaller ranges on the southern edge of the Anatolian Plateau. These mountains almost completely cut off the plateau from the Mediterranean Sea.

The 'Mesopotamian Lowlands' are located in southeastern Anatolia. This region consists of fertile plains and river valleys. Cereal grains and fruits grow well in the rich soil of this region.

This brings us to the last but most important region for the project. The 'Eastern Plateau' is situated between the Western Plateau and Turkey's eastern boarders to neighbouring Syria and Iraq. This region can be considered as the most rugged and

mountainous in Turkey. It is also the part of Turkey that is traditionally home to the Kurds, representing the Turkish portion of Kurdistan. It is in this very region that the dam I will use for the case study is situated in. This region also sees the two large rivers; the Euphrates and Tigris rivers pass through it. It is in this specific area that several hydroelectric dam projects have been planned through an initiative called the South-eastern Anatolia Project, GAP, one of the largest dam projects in the world. This project numbers up to 20 dam projects that have been built or are currently under construction over the past 25 years. It is also there for the centre of much heated debate on the way such dam and power plant construction is affecting the local population, notably the Kurds. The majority of these people live in small clustered communities; mostly on small farms where by most of what they grow and produce is done so for the family or community.

Climate

The climate in Turkey very much depends on the region as it can differ greatly as one passes from one region to another. It can be generally said that the differences in climate differ mostly between the Eastern and Western regions of the country and also generally how far one is from the sea.

In the Southern and Western coastal areas the weather is rather pleasant where by the summers are dry and hot and the winters are mild and rainy. The temperatures in the summer are on average around 30-32°C alongside the Aegean Sea and notably milder along the Black Sea coastline, at around 20-22°C. The yearly rainfall in the coastal area averages around 50-75 cm along the Aegean and Mediterranean and around 255 cm alongside the Black Sea.

The Southeastern and the central Anatolian regions of the country are of a far less desirable climate. During the winters, the weather is cold and blighted by heavy snowstorms. Temperatures in the winter can get right down to -40°C. The summers are also intense, as the landscape becomes hot, windy and extremely dry.

Population

According to the figures given by the Official Publications Department of the CIA, today's population of Turkey currently stands at 68.109.469 (2003 estimate), with a population growth rate of 1,16%.

If the population is broken down by 'Age Structure', specific trends can be identified. The break down of the population into the 3 different age brackets of child population (from 0 to 14 years of age); working population (15 to 64 years of age); and retired population (65 years or more) gives us some of the first clues of the general age of the population.

The largest age bracket is the working population, at an estimated 66,4% of the total population. The next largest segment is that of the child population, estimated at 27,2% of the total population, where by the smallest bracket, the retired proportion of the population standing at a mere 6,4% of the total population. These figures hint to a young population, where by the ratio of young people heavily outnumber the older population. This is usually seen in countries that are in development, where by each family has more children on average than countries that are identified as developed countries, such as many of the European countries that have low numbers of children per family and hence see a much larger proportion of their population belonging to the retirement age bracket.

Turkey's respective birth and death rates are ranked as average in comparison with the other 225 countries ranked by the CIA's Department of Official Publications. Its birth rate is ranked at 134/225 at 17,59 births per 1000 population, where by its death rate is ranked at 173/225 at 5,95 deaths per 1000 population. These figures are interesting.

The birth rate of Turkey compared to the rest of the world is average with a world ranking of 133 out of 225. The UK and Denmark have birth rates of 10,99 and 11,52 per 1000, which is high for the European norms. In Europe the birth rates go from around 8 to 12 births per 1000 population. So Turkey in comparison with its European neighbours has a birth rate more like its eastern counterparts such as Iran and Syria. Such a high birth rate is also common with a country in development.

As far as the death rate is concerned, Turkey has a rather low death rate, ranked in the world as 173rd out of 225. This even beats the UK and Denmark, which have much higher death rates, respectively at 10,21 and 10,72 deaths per 1000 population. This would at first seem a bit strange, but as I looked at the rankings in the world, I generally found that countries such as the UK and Denmark were found to have higher death rates. The death rates for each country are not good indicators of wealth or development, as high levels of these do not necessarily equate to healthy living standards, in many cases it

could represent the inverse. This means the same for life expectancy rates. Although in the past, countries that were recognised to be poor and extremely undeveloped in comparison to the 'west' did have and some still have shorter life expectancy rates, although the general state in the world of medicine and health awareness has improved the general life expectancy rates. Turkey's life expectancy rates are good. The average is 71,8 years, 69,41 years for males and 74,3 years for females. It is ranked at 102 out of 225 in the world, meaning it is ranked within the healthier half of the world.

A far better indicator to use in order to assess general development of countries is the infant mortality death rates. It is far more clearer to assess development levels from these statistics as they more or less tell the truth, where by general mortality rates do not follow or give any reliable data concerning lifestyles and causes of deaths. In this case, Turkey has a relative poor record. Its death rate is set at 44,2 deaths per 1000 population, which equates to 44,2 deaths per 1000 births. This is high in comparison with European countries that tend to experience no even a quarter of these figures. Just to compare, Denmark and the UK's respective rates are 4,90 deaths and 5,28 deaths per 1000 births.

By looking at the figures that I have given above, one can to some extent determine the nature and trends of the Turkish population. However, as I have explained in the cases with the birth and death rates, it is not always as 'clear cut' as one might imagine it to be. This is why I find that the use of two other forms of data concerning the demographics of a country added to the previous figures will assist immensely in getting a clearer picture of the true demographic identity and future trends of the Turkish population. These are 'Median Age' and 'Age Structure' of the population.

The Median Age of a population is the age that divides a population into 2 numerically equal groups. As these are split in half, each groups being equal in size and in a specific order in age. The Median Age for Turkey is 26,8 years of age. This means that half of the Turkish population is under and the other half of the population is over the age of 26,8 years of age. To get a comparison, the average median age of all the European countries, at least in the EU, is around 40 years of age. These figures reiterate what I assumed above, that is Turkey has a young population. This figure can also give us an indication of the Age Structure, which I have already explained above.

The literacy rates in Turkey are average. In total 86,5% of the adult population are literate. This figures breaks down into the following according to the sexes: 94,3% literacy for men and 78,7% literacy for women. Here we see a stark contrast in the rates between men and women. This difference hints at developing figures, where by literacy rates between men and women largely unequal. In the case of most developing countries, the literacy rates for men are generally significantly higher than that for women.

The median age and age structure of a population affects the nations socio-economic issues. An example of this would be a young population would need more investment in things like education where by an elderly population would need investment in areas such as health. A rapid growth of a young population is generally not good for any economy, as it requires a significant increase in the size and capacity of the labour market in order to cope with these increases in the size of the labour force.

As far as ethnic groups and languages are concerned, Turkey has one official language, although Turks themselves speak several other languages regionally as well as ethnic minorities. The other languages spoken are Kurdish, Arabic, Armenian and Greek. Of course the largest recognised ethnic minority speaks Kurdish, the Kurds who account for roughly estimated 20% of the total population. This is an estimate given to me by the CIA Official Publications. Other sources quote similar figures, despite the fact that it is not completely certain of the exact number of Kurd residing in Turkey. More facts and details on Kurds and Kurdistan will follow later in its respective section, '6.3 The Kurdish Question'.

Turkey's Economy:

Turkey's economy is an interesting economy to look at. It is recognised by the CIA as a developing one. Its economy is of a very distinctive character and is working well in only specific regions of the country where by the various conditions enable it to grow in the extent that it does. As we can see according to the regional composition of the country27, agriculture for example is most productive in western and coastal regions of the country and least productive in the regions that I am specifically focusing on, such as the southeastern region as well as the Anatolian Plateau. As far as the industrial sector goes, most units are situated in the northern and western parts of the country, especially

in and within close proximity to the large cities. Yet again, we see that the southeastern regions of the country do not provide optimal conditions geographically for industry to locate itself in, resulting in low levels of economic growth.

Turkey's economy is complex as it is a mixture of modern industry and commerce as well as having a traditional agricultural sector that still accounted for 40% of employment in the year 2001.

Its GDP in 2001 was reported at being at 489,7 billion dollars, respectively ranked at 18 out of 237 surveyed countries worldwide. It has s strong and fast growing private sector, even thought the state plays a significant role in basic industry, banking, transport and communication. The most important industry in Turkey is those processing food and drink; and those producing textiles and clothing that are mostly privately owned. There is also some extent of fertiliser, metal industry and machine parts manufacturing going on, although textiles and clothing is its largest exporter.

The GDP real growth rate of past few years has exceeded 6% each year (last years growth rate at 7,8%), which is just behind China's 8% growth rate. This seems promising, although the country's expansion has been heavily affected by its sharp declines in output from the mid 1990's until 2001. At the same time, the public sector fiscal deficit has regularly exceeded 10% of GDP- due in large part to the huge burden of interest payments, which account for more than 50% of central government spending28.

Inflation in Turkey over the years has been very high in recent years, always going into double figures, was reportedly low at 23% in 2003[29]. It's no surprise then that foreign investment in Turkey at the moment is at an all time low, currently less than 1 billion dollars annually. To top these miserable figures up, Turkey's economy was forced into a free fall in 2001 as a trade deficit that continued to grow combined with significant weaknesses in the banking sector. This caused the value of the national currency, the Turkish Lira, to plummet in value forcing the country into recession.

Turkey's Economy has seen a significant change in its sectorial structure, since its initial declaration of independence and birth of its current nation in 1923. Back in 1923,

27 Please see section concerning various land regions in Turkey, P4-5
28 Statement given in Official publications of the CIA, on the state of Turkey's Economy.
29 Figure given by the Official publications of the CIA

Turkey was almost entirely an agricultural country. In 1923, there were 118 factories in Turkey. By 1941 this had increased to over 1000 factories due to the governments directive influence on industry. Today there are around 30,000 factories accounted for. For a long time now, the government of Turkey has been involved in most sectors of its economy. It largely owns much of its communication and transports industries, although over the past 20 years or so, the government has gradually reduced its ownership of various industries and has allowed increased private control of companies.

The composition of the Turkish economy by the different sectors is interesting. According to the CIA's Official Publications, the composition by sector in 2001 was of the following:
- The Agricultural sector accounting for 12,9%
- The Industrial sector accounting for 30,4%
- The Services sector accounting for 50,7%.

This share of the economic activities by sector proves interesting when compared to the data concerning the labour force and respective share of the labour market. We can see from the figures above that the service sector leads by dominating economic activities, followed by industry with a little over a third and agriculture accounting for only an eighth of the share. If we go on to look at the labour market statistics, we will see that there is a proportional imbalance within the different sector's share of the labour force. Of the 23,8 million Turks in the labour force, 10,8% is unemployed which roughly equates to around 2,5 million people. The labour forces distribution between the various sectors is of the following:
- The Agricultural sector acquiring 39,7% of the labour force
- The Industrial sector acquiring 22,4% of the labour force
- The Services sector acquiring 37,9% of the labour force

After placing the two previous sets of data side by side, we can see that the agricultural sector employs the highest number, that is 8,43 million workers, which equates to almost 40% of the active workforce. Almost half of the country's workforce is employed in the agricultural sector which itself only accounts for 12,9% of the total economy.

As far as imports and exports are concerned, Turkey imports far more than it exports. In 2002, Turkey exported $35,1 billion worth of goods consisting of apparel,

foodstuffs, textiles, metals, and transport equipment. Despite these exports, the amount of imports to Turkey by far outweighed its exports with a total value of $50,8 billion. Most of the imports consisted of machinery, chemicals, semi finished goods, fuels and transport equipment. Overall, Tobacco is one of the biggest exports Turkey has to offer. Wool, deriving from livestock farming as well as citrus fruits and vegetables also account for much of Turkey's other export goods.

As far as the economy goes, it was my intention to provide a short but broad outlook on the general characteristics of Turkeys economy. As we can see by the statistics provided by the World Book Encyclopaedia and the CIA's Official Publications, much of the productive part of Turkey's developing economy is concentrated in particular regions of the country meaning that only specific regions of the country benefit from any growth as other regions deteriorate even more as they are left industrially neglected.

Over the past 20 years or so, Turkey has experienced a significant level of migration where by many Turks have emigrated from economically deprived regions of the country to more prosperous ones. Most of the internal migration has been that of rural to urban migration, as many deriving from isolated communities such as the Kurdish ones in Kurdistan, immigrate to the large cities in north and the west, in hope of improving their desperate economic situation and establishing a balanced and sustainable lifestyle. It is also important to note that many Turks have decided on immigrating to other European countries within the EU such as Germany, the Benelux countries as well as much of Scandinavia, in hope of sustaining an improved economic situation. In fact in most EU countries today, it is possible to find well-established Turkish communities in most of the major European cities. This is why migration is an important activity concerning Turkey, both internally and externally.

Turkey's History and Government

The actual history of modern day Turkey is very young and does not even span 100 years. In comparison with the long-standing history of the Ottoman Empire, the Republic of Turkey is still in its infancy. The formation of current Turkey began after the First World War, in May 1919, when the Allied Forces broke up the Ottoman Empire who sided with the Germans. This resulted in a temporary nationalist movement being set

up 4 months later by a popular military hero, Mustafa Kemal. The nationalist movement gave way to a provisional government until April 1920, as the provisional government founded the National Assembly in Ankara and electing Kemal as the Assembly president.

On August 10th 1921, the treaty of Sevres was signed between the Sultan's government and the occupying Allied Forces. This treaty divided the old Ottoman Empire, greatly reducing its former territories to Istanbul and part of Anatolia. The rest of the empire was divided and distributed some of Allied Forces. As a result of this treaty, the nationalist movement, spearheaded by Kemal grew as the Turks became increasingly unhappy with their 'raw' deal handed to them. As tensions grew by September 1922, the nationalists went on through the National Assembly to abolish the office of the Sultan and to drive the Greek occupying forces out of the country.

The treaty of Sevres was very unpopular amongst nationalists, as it was seen to compromise and limit the interests and perceived rights of the Turkish people to an unacceptable point. This is why the office of the sultan became unpopular and was eventually abolished. As a result of this, a new peace treaty was drawn up between the National Assembly and the Allied Forces. The Treaty of Lausanne was drawn up in 1923, setting up the Turkish boarders as they are seen today. The Treaty of Lausanne signified a new era in Turkish history. Shortly after the signing of the Lausanne Treaty, the National Assembly proclaimed Turkey as republic, electing Mustafa Kemal as Turkey's first ever president.

Kemal was largely responsible for adopting a wide set of national reforms and setting programs intended to modernise the nation. This has been a recognised part of Turkey's history, where by since its initial proclamation as a republic in 1923, especially during the 1920's and the 1930's, Turkey has gradually made changes culturally and politically, which in many instances has gone against Islamic practices. Polygamy was banned, women received equality and surnames were made obligatory. President Kemal himself was given the name Ataturk by the National Assembly. This directly translates to 'father of the Turks', and in a way reflects how he was seen by most of his loyal citizens and can be interpreted as the founder of modern day Turkey.

As Islamic Law formerly ran the country prior to becoming a republic, some Turks, especially in rural and more isolated regions have been against such changes. This

has been seen through movements of resistance against the Turkish Government such as the Kurdish Workers Party (PKK), and continues to divide the nation today.

Civil unrest is an issue that has plagued Turkey since its contemporary birth in 1923. There have been several attempts by the Kurds to revolt, although each time has suppressed by the Turkish armed forces. The Turkish Military has also taken control of the country several times. In 1960 there was a military coup after it was believed the democratic government was not in line with the Attar's principles. This resulted in the execution of the serving prime minister and the president imprisoned along with many of the country's former leaders. By 1961, a new constitution was adopted.

The 1960's were marked by a lot of political unrest. Politically orientated bombings, kidnappings and murders by radical Turks who wished to overthrow the government took place. By the 1970's, the divisions between secularists and religious groups had deepened. As a result of this deepening civil unrest, the military from the 1970's onwards has had a significant influence on the government and politics. By 1980, the military took over power again, with yet another constitution being drafted in 1982 before power was returned to civilian rule again in 1983. So far, this constitution has remained in place.

The parliamentary government in Turkey consists of 3 important entities; a president, a prime minister and his cabinet30 and the Grand National Assembly that acts as a legislature. The president is the head of state and commander in chief of the armed forces and has a term of 7 years. He is in turn chosen by the legislature. The prime minister is appointed by the president, selected from the members of the legislature that is made up of 550 deputies. The deputies of the legislature are chosen through public elections that are held every 5 years.

The local governments of Turkey are divided into 76 different provinces. Each province has a governor who is selected by the president. The councils of the provinces are chosen through public elections that are held every 5 years. Each province is divided into various districts, villages and municipalities of at least 2000 people.

From the 1970's till today, much of the civil unrest in Turkey has been largely manifested between the government interests and Kurdish interests; where by most of the

Kurdish part of Turkey wishes to gain independence from Turkey. More of this will be covered in the appropriate section on the Kurds.

As far as recent developments are concerned, Turkey over the past 15 years or so has experienced erratic political times, where by from the mid 1980's till 2000, there have been many clashes, notably the most significant with the Kurds which I will discuss in the following section.

Hopefully, this section has provided the necessary information regarding the history of Turkey since its inauguration in 1923 and an insight into the governmental structure and the significant influence that the military might have in the running of the country.

6.2 The Kurdish Question:

This section will cover all the aspects related to the Kurdish minority of Turkey. It is the Kurds that much of the attention of this project will focus on, as these are the people that are going to be affected by the construction of the hydroelectric dams in the southeastern regions of Turkey, along the Tigris and Euphrates rivers. In respects to this project, I will cover the Ilisu Dam currently in construction along the Tigris River. This Dam I will cover in its respective section towards the end of this chapter.

The Kurds make up the largest ethnic minority in Turkey. Today they are spread over the country, both in their native provinces in the south-eastern region of Turkey, as well the northern and western regions of the country where great number have emigrated to since the official recognition of Turkey as a nation state in 1923. The Kurdish portion of Turkey is part of Kurdistan, an area of land that covers southeastern Turkey and parts of Armenia, Iraq, Iran and Syria. Kurdistan does not have and never has had its own state and is merely recognised as the areas in each country where by most of the Kurds live.

The area of Kurdistan boarders on the territories of 3 major ethnic groups in the Middle East: the Arabs to the south; the Turks to the West; and the Armenians to the North. Below is a map that shows boundaries of Kurdistan in the various countries mentioned above.

30 To date, only male prime ministers have been appointed.

As one can see from the map, the Euphrates River almost serves as a western and northern boundary marking out the territory of Kurdistan. According to Izady, author of 'The Kurds', it is quite likely that over half of all Kurds residing in Turkey live within the 'Kurdistan' region, the rest live in the central Anatolian area, mostly having immigrated to the cities such as Ankara as well as emigrating north and west to Istanbul or Izmit.

The Kurds of Turkey make up the nation's largest minority group. Most of them live in the mountainous regions of the southeastern part of the country. They herd sheep and goats and grow such crops as cotton, tobacco, and sugar beets. As you can see from the map, the Kurdish area of Turkey is the one of the largest of the 5 countries that is encompasses. The actual proportions of Kurdistan in each country are of the following:

- Turkey - 43%
- Iran - 31%
- Iraq - 18%
- Syria - 6%
- Armenia - 2%

The official population of Kurdistan is not officially known but it is estimated that around 25 million Kurds live in the area. Another problem that relates to this is that the Kurds have never been issued with passports so it is almost impossible to get an idea of

31 Map source: http://www.nationmaster.com/encyclopedia/Kurdistan

precise numbers although general estimates claim that there approximately 25 million Kurds living in Kurdistan a whole. According to analysts, half of this number resides within the Turkish portion of Kurdistan.

Another important fact to take into consideration is that over the second half of the 20th century, the Kurds have been the subject to discrimination and repression from the various countries that cover the area of Kurdistan. The most recent were in Iran and Iraq during the 1970's and 1980's. In Iran, after the revolution in 1979, and in Iraq during the late 1980's as the Kurds have tried to organised a dependent form of government to the ones they live under. The Kurds currently in Turkey have no political organisation and due to their repression when they have attempted to form any form of governance in the past, have no current governmental structure. Most of the Kurds live in tribal groups, adhering to tribal law that differs to that of Turkish law. This form of isolation and marginalisation has in effect split the Kurds and made them ineffective in organising themselves against the States which are actively dictating their own existence.

Many Kurds were killed during such uprisings and where by the international community was aware of this but did little to stop it. A case that did attract the world's media attention was in 1988, when Saddam Hussein wiped out a whole Kurdish town in northern Iraq with Chemical weapons. After the first Gulf War in 1991, the largely outnumbering Iraqi forces yet again systematically crushed the Kurds attempts to revolt again. It was estimated that after the failed revolt, millions of Iraqi Kurds fled to the North of Iraq and even into Kurdish region of Turkey.

Turkey itself has a shaded past with its relationship to its Kurdish citizens. From 1984 to 2001, the country was embedded in civil war with the PKK, the Kurdish Workers Party. Many Kurds have expressed the sentiment for a separate state of Kurdistan ever since the birth of Turkey as a republic in 1923, although the tensions between Ankara and the PKK were amplified after the Turkish military coup of 1980. As the military took control of the government, the Turkish State's anti-Kurdish policy worsened and as a result the PKK decided to take up arms.

The war took a decisive turn in 1999, when Turkish intelligence agents arrested the Kurdish rebel leader Abdullah Ocalan. This 16-year conflict devastated the area in which the Berke Dam and Ilisu Dam are located. The conflict itself killed over 30,000

people and displaced up to 3 million people. Despite this, many Kurds are under threat of displacement when the planned dams are completed. Many of the Kurds displaced by the war moved to the cities in the region as well as the cities in the western and northern regions of the country. These ´refugees of war´ stemmed from the rural areas where most of the fighting took place.

The recent civil unrest in the Kurdish region is not something that is new development. In fact, the tensions between the Turkish State and Kurdish minority date back centuries. The earliest reported deportations of the Kurds are the mass deportations of the populations of the conquered Kurdish territories have been the norm since at least 2000 BC32. Kurdistan has constantly since the initial colonisation's been divided up by its respective conquerors. As a result of this, the Kurds have constantly been 'on the move', often being forced to resettle.

The earliest deportations of the Kurds were carried out by the Assyrians where by the earliest documentation of this dates back to 745-612 BC. According to Izady, large numbers of Kurds that were resettled did not survive their ordeal as they lacked resources to support themselves to the new land.

From the very start of contemporary Turkey, in 1923 until 1938, the Turkish authorities dispersed Kurds where by just a few families per alien-host community were allowed. This was in order to dissuade the displaced Kurdish families in retaining their ethnic identity through isolation and loneliness. These displacements were one of many initiatives undertaken by the Turkish State in an attempt to break up the Kurdish minority and to assimilate them into Turkish society.

After the old Ottoman Empire was disbanded at the end of the First World War, the Kurdish homelands were divided. The Treaty of Sevres, that was drawn up by the Allied Forces and the Nationalists outlined the Turkish boundaries, anticipated an independent Kurdish State covering a large area of former Ottoman Kurdistan. The treaty itself states in article 62 of the treaty a need for 'local autonomy for the predominantly Kurdish areas'. Article 64 opens up the discussion on how the Kurdish People might be granted independence. The National Assembly did not accept this sentiment at the time and eventually by 1923, the Treaty of Lausanne was signed.

32 Izady,'92

This treaty of Lausanne was a significant change in the rights that were to be granted towards the Kurds of Turkey. Although the treaty stated that 'no restrictions should be imposed on any Turkish national of any language in private intercourse, in commerce, religion, in the press or in the publication of any kind', the Nationalists saw this as an emphasis on language where by the National Assembly officially stated that these rights were only to be applied to non-mosul communities in Turkey such as the Greeks, Jews and Armenians, which meant that there were absolutely no assurance for the Moslem minorities in Turkey such as the Kurds.

The fundamental rights that were accorded by the treaty of Lausanne regarding language rights were taken away in 1924 when a law on 'unification' was passed. This law saw the closure of religious schools, which indirectly lead to the closure of schools where by the language of instruction, was Kurdish. The reason given by the authorities was 'to protect the integrity and indivisibility of the state and nation'. It appeared that there was a prevalent feeling among official circles in Turkey at that time that the granting of certain rights to an acknowledged ethnic or national minority would inevitably lead to further demands, including ultimately calls for secession in the name of self determinism33. This was assumable out of fear as Turkish officials were afraid that granting certain rights might 'reawaken' the consciousness of other ethnic groups in Turkey.

The 1920's in Turkey were times where there was no certainty of the long-term future for Turkey; hence people were worried what the future had in store for Turkey. It was a time that saw the transition from the late Ottoman Empire to the Turkish State. A well organised and orchestrated campaign was undertaken in the cultivation of the Turkish Nation state, where by the nationalists running the country at the time, spearheaded by Mustafa 'Ataturk' Kemal, wished for the whole of Turkey to unite and become one country. In doing so, all people in Turkey, including the minorities were expected to assimilate into Turkish society, adapting to the Turkish language was one of them. The other reforms imposed by Kemal such as the banning of polygamy, the introduction on surnames and equality for women, were part of the these reforms that were aimed at modernising Turkey, unifying it in a way, bringing it into line with the

33
Krisci & Winrow, 1997; p.45

West at that time, i.e. Europe and America. There is no evidence till date that Kemal or Ataturk did anything to directly repress the Kurdish minority, as by his own meaning he wanted to bring the State together. Whether that meant pushing away the Kurdish identities is a matter of how the Turks themselves perceived the unification process, a process which was to bring all in Turkey together and attempt homogenise the population, without taking minorities into account.

A settlement law was passed in 1934, is a typical government policy that was to emphasise Turkish ethnicity and language. This law divided the people of Turkey into 3 distinctive groups: people who spoke Turkish and were of Turkish ethnicity; those who did not speak Turkish but who were still considered to be of Turkish culture; and lastly those who neither spoke Turkish nor were of Turkish culture34. During the debate before adopting this law, no discussion referring to the Kurds was made despite the fact that the term regarding 'those who were not belonging to Turkish culture and whom did not speak Turkish' were generally used when referring to the Kurds or Arabs. The same law also went on to divide the country into 4 specific zones.

The first zone would include all those areas in which it was deemed desirable to increase the density of the culturally Turkish population.

The second zone would include those areas in which it was deemed desirable to establish populations that must be assimilated into Turkish culture.

The third zone would be territory in which culturally Turkish immigrants will be allowed to establish themselves freely but without the assistance of the authorities. This zone was pretty much referring to the southeastern regions of Turkey, which is why I am setting my focus on in the context of the project. As one can see from the map shown above, this area encompasses more or less the area that is seen to be part of the Kurdistan region of Turkey.

The fourth and final zone would include all the territories which had been decided should be evacuated due to issues concerning public health, material, cultural, political, strategic or security reasons35.

34
Settlement Law; p98-99; Kirisci & Winrow,1997
35
Izady, 1992, p.109

It can be seen through laws such as the passing of the Settlement Law 70 years ago that the Turkish government devised specific mechanisms in order to attempt to get the Kurds to assimilate into Turkish society, although it often had the opposite effect of pushing them away.

The mechanisms and means of getting the Kurdish communities to assimilate were numerous, although many were suppressing the Kurdish culture, language and history of the to such an extent to where exercising one's identity as a Kurd was almost criminal. As a result, Turkish Kurdistan over the past 70 years has become neglected, regressing and detached from the mainstream36. In social and economical terms, these reforms have been providing a hostile social environment for the Kurds. According to Kirisci and Winrow, certain privileged status was extended to those of Turkish ethnicity. Article 7 of the Settlement Law permitted immigrants of Turkish ethnicity to freely settle where they wished to settle, except not in those areas designated closed to public use. The settlement of other immigrants would be regulated and directed by the government. As a result of this, some of the Kurds were relocated in western regions of Turkey. Others were settled in the southeastern region of the traditionally Kurdish areas.

It is not hard to see that at such early stages of the country's status as a republic, discrimination against certain ethnic groups was already openly happening, even though the government would point out that it was in the best interests of a unified Turkey and for the well being of Turkey's population as a whole. But how can this be the case when almost a quarter of the population is open to legitimised discrimination?

The actual definition of what it means to be a Turk is still unclear where by the exact nature and ethnic original background of Turk is not 100% certain. Many of the values of what it was to be a Turk are self-defined. These were reconstructed by Mustafa Kemal 'Ataturk' and his associates with the use of myths, symbols and interpretations of

Turkish history37. According to such definitions, the Kurds are not part of the Turkish culture and are considered as an outside entity and yet still does not gain recognition of that either. One could almost say that the Kurds are stuck in no-man's land in respect to their perceived identity in Turkey.

36
Izady, 1992;
37
Kirisci & Winrow, 1997;

For all the Turks in general, as far as self-perception is concerned, some Kurds in Turkey see themselves as Kurds, some see themselves as both Kurdish and Turkish and some as Turks. Since there is no real common self-perception of the Kurds amongst themselves as a people, it is then very hard for them as a whole to agree or organise any form of unified representation due to the problem of divisions that have opened within the Kurdish communities. This in turn has impaired political mobilisation amongst the Kurds. Years of constant attempts by the Turkish government to fragment and dilute the Kurdish minority into the mainframe of Turkish nationalism has gradually disabled the Kurds, preventing them in having a common agreement on what should happen to their native homeland.

One might suggest that Ankara's persistent efforts in reunifying, if that is the term to be used, has in effect had the opposite effects on the Kurds collective ability to decide what is best for themselves.

By the 1990's, the general feeling of the Kurds demanding recognition Kurds and not Turks and their right to express their identities had increased significantly enough to pressure the government. Nevertheless, Turkey has not yet addressed these demands seriously; as it has been argued repeatedly by government officials that Turkey is facing a terrorism problem form the Kurdistan Worker Party, otherwise known as the PKK. This is true in respect to the government's claims, although since the capture of the PKK leader, Abdullah Ocalan, in 1999 there has been little significant 'terrorist' activity in the region. It would appear that since the leader's capture, there has been a general decrease in PKK activity, though sporadic isolated incidents still occur occasionally in the southeastern region despite the PKK unilateral ceasefire launched on 1 September 1998. This ceasefire was advanced to a more certain point 11 months later, with a statement produced by Ocalan stated in its words " to suspend the armed struggle and withdraw the forces beyond the border for peace". This statement in effect calls on Turkish administrators to demonstrate a sensible and respectful approach to current realities, which in reality is a case where by the Kurdish side to the conflict are willing to work out peaceful solutions in order to find a common solution to the Kurdish Question.

Despite its initial intentions, the Kurdish side called off the ceasefire as they saw the Turkish side as unwilling to make significant progress towards peace. The halt to the

ceasefire in September of 2003 signified the end to the third ceasefire of the 16-year conflict, one lasting 5 years. The reasons for the end of this ceasefire was due to the fact that the PKK in as well as outside observers blamed Ankara's attitude towards the Kurdish fighters and a lack of progress on the legal reforms that were to be initiated for the Kurdish minority.

The reforms were put forward by the Turkish president, Recep Tayyip Erdogan, and were intended as confidence building measures that would give the minority groups in Turkey, especially the Kurds, improved rights and more equal civil stature alongside the Turks. These reforms were also part of a set of demands put forward by Brussels in the view of Brussels eventually considering Turkey as a candidate for EU member state status. The authentic intentions for these reforms are still unclear as many critics see them as a ploy to move closer to Brussels and not to specifically improve conditions for the Kurds by the further democratisation of Turkish society. The reasons for such critical views could be traced to the recent decisions by the Turkish judiciary in March 2003 to ban the biggest legal Kurdish political group, the People's Democracy Party (HADEP). The reasons given for these decisions have not been specific and like many of the amendments made in the past that have discriminated against Kurdish interests, they have been done so in the apparent safeguarding of national interests, such interests having allegedly been seen as threatened.

Opposed to the view that many government officials in Ankara hold, notably that once the 'terrorism' is contained the Kurdish Question might be resolved is the widely held view the problem as a socio-economic one. The reasons for this is that such persons believe the Kurdish Question can be solved once basic amenities and infrastructural amendments are made. Such changes would bring this region of the country inline with the rest of the country in terms of development. According academics such Izady and Kirisci & Winrow, much of the problems have a lot to do with the fact that the Turkish government for years have decided to shun the Kurd region of its development. One only has to trace back to the Settlement Law of 1934, amongst many other laws that have been discriminatory toward the Kurds to understand this. The third zone of the Settlement law, where by Turkish immigrants were allowed to establish themselves freely but without

any assistance of the authorities, directly goes to show the embedded prejudice that Kurds have had to put up with from their respective acting government in Ankara.

The areas that have been traditionally inhabited by the Kurds of Turkey have more than often been the least developed of all the regions in Turkey in terms of social indicators. The southeastern region according to Kirisci & Winrow has the lowest scores for indicators such as illiteracy rates and number of medical doctors. It also performs poorly in gross per capita figures; most communities in the south-eastern region survive on subsidiary farming, where by their use of the land rarely exceeds that of their personal needs and further more rarely sees the any profit based agricultural development intended for commercial use.

It is not an assumption that the east and southeastern regions of Turkey are the most neglected in the country. By looking at simple national statistics, it becomes quite clear that there is disparity between these regions and the more developed in the north and the west. Figures relating to per capita income and literacy rates for these regions score well below the national average. When comparing the per capita income to the national average, the region scores well below par, at 42% of the national average. According to government aims, the GAP aims to improve the regional score to approximately 53% of the national average. This can be seen as an improvement but at the end of the day, that still equates to about half of the national average which is still a huge difference. David McDowell, author of "A Modern History of the Kurds" points to the fact that these regions, despite their extremely low levels of social and economic development, only manage to receive less than 10% of the national development budget. How much further will these regions have to decline in terms of development before they are seen as worthy of receiving significant and effective funds for development purposes? Clearly, these are not issues that happen to have been accidentally overlooked but a clear and defined case of institutionalised neglect. Unfortunately, this has been the case for long time and has been a main identifiable character of Turkey's long-term determination to 'assimilate' Kurds into Turkish society. Many critics of the Turkish long-standing efforts of cultural and national assimilation of the Kurds into Turkish society define this form of 'assimilation' as repression and the attempt to remove any form of Kurdish identity. I personally agree with the latter, as there is an overwhelming evidence to

support this claim and very little, if any, supporting claims of beneficial reforms intended for assimilation.

Another crucial indicator that would suggest neglect on the part of the Turkish authorities is the literacy rates and education statistics regarding the southeastern regions. It is a fact that the dominant language within the rural Kurdish communities is Kurdish. Despite this, as explained earlier, the language of instruction in the schooling system is Turkish by law. This has resulted in a high dropout rate from schools. The drop-out rate seems to increase with the level of schooling. According to McDowall, the literacy rates for the 1980's averaged fewer than 50 % compared with a national average of 77 %. Enrolment statistics in the south-east tell their own tale: only 70 % enrol at primary level, only 18% proceed to the secondary cycle, and only 9 % complete it. The pupil-teacher ratio in the southeast is only 41:1 compared with a national average of 31:1. Such facts contradict official claims of concern38. This statistics are worrying if one is to take the repercussions of these statistics into consideration on the long-term basis. Education is one of the fundamental foundations that society can base it on and is one of, if not 'the' main ingredient required for development, especially in regions that are in need of development such as the southeastern regions of Turkey. Social and economical development cannot be initiated without the basic requirements, education being one of the most critical requirements to sustain a level of development anywhere near those of the more developed regions of the north and west.

In recent years, there has been more money put into the south-eastern region for development purposes but this has only increased as construction of specific dam projects in the region have gone underway. It is hard to assume that the government is deciding to increase spending in the region in favour of the Kurds whilst it still embedded in its heated issues over Kurd Question. Like Kirisci and Winrow, I take full assumption in the fact that any significant changes in budgetary spending would be solely for the benefit of the GAP project. Even if we were to take this into consideration in light of how it could benefit the Kurds, it would be very hard to see just how any investments in the area directly concerned with the GAP project will help the situation of the Kurds.

38 McDowall, http://ilisu.org.uk/david.html

One of the promised features of the GAP project was the apparent development of capital-intensive agriculture and agro-industry. Despite this feature, the State has never made any improvements on alleged promises in providing necessary land reform in the southeast of the country. Such land reforms have been needed so that the most of the current land that is controlled and held by landlords or tribal leaders can be divided and distributed accordingly to the local needs. The big problem with this is that there is massive imbalance in land ownership amongst farming families where by 8% of the farming families own almost half of all the land, in comparison with almost 80 % who own 5 hectares or less. This big failure has pushed many into the cities to work as day labourers, which does not constitute long-term stability in their lives. In this case, the GAP projects have nothing to offer this majority, which largely represent those who are affected by GAP. As most of those affected by the GAP projects have no legal tenancy rights, they have no say in what happens to the land they use to live on. More details on the specifics of the GAP project and its effects on the Kurds will follow in its respective final section of this chapter on the case study dams.

It also the case in the writings of David McDowall, one of the most respected and revered authors on literature concerning Kurdish history and identity. He is the author of the acclaimed book, "A Modern History of the Kurds". In addition to this, David McDowall has also taken specific interest in the Ilisu Dam project, joining the growing number of critics of the project. In McDowall own chosen words, "Ilisu makes no development sense for people of the region, and it cannot help the healing wounds of the war, only exacerbate them"39. I shall elaborate more on this in the last section of this chapter that will deal directly with the Ilisu Dam case study.

In summarising the debate on how to tackle the Kurdish Question, it is pretty obvious that there are two opposing views to the debate.

The first view is widely held by government officials in Turkey. This view assumes any political party or movement associated with the PKK, now called the Kurdistan Freedom and Democracy Congress (KADEK), would constitute terrorism. Hence, this would be seen as an unacceptable entity to negotiate with and would call for the containment of such a movement in order to gain a solution to the problem.

Furthermore, any political movement that is to question or challenge the idea of Turkey as a nation state by suggestion of an independent State of Kurdistan within the boarders of Turkey is impossible to contemplate. This is due to the fact that it would be considered by the Turkish government as going directly against national interests and hence would bring Turkey's perceived national security into question.

Kurdistan Freedom and Democracy Congress as well as many impartial observers such as NGOs and various human rights organisations hold the other view. This view claims that Ankara should make initiatives to bring the socio-economic problems of the region to the forefront of the debate, which constitute a solid commitment that the Kurds would see as progress in the establishment of their ethnic identity and constitutional rights. In doing so, it would soften relations between officials in Ankara and hardened separatists convinced Turkey still has no plan in accepting the Kurdish minority within its perceived national status. This in turn would improve conditions for the majority of the Kurdish minority merely wishing to have piece and stability in the region. Piece and stability would then in effect enable social and economic development in the region.

Before end this section, I want to briefly summarise the main points that relate to the situation that the Kurds are faced with in terms of sociological and cultural isolation. They are separated from mainstream society in Turkey in five main ways:

1. Through political discrimination, the Kurdish communities have been repetitively denied the right of political representation and have had their political parties and respective member's rights abused. Even though over 2 million people voted in favour the HADEP (the People's Democracy Party), none of the party members were granted representation in Parliament. The party was subsequently banned last year.

2. Through constant human rights violations, the Kurds have been subjected to torture. This has been an open secret for years, and has been documented by respected organisations such as the UN and Human Rights Watch, as well many other Kurd-organised groups outside Turkey.

3. Through population displacement, where by over 3 million Kurds have been displaced by the civil war. Much of the displacement due to village and town destruction carried out by Turkish armed forces and Kurdish militia working with Turkish armed

39 McDowall, http://ilisu.org.uk/david.html

forces. Since these initial displacements, many Kurds have been refused the rights to return to their native villages by the Turkish authorities, effectively causing them to migrate to the cities and join the already swelling enclaves of displaced Kurds in the city ghettos.

4. Through cultural discrimination by the subsequent banning of Kurdish language up until 1991. Reforms intended to improve conditions in 2002 through the Harmonisation Laws that were passed. Kurdish television and radio is broadcast but through strict censorship by Turkish officials. Special rights have to be obtained to open schools that teach in Kurdish. The expression of Kurdish identity is still a touchy subject, as people are still being persecuted for exercising their cultural rights such as publicising or publicly expression of Kurdish values40.

5. Last but not least, economic neglect has been one of the main forms of marginalisation and isolation on the part of the Turkish authorities that has largely had the most effective impact. It's no secret that the Turkish government has constantly reduced the budgets for the Kurdish regions. This has been widely seen as a government led effort to destabilise the regions even further in order to incite migration to the cities and hence clear the land for government development.

It is essentially through these five points the Kurdish communities have to deal with in their on-going saga of trying to establish normal lives. Under one or two of these set backs, there might be some chance of improving their plight. Unfortunately, with the numerous and varied challenges they are faced with, it is hard to see how or where they should start the fight-back.

Finally, in concluding this section, I want to stress that amidst arguing and bickering for what the effective solutions should be to the Kurdish question, the ordinary Kurds who have no specific national interest or political goals in mind are the ones who are affected most by this issue. These ordinary´ Kurds constitute the majority of the Kurdish population in the region and unlike those who have specific extreme interests at heart, these are the people who are mostly affected by the outcomes of the ongoing dispute between the government interests and radical separatist guerrillas. To this very

40 BTC pipeline (Turkey section) - EIA REVIEW, October 2003; Ch8, p.8

day, this portion of the Kurdish population has been consulted the least in light of this issue. To me this seems absurd as they lie at the heart of the issue.

6.3 Turkey's Energy Sector and National Energy Policy:

In this section, I shall be exploring and discussing the structure of Turkey's energy sector and investigating its current energy policy. Here I shall be discussing current energy trends by looking at the demand, supply and energy efficiency. Most of the data for this section I have compiled from various sources, though most of which have come from the International Energy Agency's 2001 review.

Turkey is one of the founding members of the International Energy Agency. The IEA is an autonomous body, which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD). The purpose of the EIA is to carry out a comprehensive program of energy co-operation among 25 of the OECD's thirty member countries.

6.3.1 Turkey's Energy Market

Turkey's energy market is amongst one the fastest growing energy markets in the world. With a Total Final Consumption growth rate of around 4% over the last 30 years41, this growth rate is the fastest amongst the IEA member states. Much of the increase in energy demand in Turkey is due to an expansion of the industrial sector over the years. In the past, the energy consumption distribution between the various sectors of the economy was pretty much evenly distributed. Due to the expansive nature of the industrial sector of the past 30 years, the industrial sector has taken over and dominated the share of energy consumption compared to the other sectors of the economy such as the agricultural, household and services sectors that have remained in comparison at a steady rate.

Most of the thriving industry in Turkey is situated in the western regions of the country, which is characterised by the bustling cities that are thriving in trade, industry and finance. This is strongly contrasted by the eastern and south-eastern regions of the country, such as the region the Ilisu Dam is located in, which are heavily undeveloped in comparison. In such areas, subsistence farming is the major form of economic activity, if any. This has resulted in significant migration patterns stemming from the undeveloped areas towards the developed ones.

Much of the energy sector remains state-owned and according to the IEA report in 2001, is unable to efficiently meet the increasing energy demands. Despite this, the government has slowly begun privatising its energy sector in order to improve competition in the sector and hence improve supply. The Law on State Economic Enterprises was amended in January 2001 so that the restructuring of the state-owned electric utility Directorate-General of Turkish Electricity Generation and Transmission (TEAS) into separate companies that was to deal with generation, transmission and trading individually. At the end of June 2001, the government launched a privatisation program that was initially intended to transfer operating rights of power plants and electricity distributors from the state owned to private companies. Although privatisation has been initiated, the main functions and controls of the sector are largely done so by the state. The initial restructuring, liberalisation and privatisation of the energy sector is positive step towards the modernisation of its energy sector although it is important for Turkey to keep this process going if it wants to contribute to greater stability and prosperity in the long run.42

In 1998, industry accounted for 51,5% of the total electricity consumption, leaving the three other sectors of the economy; agriculture, household and services taking a combined share of 48,1% of the electricity consumption all together. This balance of consumption means that most new power plants that are constructed in the near future will mostly benefit industrial production more than it will benefit the private sector. This is very important to take note of because when debates arise in the future concerning the choice of energy provision and which sources of energy production are to be acquired, it will be vital to know whom the main beneficiaries are and how such energy provision will be met.

As far as energy supply is concerned, the government forecasts a necessary tripling of its current power generation capacity by 2015 in order to meet the current

41 IEA, 2001; p.24
42 IEA, 2001; p.5

increasing energy demands. The current share energy productions shows that coal and oil are the two largest forms of energy producers within the energy sector with respective share percentages of 28,5 and 41,8% of the total supply in terms of total primary energy supply (TPES) for 1999. Combustible renewable energy sources accounted for 9,7% of TPES, where as hydroelectricity accounted for a mere 4,2% of TPES. Government forecasts predict that there will be a strong increase in energy demand growth, where by TPES is expected to increase from 70,33 Mtoe for the year 1999 to 298,45 Mtoe for the year 2020. This represents an increase of 4,2 times and will mainly come from an increase in the production and usage of coal, increased gas imports, and eventually nuclear power43.

The overall share of Turkey’s energy production in TPES has decreased significantly over the past 30 years or so. This is obviously due to the sharp increase in energy demand combined the state’s inability to keep supply up with the demand. In 1999, it was noted at 35% compared to 49% in 1990 and 64% in 1973. According to the IEA, much of this has to do with the increase in oil imports of 3,5-fold of the 1973 value and 40% TPES in 199944.

Nuclear power will increase when the proposed nuclear power station at Akkuyu, by the southeastern Mediterranean coastline is built which was initially planned to materialise by 2005. These plans have been set back to 2015 due to problems of not being able to secure the foreign investment required to make such plans possible. The Government is relying on the availability to use nuclear power, but to date the likeliness of benefiting from such technology is slim and will not happen for at least 11 years.

6.3.2 Turkey’s National Energy Policy

The development and implementation of the national energy policy is so through three specific government bodies. Each body has its own specific role in policy development and implementation. The government bodies that are responsible and actively involved in the energy policy development and implementation are the following:

43 IEA, p.27
44 IEA, 2001; p. 27

- The Ministry of Energy and Natural Resources (MEN). The Ministry of Energy and Natural Resources was founded in 1963. Its main function is to supervise and control all exploration, development, production and distribution activities for energy and natural resources; reporting all of its activities straight to the prime-minister. The MEN is the main body for the formation and implementation of energy policy. This ministry is subdivided into a further 4 departments that carry out its main functions.
- The State Planning Organisation (DPT). The State Planning Organisation acts as an advisory panel to the prime minister. The role of this body is to help the government in deciding on economic and social policy. Under the 1984 Electricity Act, it has the power to evaluate investment proposals submitted by publicly owned companies and organisations, and also select s the projects that it deems suitable for inclusion in annual investment programs.
- The Electrical Power Resources Survey and Development Administration (EIEI). The EIEI has a specific role of conducting investigations and surveys to identify the energy potential of water resources. This body is responsible for the preparation of dam and hydropower plant projects such as the ones that are to be used as the Berke and Ilisu Dams. The EIEI carries out specific activities that relate to energy efficiency and also new and renewable energy resources. The EIEI is responsible for energy efficiency, which it delegates to the National Energy Conservation Centre (NECC). The NECC works within the EIEI, and was established in 1992 in order to improve energy efficiency where by one of its principle functions was to investigate potentials for energy conservation by specific sectors.

The main objectives of Turkey’s energy policy in 2001 were of the following45:

- “To meet demand using domestic energy resources as the highest priority. In the medium and long term, this is to occur through a mix of public, private and foreign capital.

- To develop existing sources while accelerating the penetration of new and renewable sources.
- To diversify energy sources and to avoid dependence on energy imports from a single source or country.

- To encourage private-sector investment and to accelerate capacity construction and privatisation in the power industry. Preparations are to be made for the introduction of nuclear power.
- To improve the reliability of electricity supply through upgrades in the power transmission and distribution grid.
- To protect the environment and public health.
- To make use of Turkey's geopolitical location to establish the country as a pivotal transit area for international oil and gas trade (´´Eurasia energy corridor´´)."

The energy policy as stated above largely reflects Turkey's ambitions to meet its predicted increases in energy demand. One of its biggest weaknesses is that much of its energy sector is still predominantly state-owned, despite the fact that it is slowly being privatised. This process needs to be speeded up in order to improve competition and hence provide a better service.

Fossil fuels are still largely being used more intensively than hydropower as hydropower has suffered from decreases in performance over the past three years due to problems of draught that has plagued the country, especially in the south-eastern regions, where most of the hydropower plants are located46.

Another problem associated with hydropower is the associated problems that Turkey has with power transmission constraints. Most of the power generated in the southeastern hydropower plants is intended for industrial and private use located in the western regions of Turkey. Transmission flows have been reportedly constrained due to problems associated with the large cross-country flows. Furthermore, transmission losses are reportedly above the international norms47. Despite these problems, it is government policy as seen above to improve on transmission losses and modernise the distribution grid.

As far as 'developing existing resources while accelerating the penetration of new and renewable sources' is concerned, there has been very little evidence of this happening. The Government is going ahead with its largely criticised plans to expand its

45 IEA, 2001; p.17

46 O.E.C.D., 2002; p.107

47 O.E.C.D., 2002; p.108

hydropower generating capacity, although there is very little evidence to show of developing other renewable resources such as solar, wind or photovoltaic technologies. This comes as a surprise because as far as solar energy is concerned, there is much potential for further development48. Wind power generation has also been identified as a potential valuable resource. The southeastern region of Turkey has been identified by the IEA as a favourable location for wind power generation, with annual wind speeds of 2.5 metres per second and annual power densities of 2.4 Watts per square metre.

According to IEA review of Turkey's Energy Policy, there is much room for improvement for energy efficiency. If this can be achieved, then it would mean improvements towards to the supply sides to the equation. This would mean improving the industrial usage of energy, as this does consume over half of Turkey's energy consumption. Also, the energy destined towards industrial usage is significantly subsidised by the Government. This means that it is relatively cheaper than energy supplied for household and private use. By balancing energy prices more fairly, the industrial usage of energy would become more rationally managed, where by measures would be taken by industry to reduce inefficient usage of energy.

Penultimately, the possibility of combining solar and wind farms with the already existing hydropower schemes could be an idea for the future. Wind energy systems can serve as a source of energy that is complimentary to hydropower in some regions where water shortages limit the energy output of hydro projects49. Large-scale hydro installations often have the ability to store large amounts of energy, which makes them very complimentary with installations using wind and solar technologies50.

Finally, it is important to mention that the current state of Turkey's financial situation, where by government expenditure has to be tightly controlled, is of high importance to use the most cost-effective resources to develop. This is due to the fact that the reliance on resources that require constant financial support would be risky to invest in and would require careful consideration, therefore would need to be evaluated by the Government on a regular basis. We must remind ourselves that Turkey does not have

48 I.E.A., 2001; p.49

49 I.E.A., 1997; p.185

50 I.E.A., 1997; p.187

endless funds to fritter on energy development, so hence cost-effectiveness should be the way to go.

6.4 The proposed Ilisu Dam:

The dam that I am using for the case study of the project is part of a monstrous hydropower and irrigation scheme on the Euphrates and Tigris rivers in the Kurdish region of Turkey. This scheme is called the South-East Anatolia Project (GAP), and scheme is one of the largest of its kind in the world, comprising of 21 dams and 19 hydroelectric power stations on both rivers.51 The scheme itself was first originally conceived as long as 50 years ago, dating back to 1954. The decision to use water resources for economic development had been taken by Ataturk, the initial founder and perceived national hero of the Republic of Turkey. 50 years on, the scheme seems to have become a reality, with most of the dams having been constructed by now. It was originally intended that two projects were set out, one for the Euphrates basin and one for the Tigris basin. In 1997, the two projects were united under the name of 'the South-East Anatolia Project.

The scheme upon final completion will have a total estimated capacity of around 8,000 MW with an annual energy production of 27,300 GWh. The total area irrigated by the GAP will cover approximately 17,600 square kilometres.52 The total estimated cost of the whole scheme has been set at around $32 billion. Of course this has been a general estimate that does not include the costs of financing the scheme.

According to the GAP authorities, the official objectives of the GAP are of the following:

- "To develop all the land and water resources in the Region, in order to achieve accelerated economic and social development;
- To alleviate disparity between the Region and other regions by increasing production and welfare levels in the Region;
- To increase the productivity and employment capacity of the region;

51 Dam Projects in Turkey; http://www.rivernet.org/turquie/reisb_e.htm
52 The Ilisu Dam Project; http://www.rivernet.org/turquie/reisb_e.htm

- To meet increased need for infrastructure resulting from population explosion and urbanisation;
- To organise economic and physical infrastructure in rural areas, in such a way as to utilise the resources, in the most useful ways and to direct urban growth in desired directions;
- To contribute to the national objectives of sustained economic growth and export promotion by efficient utilisation of the Region's resources."

The Ilisu Dam was first planned in 1954, when the South-East Anatolia Project (GAP) was first conceived, was brought forward by Ataturk, the initial proposals put forward by the founder and 'father' of the great republic and his advisors. The initial dam proposal is 50 years old and was conceived when the world had a completely different perception of environmental awareness and even more importantly, sustainable development.

The site of the dam is on the Tigris River, approximately 65 km up stream of the Syrian boarder. It is currently the largest rock filled dam project in Turkeys pipeline. The dam itself when completed will measure a total height of 135 metres and a total length of 1820 metres, entailing a reservoir behind it that will have a surface area of 313 square kilometres, containing a volume of around 10.4 billion cubic metres of water. The Ilisu Dam is expected to produce 3,800 GWh of electricity per year, with an expected capacity of 1,200 MW. The costs of the dam have been estimated at around 1.52 billion US dollars, which does not include the financing costs. Furthermore, the dam like most other mega projects is likely to experience cost overruns. This could be from anything ranging between 5 and 250 percent, all depending on the running and management of the project itself. Construction of the dam began in 1999 and is expected to be completed sometime in 2006.

The pre-feasibility studies for the Ilisu Dam were carried out on it in 1971. The final design of the dam was approved in 1982. This is quite astonishing that the final plans of the dam are over 20 years old, where by over this period of time there have been no changes to the dam plans. In the past 20 years, there have been numerous advances in the dam building technologies, as well as the recognition of important issues of development, i.e. Sustainable development, where by crucial factors in development

theory have been developed. One would expect to see some form of alterations made to a dam plans conceived 20 years ago, especially if environmental impacts assessments were carried out in 1998.

Some of the reasons for the delay for the construction of the Ilisu Dam have been due to a combination of the 15-year civil war that has claimed the region of the country as well as financial problems that have incurred since the initial end to the war.The main reason for the delay of the project was initial lack of finance. The World Bank refused to fund the project back in 1984 due to the problems of the civil war that was raging on in that specific region of the county. Since then, the World Bank has continued to refuse to fund the project due to the problem that the project does not comply with the current guidelines of the World Bank.

In 1996, funds were made available for the project when the government of Turkey offered the project to the private sector through a "Build-Operate-Transfer" project53. Despite these initiatives, no bidders were found. Shortly after, the country's State Hydraulic Works (DSI), those in charge of the running of the GAP chose Sulzer Hydro and ABB Power Generation, both of Switzerland, as their main contractors for the job. The construction for the job was made up of an international consortium consisting of the following companies: Balfour Beatty (UK), Impreglio (Italy), Skanska (Sweden), and three Turkish companies, Nurol, Kiska and Tekfen. But the developments just highlighted were not as progressive as the Turkish Government was led to initially believe.

In March 2000, ABB sold its hydro business to Alstom of France. Its excuse was that it saw more market potential in wind and solar technologies. At the very same time, large campaigns by Swiss and international NGO's were being led, calling for the end of large scale hydroelectric dam development. These campaigns were stressing on serious social and environmental concerns associated with hydropower technology, claiming that valid stakeholders such as indigenous populations were being ignored and thus sidelined in the planning stages of development.

53 http://www.ilisu.org.uk/compsum.html ; p.1

In September 2000, the consortium lost the Swedish contractor Skanska for given reasons of unspecified negotiating problems with DSI54, according to the Financial Times. As far the Turkish newspaper, the Ozgur Politika, is concerned, Skanska's company spokesman, Thor Krussel, claimed that the firm had an adopted a new environmental policy. This policy apparently was committed to caring for the people and the environment. Krussel also went on to confirm that Skanska does not participate in projects that are of no benefit of society and the environment.

According to the Ilisu Dam Campaign, the Italian contractor Impreglio has been accused in the past of involvement in a number of dams that have had adverse environmental and social effects. One of these dams is the Highlands Water Project in Lesotho that was marred by a corruption scandal involving Impreglio and also Balfour Beatty, which have subsequently withdrawn from the project. Balfour Beatty was never prosecuted despite the fact that it was in a consortium lead by Acres International, a Canadian engineering consultancy firm. Acres international were subsequently convicted by the High Court in Lesotho for paying bribes to win contracts on the project. Balfour Beatty and Impreglio also face possible prosecution although it is feared that Lesotho, one of Africa's poorest nations, will not have the financial resources to complete prosecutions.55

Getting back to the Ilisu Dam, I find it reasonable to assume that due to the strange successive withdrawal of several of the main contractors of the Ilisu project that there must be issues that are strongly suggesting the adverse affects of the proposed dam.

A big problem associated with the dam and like so many of the projects in Turkey is the fact that access to important data concerning research on the dam such as the official environmental impact assessment of the dam that was carried in 1998 has been extremely restricted, if not very secretive. Sulzer Hydro first commissioned the EIA for the Ilisu Dam in 1997. The actual EIA was undertaken by consultants from Hydro Concepts and was finalised by the spring of 1998. As mentioned above, the results of the EIA have never been disclosed to the public, despite numerous attempts by various Swiss and British NGO's to access this information. Balfour Beatty, after it withdrew from the

54 http://www.ilisu.org.uk/compsum.html ; p2
55 http://www.ilisu.org.uk/news31.html

Ilisu project acknowledged some potential impacts that were to affect the dam. These were of the following: population resettlement; issues affecting the water rights of downstream users; flooding of cultural heritage (such as important archaeological sights)56. The impacts mentioned are of the social impacts that can be experienced through dam development. According to Balfour Beatty, the EIA report on the Ilisu Dam proposal confirms that there are no problems as regards to the potential effects of the project on local flora and fauna, climate, landscape, ground water, earthquake risk, flooding risk, sedimentation or erosion57. This statement is true in terms of the acknowledgements made my Balfour Beatty on the potential impacts, due to the fact that those impacts researched given are of environmental nature and not of the social. The fact that virtually no public access to the EIA report has been granted signify that Balfour Beatty's initial confirmation is therefore futile as there is no hard evidence that backs up these claims. According to the Ilisu Dam campaign, even without the results of the EIA, the dam itself and the fragile and vulnerable character of the environment the dam is to be located in suggests that severe potential risks to the environment and the local population are very likely and therefore would back up the argument against the development of this Ilisu Dam.

6.4.1 Impacts of the Ilisu Dam:

Firstly, the obvious nature of the dam itself will serve as a concrete obstacle running against the river's natural course, which in effect will be altered. This altering will have various effects things located downstream of the dam. The affected river flow will be reduced. According to governmental claims, the flow will only be affected marginally. Nevertheless, it is important to realise that the dam will be situated only 65 kilometres from the Syrian boarder that in effect could cause an international dispute between Syria and Turkey. This impact is an important one, but is not in the main scope of the project, as it does not concern the local communities affected by the dam.

Secondly, there are the immediate effects of the dam's reservoir upstream of the dam. The most obvious effects are those such as the loss of land, forest submerged,

56 www.ilisu.org.uk/enviro.html ; p2
57 www.ilisu.org.uk/enviro.html ; p2

valleys and whole villages lost to the flooding. There are various sources quoting different figures for villages and communities that are to be displaced by the flooding of the dam. There are approximately 32,000 people living in the reservoir area, of which 25,000 people will be displaced. A further 11,000 will lose their farmland and livelihoods58. Some of the towns and villages affected will lose important archaeological and cultural artefacts. The town Hasankeyf is a Kurdish town with a population of around 10,000 people. It is at least 10,000 years old and holds tomb of Imam Abdullah, grandson of Cafer-I Tayyar, the prophet Mohammed's uncle. The town itself has survived nine civilisations, going from the Assyrians to the late Ottomans. The town itself has only recently been open to archaeological research. When the town becomes flooded, one of the most important parts and relics of Kurdish society will be lost forever.

These effects entail secondary effects and tertiary effects that are not obvious in the initial planning of the dam such as the subsequent displacement of the local communities and isolation of others, cut off by the reservoir from its neighbouring communities. These indirect impacts are first realised after the reservoir has taken its space meaning that it is virtually impossible to reverse the effects. Most of the impacts that arise indirectly as result of the immediate environmental impacts are social impacts, most of which relate to the disruption of the lives of the Kurdish communities around the dam. These disruptions often lead most people to leave their villages and move into the cities as their well being worsens with the construction of the dam.

Another considerable impact would be the actual contents of the river trapped by dam. Contents such as the nutrient-rich silts trapped by the reservoir. The siltation of the reservoir is something occurring in all large dams, and hence cannot be avoided. According to Rivernet, Hydro Concepts Engineering, the consultants responsible for the EIA carried out on the dam were not able to present any reliable data on the sedimentation rates of the Ilisu reservoir. According to HCE, the reservoir would fill up at 10 to 20 percent after 50 years, implying the initial life of the reservoir to be between

80 and 100 years. Unfortunately, according to Rivernet, there are often under estimations by planners regarding sedimentation rates, so estimates given are usually over ambitious

58 Quoted by Kerim Yildaz, executive director of the Kurdish Human Rights Project and chairman of the Ilisu Dam Campaign; http://www.ilisu.org.uk/

and generally favour the developers, beefing up justifications for the dam. In addition to this, the lack of sediments being carried to downstream parts of the river will in effect cause erosion to the riverbeds, where by they might be lowered significantly. This will in effect cause a simultaneous lowering of the valley the river is running through causing ground water levels in the valley to drop.

An important impact that has not been contemplated by the GAP authorities would be mitigation measures dealing with the need for marine organisms to move freely between the upper and lower sections of the dam. Mitigation measures such as 'fish passes' that enable fish to pass from the lower part of the dam to the reservoir part of the dam have not been included in any of the completed GAP dams and so far have not been included in the plans for the Ilisu Dam. Most of the dams built in Europe such as those in Norway have included these measures as to minimise the 'barrier effect' that the dam wall would have on the organisms living in the ecosystem. In the case of the Ilisu dam, this has not been deemed a priority and thus will lead to a fragmentation of habitats in the rivers.59

Mitigation measures such as reforestation by the GAP authorities have been promised in order to reduce erosion. This is directly contradicting some of the deforestation methods the Turkish armed forces are using in their fight against Kurdish 'terrorist' activities, using herbicides and napalm as methods of deforestation.60

The above impact will also definitely give rise to a change in characteristics of the water within the reservoir. This issue of water quality is one that has been acknowledged by Balfour Beatty, who themselves have expressed concerns regarding the quality of the river water. Such issues regarding water quality would seen as the following:

Significant levels of eutrophication of the reservoir water, that is oxygen levels in the water stored in the reservoir will greatly reduce the water quality. This will greatly affect the marine life downstream, as the water passing through the dam will have reduced oxygen content and in turn have negative effects on the food chain. Local communities relying very much on the river as food source, i.e. fishermen will be affected. Changes of the water temperature in the reservoir will be experienced, thus also

59 http://www.rivernet.org/turquie/reisb_e.htm ; p. 3
60 http://www.rivernet.org/turquie/reisb_e.htm ; p. 3

having detrimental affects downstream. The EIA that was commissioned was done so through a foreign company by the Swiss company Sulzer Hydro, and hence would not share the same priorities of values for the EIA as those seen by the locals.

According to the Ilisu Campaign61, Sulzer and ABB, have expressed direct concern in relation to the potential effects downstream of the decrease in water quality. In their own words, they see this impact as "one of the most important health risks"62. This concern relates to the combined problem of the decrease of the rivers ability to clean itself through the decrease of the water quality and the issue of cities located downstream of the dam that are receiving large numbers of migrating Kurds from the dam location. The cities infrastructures are being stretched by the influx of migrants (as we shall see in the next section on social impacts of the Ilisu Dam). These cities in question, Diyarbakir, Battman and Siirt, discharge their solid waste and wastewater into the Tigris River without any primary treatment processes. It is therefore acceptable to consider the reservoir reducing the river's natural ability to purify itself and thus become less effective in its ability to deal with the increasing levels of pollutants being discharged into it in from the cities cited.

An issue that will arise through the impacts mentioned above will be that of the health risks to the local populations. Several issue concerning implications on human health are a concern. Firstly, the decrease in the rivers ability to auto purify itself will mean that there will be an increase in pollution levels downstream. The Government of Turkey, according to Balfour Beatty, have put forward plans of introducing waste treatment facilities for Diyakbakir and are reported to be financed by the German Government. According to Rivernet, the other two cities have seen no planning of such kind. Despite the alleged plans, it is not known whether any legal binding frameworks for the construction and financing of these facilities have been taken place. This is a worrying issue, considering the fact that these are cities of populations to be of 1 million inhabitants or more. So as far as locals are concerned this is another worrying issue.

On another note, the city Battman is situated within the proximity of the Ilisu Dam reservoir. Battman holds an industrial significant role through its oil production

61 http://www.ilisu.org.uk/enviro.html ; p.2
62 Cited by Rivernet; source: http//www.rivernet.org/turquie/ilisu.htm

industries. The majority of its hauling plants are located quite close to the proposed Ilisu reservoir. According to Rivernet, this would in effect add to the mounting concerns on pollution issues related to the reservoir. No evidence concludes that these oil industries will raise pollution levels of the Ilisu reservoir, although the planners of the dam have not taken any indirect or secondary impacts of the dam into consideration, it would be unlikely that this has been thought through either.

The second health issue concerns the health implications brought on by the reservoir of the dam. The reservoir will bring about changes to the local climate. The climate is very hot and dry during the summer months. A large body of stagnating water will in effect be perfect conditions for certain bacteria and water-related diseases to bread, hence increasing the risks of disease such as Malaria and Leishmaniasis. This will in turn see the increase in cases of anaemia, fever, dysentery and pneumonia, all potentially fatal if left untreated. Mitigating measure have been planned for the reservoir region, which are supposed deal with this problem, though judging by past experience with previous GAP dams, these measures will not protect the local communities from these waterborne diseases63. According to government claims, the reservoir will benefit from a change in ecosystem where by organisms adapted to such limnic environments will immigrate to the reservoir area. This is fine in theory but the region is dry and does not have many lakes, so where are these organisms going to immigrate from in order to adopt such environments? Like so many promises set by the GAP authorities, more questions arise challenging those promises and hence challenging the sustainability of the project as a whole.

As we can see by the negative environmental impacts forecast for the Ilisu Dam, the impacts accumulate especially in terms of secondary and tertiary stage impacts that derive from the primary impacts. This can be seen as 'snowballing effect' that the dam has on the environment, where by most of the impacts are derived from primary impacts not initially deemed as a problem. Since these impacts are indirect, they build and accumulate alongside the primary impacts, often becoming amplified through the poor socio-economic situation that the indigenous populations are faced with prior to the development of the dam.

The failure of looking beyond the primary and classical impacts and establishing links between these and the indirect impacts will give the GAP authorities even more cause for concern, after the completion of the dam.

Of the impacts that are associated with hydroelectric dams, many are a result of the primary environmental impacts such as the formation of the dam reservoir. Primary impacts such as these will cause social and economic impacts to arise, such as population displacement of the communities that are in the way of the reservoir. I find that the social impacts that arise from primary impacts and hence could be considered as indirect impacts are of the most damaging, especially in the context of the Ilisu Dam. One only has to look at the chequered history of the Turkish government's relations with the Kurdish minority and see the extent to which the Government has attempted to 'integrate' this minority into Turkish mainstream society.

One of the apparent objectives of the GAP was to bring the much-needed development to the region but judging by the GAP's history of ignoring impacts affecting the local populations, it just seams to be an extension and change of strategy of the civil war. Over the past 25 years, several dams have been built, despite the reoccurring social impacts that each dam has had on the local communities, no significant or effective mitigation strategies have been adopted to cope with these adverse impacts. Many of the negative socio-economic impacts that have effected the Kurds since the first GAP were built have gone largely ignored by the Turkish Government as little effort has been done over time to mitigate those impacts resulting in their reoccurrence with each dam built.

The most obvious and significant impact that will arise from the Ilisu Dam has got be population displacement. Like all the previous GAP developments over the past 25 years or so, this is definitely the most notable impact. The displacement of the local communities mostly made up of ethnic Kurds has had various consequences for the Kurds, all depending on the nature of their displacement and the various compensation choices given to them by the government.

The displacement itself can be a traumatic and unpleasant experience, and therefore it is the government's obligation to fairly deal with those affected. In theory, the Turkish government has devised various alternative forms of resettlement or

63 http://www.rivernet.org/turquie/ilisu.htm

compensation. In reality, like many laws amended for the benefit of the Kurds in recent years, their fairness and their appropriate implementation have not followed suite.

The Rivernet website which is run by the European Rivers Network agency has documented many of the problems that the Kurds are faced with in relation to the Ilisu Dam. Travel reports have been submitted to the Rivernet64, describing the situation in the area. Despite the end of the conflict between the Kurdish separatist fighters and the Turkish security forces, people have either been directly prevented by military personnel in investigating sights for environmental impacts of the dam and reservoir or been advised of the dangers by the local Kurds they happen to be interviewing. Furthermore, there have been several credible reports of intimidation of journalists from various press organisations during visits to the host area of the dam. The BBC World Affairs correspondent David Shukman visited the Ilisu sight in 2000. Whilst interviewing locals in Hasankeyf about their concerns, Shukman was repeatedly monitored by plain clothed security officials and constantly asked to cease filming65. Shukman also went on to report that many would let their opinions be heard in private but not in public. Mathew Chapman, also working for the BBC experienced similar harassment from security officials who would forcibly demand what was being said during interviews with locals66. Another reporter, this time Anne Treneman, reporting for the Times, was followed by 41 different men and a tank in the small space of 24 hours, despite carrying official documentation to prove her free access to the area67.

Of the communities displaced, the Turkish government offers two resettlement options. The first option involves monetary compensation for the assets lost through the flooding otherwise seen as 'self-resettlement'. The second option involved the application for government assisted resettlement which involves receiving new housing in pre designated area and assistance in restoring pre-displacement income. In addition to this, the Turkish Government will offer loans to the displaced people, with a pay back scheme lasting 25 years. The problem with these Resettlement laws is that they were passed in the 1930's and since then have been minimally amended since then. Also, most

64 http://www.rivernet.org/turquie/reisb_e.htm ; p5

65 Shukman, 2000; http://news.bbc.co.uk/1/hi/world/europe/614235.stm

66 http://www.heureka.clara.net/sunrise/ilisu.htm; p.2

67 http://www.ilisu.org.uk/social.html,;

of the affected people live in scattered rural communities and do not have any legal ownership of the land.68 As shown in the section on the 'Kurdish Question', Turkey is still in urgent need of landownership reforms in order to fairly distribute the land amongst the rural communities, especially in this region of the country. This has to be effectuated before the displacement of the communities so that compensation and resettlement procedures can be justifiably effectuated. The way the situation stands today, of the many people that will be affected by the reservoir of the Ilisu Dam, only a minority will get compensation for land lost to the reservoir. These people in question will be the 'landlords' and tribal leaders of the Kurd population. These people were awarded land during the Ottoman Empire so that they're support could be counted on during times of conflict. These land rights have been passed down through the generations, leaving the land unequally distributed. Most of the large farming areas are owned by 8% of the rural population, owning approximately half of all the farming land. A further 80% of the rural population own 5 hectares or less, where by most of such land is owned by the landlord who rents the land to the farmers. As a result of this huge imbalance in the legal tenure of the farming land, only a minority of the Kurdish population affected by the Ilisu Dam and reservoir will benefit from state lead compensation and resettlement schemes, where by the majority will be left with nothing.

The Resettlement laws will in effect benefit the minority of tribal landlords that are living comfortably where by those who are in need of the financial compensation in order to resettle elsewhere will be entitled to nothing. Of those to be resettled, those with landownership will be relocated in rural areas with land to compensate for land they have lost to the reservoir. Of those without legal tenure of land, they are most likely to be resettled in the urban areas of the region in one of the three large cities located down stream of the dam. One of these cities, Diyarbakir, is already thoroughly been accustomed to Kurds migrating from the rural areas into its city limits ever since the start of the civil war in the mid 1980's. In fact its population of over 1 million has doubled since 1995.69 The equal need to update its infrastructure to cope with its rising population has not materialised and as a consequence issues such as pollution levels and

68 Landownership amongst the Kurds, see ch. 6, section 2 on the Kurdish Question.
69 Figures given in http://www.rivernet.org/turquie/reisb_e.htm

employment opportunities remain extremely grim. The city has plans of improving its waste treatment facilities, which are currently non-existent. The other two cities in the region, Battman and Siirt, have no plans to introduce waste treatment, which pretty much makes the waste treatment initiatives of Diyarbakir futile as they will have insignificant effect on the predicted increasing pollution levels in the Tigris.

Another issue that is a concern is the future outlook for the displaced rural Kurds once they have been moved to an urban environment. The contrasting change of requirements and lifestyles is going to be a big issue to deal with. The displaced communities will be faced with a different social and economical situation than they were previously accustomed to in the country. Whole communities and villages will be separated for the first times in generations as it is quite impossible for the authorities to move whole communities into the same parts of a city. Most of those displaced will have been accustomed to working in farming environments and will not possess the required skills for obtaining employment in an urban environment. The fact that there is a large proportion that possesses the required literacy skills is a 'disability' that will confine them to a very limited portion of the employment sector. Of the jobs available to these people, the crucial necessity to support a family with the incomes offered by these low-skill jobs will be unfulfilled. As far as those who possess the required literacy skills, the employment opportunities will still remain slim due to the overpopulated cities such as Diyarbakir, which is already struggling to provide its population with a capacity to provide its citizens with the necessary means of employment. In summary of this situation, the majority of the displaced Kurds will become part of a developed city environment that they will be unaccustomed to, in turn alienating them from the mainstream of society. This in turn is the opposite to what the Government of Turkey has been attempting for decades, the notable integration of the Kurds into mainstream society. Since there has been no resettlement plan devised to see these changes through, it is hard to see how the Kurds will manage the transition into their newly acquired environments without experiencing the backlash to this transition.

Only very recently has the Government of Turkey assigned a firm to work on a resettlement plan for the Kurds. This initiative was taken after years of international pressure calling for a suitable resettlement plan for the displaced communities. Semor,

the firm that has been assigned the job will have a great deal of problems dealing with the resettled communities. It has no previous experience with resettlement issues with its main business interests lying in the tourism industry and seminar organisation. In addition to this, the successful resettlement and compensation of the affected communities will reacquire specific socio-economic information on the region. This information does not exist, as the government has never compiled the data needed for such information. The fieldwork needed for this information will take years to complete, something the developers of the dam will find unlikely to accept. In light of these measures taken by the government, they appear to be more than a gesture and do not constitute measures that will improve the problem of resettling or compensating the affected communities.

In the guidelines set out by the World Commission on Dams, it states clearly that resettlement plans for displaced stakeholders should be drawn up, "which reflect international accepted practice and includes international monitoring." In many cases with large dams in the developing regions of the world, which incidentally is where almost all large dams today are being built; such international guidelines are often ignored and in many of these cases, the locals who are directly affected by them are at the bottom of the power ladder, i.e., have no equal opportunity to express their needs. This is almost always the case; where by there is a lack in general equality or were the social hierarchy does not enable this. This directly applied to the situation that the Kurdish minority is faced with in light of the Ilisu Dam. The required social and economic conditions do not exist, where by there is an urgent need of restructuring of the laws which would see more equal opportunities for Kurdish communities.

As we can see from this section on the impacts of the Ilisu Dam, there is much controversy surrounding the potential impacts on political, social, environmental, economic and archaeological contexts.

According to Berne Declaration, drawn up in November 1998, the Ilisu Dam violates five policy guidelines of the World Bank on 18 instances. The guidelines set up by the World Bank have been considered around the world as internationally recognised benchmarks for the funding and implementation of infrastructure and development projects. It is mainly due to these violations that the World Bank has refused to be involved in the Ilisu Dam project. The violations that have been cited contradict the following guidelines (operational directives) of the World Bank: OD 4.00 (Annex A, Environmental Assessment, and Annex B, Environmental Policy for Dam and Reservoir Projects) where by the results given by the Environmental Impact Assessment done on the Ilisu sight have not yet been made available to the public, despite repeated promises by the Turkish Government to do so; OD 4.30 (Involuntary Resettlement) where by the indigenous communities in the host location have been told to resettle after the plans of the dam had been made public. In this case, no form of public participation was used as local communities were never included in the planning phases of the dam; OP 7.50 (Projects on International Waterways) where by the initial development of the Ilisu Dam as well as many of the other GAP projects along the Tigris and Euphrates rivers were done without the consulting the Iraqi and Syrian authorities goes against international treaties; OPN 11.03 (Management of Cultural Property), where by the actual disregard for important archaeological artefacts that are concerned with the Kurdish heritage and culture are deemed expendable; and BP 17.50 (Disclosure of Operational Information). The disclosure of the GAP plans to the local communities and even the local government have never been properly initiated. According to some surveys that have carried out in the region[70], the GAP authorities planning never involved the population of the southeast. According to opinion poles conducted in 1998, a whole decade after the plans for the Ilisu dam were inaugurated, only 42 percent of the local population were aware of what the GAP was. According to the Berne Declaration, the local authorities of the Ilisu Dam region were only officially informed about the project in December 1999[71], a whole year after the secretive EIA was conducted. Furthermore, no public consultation regarding resettlement plans or foreseeable environmental impacts have taken place.

Through this last section on the impacts of the Ilisu dam, the most important and significant impacts related to the indigenous Kurds affected by the dam have been highlighted. Of course there is such a wide range of negative impacts associated with the

70 McDowall, 2000; p.2

71 http://www.ilisu.org.uk/debate1.html

dam, which is why I decided to focus in mind on the most important and relative impacts that are concerned with the scope of the project.

Chapter VII: Analysis

The task of analysing the data for this project was one that required much careful thought and consideration. The wide range of impacts that were seen to affect the Kurds in the host location of the dam presented a task of having to establish links between the various environmental and socio-economic impacts on the Kurdish population, notably how the direct environmental impacts of the Ilisu Dam would affect the socio-economic impacts on the host communities in the region. The analysis would therefore call for an interdisciplinary approach in analysing the impacts, requiring the inclusion of all factors, in particular the combination of physical and social dimensions of the host location and seeing how a change in their dimensions would change the outcomes for the locally affected populations.

As far as the stated objectives of the authorities responsible for the planning of the Ilisu is concerned, the main aims for the GAP project is to develop the resources of the region in order to accelerate economic growth and social development in the region. This is from a very non-regional but nationalistic governmental perspective. The reality of the situation is that only the water resources will be developed, the main beneficiaries will be industry in the west. Accelerated economic and social development will only occur on a small and selective scale. Those who will stand to benefit from the dam are those who did not need it in the first place. These are the large-land owners who own most of the land in the region and who do not represent the needy proportion of the local population. Those who are in most need of development (the indigenous Kurds) will stand to loose what they have and become increasingly marginalised from mainstream society in Turkey.

As far as ‘alleviating disparity between regions and other regions by increasing production and welfare’[72] is concerned, this only seems to be benefiting the large-land owners who were seeing significant levels of agricultural production in commercial terms prior to the implementation of the dam development schemes and whose welfare was not of the same undeveloped status as that of the majority of the local indigenous population. In fact this objective is in fact contradictory to what the real situation on the ground is,

72 Objectives of the GAP; http://www.mfa.tr/grupd/dc/dcd/gap1.htm

where by the disparities will increase with the implementation of the dam and that the welfare of the majority of the local population will decrease significantly.

Another objective given by the GAP authorities is that rural areas will experience a reorganisation of economic and physical infrastructures and that ‘urban growth will be achieved in the desired directions’[73]. Now in the case of the reorganisation of the rural areas this will be the case, where by Kurds will be pushed out of the regions and that urban growth will be achieved only in terms of overpopulation and that those urban infrastructural capacities will be overloaded. Is this the ‘desired direction’ of the Turkish government in terms what to do to the Kurdish population? If we are to go by the manor in which the government has systematically discriminated against the Kurdish minority since its existence as a republic since 1923, this would definitely be an objective it is managing to fulfil.

Lastly, the final objective of the GAP authorities is to 'contribute to the national objectives of sustained economic growth and export promotion by efficient utilisation of the region's resources'. This is very true in terms of sustaining economic growth, only that this growth will be sustained in the western, industrialised regions of the country. Also the utilisation of the region's resources will be done effectively rather than efficiently albeit at the expense of the majority of the local indigenous population.

Altogether, the stated objectives of the GAP authorities do not give any mention whatsoever of sustainable development in regards to the goals of the GAP programme or in regard to the local communities. There is only mention in regard to objectives of national interest in providing economic development through the GAP. Those who will benefit from this perception of development will be the industrial sector that is mostly situated in other regions of the country. This signifies a development in national interests of economic gain through the exploitation of the region and not the local development of economic and social interests.

Ilisu is an expensive project, even in terms of hydroelectric dams. The financial situation of Turkey is already in dire straights and is having to rely heavily on foreign aid packages. It seems to make more sense investing in more cost-effective and diverse renewable energy technologies due to the fact that many export credit agencies are

73 Objective as stated by GAP authorities; http://www.mfa.tr/grupd/dc/dcd/gap1.htm

turning in that direction. If we take a look at the state of the consortium that was leading the Ilisu from the start, many have abandoned the project citing a change in direction concerning their investment in renewable technologies. Only two years after the consortium for Ilisu was established, almost all foreign contractors had pulled out of the project, except for the main contractor for the job, Sulzer Hydro. The official reasons cited were a change of company interests into other renewable technologies that were seen to be more potentially profitable than hydropower. It is not known for sure if these were the real reasons due to the fact that the EIA study done on the host site had never been released to the public. As long as this EIA remains unpublished, one has to question the motives of the contractors withdrawing from the project.

An important issue worth mentioning is the inefficiency of the current electricity transmission systems. Transmission systems in Turkey need to be brought up to date. The current system is known to be highly inefficient. Many consultants abroad have stressed that the transmission system could be modernised and hence significant power could be saved through such modernisation. This has been echoed by the IEA, in its review of Turkey's Energy Policy. These reforms would come at a much cheaper cost than the construction of the Ilisu Dam and therefore would have noticeable results in the improvements of supply meeting the demand. In addition to this, supplementary renewable resources such as wind and solar energy that could effectively combine with the hydroelectric dams in the southeastern region of the country have not been significantly considered. The terrain and weather conditions could make the implementation of such technologies are real possibility. Also, adopting a wind generation scheme such as ones in Denmark, where by households receive loans to set up a wind turbine to generate electricity for private use in addition to coupling their generator up with the national grid could be real incentive for development in the region. This dual use of the technology would benefit the repayment of the loan used to acquire the technology as well as adding to the national grid.

No supply-side alternatives or demand-side alternatives were considered during the original feasibility studies that were conducted during the early 1970's. A very realistic alternative to the Ilisu Dam would be one proposed by the Swiss Government that would provide Turkey with a far more cost-effective solution than the Ilisu. This

would be the proposed Ankara Power Project[74], which in comparison with the Ilisu Dam would serve as a far more efficient technology than the dam. The initial proposed sight of the dam would also be more beneficial to the majority of the beneficiaries of the increased demand for energy in Turkey, industry. As most of the industry in Turkey is situated in the western regions of the country, it would make more sense to have such a power plant located closer to the industry. Below I have made a table to illustrate the differences in cost and capacities between the two schemes so that one can really see the potential financial burdens of the Ilisu project.

	The Ilisu Dam	Ankara Gas-Powered Project
Capacity:	1200 MW	720 MW
Cost:	$1,520 million US	$276 million US
Cost/MW:	$1.27 million/MW	$0.38 million/MW

[75]

As we can see from table of figures above, the Ilisu Dam is considerably more expensive than the proposed gas powered project and far less cost effective. With the known transmission problems that Turkey has, it would make more sense financially and geographically to invest in the gas powered project instead of the Ilisu project.

The situation regarding public participation in the region is a problem that needs to be urgently resolved. The scars from the civil war that have ravaged the region from the mid eighties to the late nineties are still present, both in the infrastructure of the region, whereby villages and communities still remain largely abandoned, and also due to the psychological impacts of the civil war where by people remain weary in trusting the local authorities. In the case of consulting with the local communities about the possible development possibilities of the region, there is little hope of achieving anything positive. As individual reports by various British media coverage have pointed out, the trust in government officials is at an all time low due to their treatment over since Turkey became a republic in 1923. Even since the official end to the civil war no attempts have been made in improving dialogue with the Kurds of the region. As seen many times

74 Proposals for the Ankara Power Project; http://www.ilisu.org.uk/altern.html

75 Source of figures for proposed projects; http://www.ilisu.org.uk/altern.html

before, it has been a one-way dialogue process where by conditions have been dictated by the Turkish government and the Kurds have had not choice but to comply to those conditions set by the Government. This goes against international guidelines and directives that were set up by the WCD where by full participation of all stakeholders during the planning phases of the project need to be accomplished with an open dialogue of consultation with the local population needs to be affected. These need to be undertaken so that the interests and needs of all stakeholders can be taken into consideration, as well as the locally perceived development priorities, as it is them that the project supposedly is meant to serve.

The most significant impact experienced by the host communities of the dam has to be population displacement. Despite official claims by the Government that compensation procedures will be put into effect, the majority of the affected communities do not fit into the criteria for compensation measures due to their legal tenure of the land. Specific land reforms that have been promised by the Government have not been implemented and thus resettlement and compensation schemes will not apply to the majority. As a result, being moved into urban areas of the region will marginalise most of the affected population. There is only evidence of the downgrading of their standard of living, as seen in the sections concerning the socio-economic impacts of the dam and the Kurdish Question. With the ever increasing population of Diyarbakir, increasing from half a million inhabitants in 1990 to one and a half million inhabitants in 1995 mainly due to the civil war, the obvious need for alternative resettlement measures would seem quite clear. Despite this, Government initiatives are still aiming to resettle the majority of the landless population within the cities of the region such as Diyarbakir. How this will seem sustainable for the majority of the Kurds displaced is obviously questionable.

As stated in the previous chapter, the resettling of the indigenous Kurds into the cities will have more negative impacts as the new environment will not fit their social and economical status of being formerly tied to rural lifestyles of subsidence farming. Furthermore, the transition from a rural environment very much isolated from mainstream society to an urban setting of more advanced levels of development will in effect require some form of transitional programme set up by Semor, the company that has been charged with dealing with the resettling and compensation of the displaced

population. But as stated before, no official programme has been devised up to date and without the proper socio-economic data on the local population, it will be hard to see how Semor will effectuate the necessary measures to accomplish its given task.

Clearly the Turkish government is not looking ahead at long-term impacts of the socio-economic considerations that it is making for the displaced Kurds, as its given short term solution of confining them to urban slums can not seriously be seen as sensible solution. Furthermore, by glancing at the history of Turkeys regard towards the Kurd minority, it is highly unlikely that the Government's stance on the matter will change anywhere in the near future.

Issues associated with decommissioning of dams, such as the real possibilities of decommissioning large scale dams has caused the questioning of the sustainability of hydropower significantly. Decommissioning of hydropower is problematic and could be associated with the problems of decommissioning of nuclear power. Since the actual nature of developing large-scale hydroelectric dams involves the almost reversible action of altering landscapes and their respective ecosystems, it can be considered that there is almost no turning back once the dams and respective reservoirs have been filled. Comparing this to the decommissioning of a gas power plant, the immense need for funds to effectuate such transformations puts a huge question mark over the benefits of hydro technology.

Chapter VIII: Conclusions and Discussion:

The solution to the dilemma that the indigenous Kurds are faced with is something that will take a long time to resolve. For the community of Kurds that are directly affected by the impacts of the Ilisu Dam, this would just appear to be the latest initiative by the Turkish Government to inflict its will upon their community. After having endured a bitter and lengthy civil war against the Turkish security forces, the sight of the government officials determined to evict Kurds from their longstanding homeland would most probably not surprise them as such as they have become accustomed almost since the inauguration of the Turkish republic state in 1923 to the continual repression that has been inflicted upon their communities.

Since the initial plans of the GAP project were put forward 50 years ago, the inclusion of the indigenous Kurds into the planning process of the GAP project is something that has not figured in the plans of the Turkish authorities. The initial scope of the GAP project has changed very little over the years, where by nothing seems to suggest that things will change soon.

After having sifted through the data collected for this project, it appears to be the case that the negative impacts that are likely to affect the host population, heavily outweigh any likely benefits that the dam will bring to them. It is vitally important to realize that the last assertion applies to the majority of the indigenous population who represent the landless portion of the community. The fortunate minority that fall within the bracket of people who stand to benefit from the resettlement and compensational schemes offered by the government will still be affected by the unconditional impacts of the dam such the environmental impacts.

Even in the event of policies being altered so that the majority were to benefit from compensation measures, the backlog of those waiting to be compensated from previous GAP dams would be enormous and hence the delay in receiving compensation would be considerable

As far as the estimates for displacement are concerned, there seems to be a conflict between the estimates given by the various reports given by NGO's, as well as one commissioned by the British Government, and the official estimates given by the Turkish government sources. The dam and reservoir will displace the former estimate between 24 and 36 thousand, where by estimates given by the Turkish government source estimates between 12 and 15 thousand people. Despite the fact that no accurate information is available on the region, these estimates seem to reflect the trend of most of the statements given by the two various sources. Each time NGO's bring out statements that voice the concern of Kurdish interests, the Turkish authorities always seem deny or at least refuse to comment on the issues. It just seems to be the case where there is constant refusal on the part of the Turkish authorities to acknowledge any mention of concern that the Kurds might have in relation to the dam

Despite some of the variable estimates obtained for the project, it is still obvious that the main impact that is likely to affect the Kurds is involuntary displacement. The problem with this is not so much the actual displacement, but more the consequences of the displacement. Seeing as most of those who will be displaced will most probably end up in cites of the region, the problems associated with this transition will depend on their ability to cope with the transition from the rural environment to the urban environment. In any case transitional measures would need to be taken into the account by the authorities to aid the displaced communities in adapting to the significant changes.

As far as solutions are concerned, 2 paths could be taken to solve the Ilisu issue. One solution would be to deal with the main socio-economic impact of displacement and its consequential problem of urban migration. A solution that could alleviate the problem of the urban migration would be to amend the resettlement and compensation procedures for those displaced by the dam. In particular this would concern the landless Kurds who would have no choice but to move the cities. In doing so, their welfare would decrease as they have no option but to move into the slums that are already swollen due to the emigrational flux stemming from the civil war. The city of Diyakbakir is already struggling with its tripling of its population over the past years which will have no doubt put considerable strain on its infrastructural capacity. Furthermore, the most indigenous would be the most likely to move to the city and have problems adapting to the transition, as discussed in the case study chapter, due to their limits as they are used to traditional and subsistent lifestyles.

The only way to successfully mitigate their displacement would be to bring on the much-needed land reforms that have been promised for the past 30 years or so. In doing

this they would have legal tenure to land otherwise held by landlords (see 'Kurdish Question' section) and hence be entitled to resettlement in other rural parts of the region. Furthermore, such measures would relieve the authorities of long-term socio-economic challenges that they would be faced with in dealing with the consequences of the influx of rural migrants stemming from the Ilisu area. The introduction of such measures would also prove to NGO's, groups critical of Turkey's treatment of the Kurds and more importantly export credit agencies that they are capable of responding to the socio-economic impacts of the dams with adequate mitigation (entitling GAP to much needed foreign financial that has been withheld from them until now). In addition, it would make the Ilisu more sustainable in terms of development for the local population.

The second and more rational solution to the problem would be to consider alternatives to the Ilisu dam. A discussed in the project alternative power generating options such the gas-powered projects in the region of the capital combined with improvements in the efficiency of energy use and transmission would be a cost effective option alternative to the Ilisu dam. It is important to note that the estimate cost of the Ilisu dam is just for the dam itself and does not include the consequential cost of resettling and compensational costs the authorities are going to have provide in the long-term; both financially and socio-economically. Also, the government wishes to stimulate much needed development in the southeast; displacement of the indigenous communities into the overcrowded cities such as Diyakbakir would cause a reversal of development, thus increasing the disparity between the region and rest of Turkey. Alternatives to the gas-powered projects such as complimenting already existing hydropower structures in the region with wind and solar farms would also be a cost-effective solution and be seen as beneficial in conserving the region's unique identity. It may also serve as an incentive to focus more on such renewable resources. In doing so providing an example for future supply-side options in meeting Turkey's increasing energy needs and thus providing sustainable development in meeting those needs. Turkeys developed neighbouring countries such as Greece and Israel have invested significantly in wind and solar technologies, so it comes as surprise that this has not been equally considered.

Issues associated with decommissioning of dams, such as the real possibilities of decommissioning large scale dams has caused the questioning of the sustainability of

hydropower significantly. Decommissioning of hydropower is problematic and could be associated with the problems of decommissioning nuclear power. The reason for this association would be due to the equal difficulties and considerable costs in decommissioning these two types of facilities when they have become obsolete.

Since the actual nature of developing large-scale hydroelectric dams involves the almost irreversible action of altering landscapes and their respective ecosystems, it can be considered that there is almost no turning back once the dams and respective reservoirs have been filled. Comparing this to the decommissioning of a gas power plant, the immense need for funds to effectuate such transformations becomes apparent and thus puts a huge question mark over the benefits of hydro technology. The use of more manageable renewable resources such as wind, solar and photovoltaic technologies can be easily decommissioned in comparison with hydropower, so in the absolute need for using hydropower if these technologies were not adequate in meeting energy demands, turning to hydropower would be a last resort option.

In light of the concept of sustainable development applied to this project, where by the 'ability to apply sustainable development by ensuring the upholding of the needs of the present indigenous Kurdish community without compromising the ability of future generations to meet their own needs', the Turkish government needs consider serious re-evaluation of the Ilisu project and of its alternatives if it wants to achieve regional development. The window of opportunity to do so is still open however unless action is taken soon, the chances of amending the potential impacts may be lost indefinitely.

List of Abbreviations:

- AD Anno Domini
- BC Before Christ
- BENELUX Belgium, Netherlands and Luxembourg
- CIA Central Intelligence Agency
- DPT The State Planning Organisation
- EIA Environmental Impact Assessment
- EIEI Electrical Power Resources Survey and Development Administration
- EU European Union
- GAP South-eastern Anatolia Project
- GDP Gross Domestic Product
- HADEP People's Democracy Party
- IEA International Energy Agency
- IHA International Hydropower Association
- KADEK Kurdistan Freedom and Democracy Congress
- MEN The Ministry of Energy and Natural Resources
- NECC National Energy Conservation Centre
- NGO Non Governmental Organisation
- OECD Organization for Economic Cooperation and Development
- PKK Kurdistan Workers Party
- TEAS Directorate-General of Turkish Electricity Generation and Transmission
- TPES Total Primary Energy Supply
- UK United Kingdom
- US United States
- WCD World Commission on Dams
- WCED World Commission on Environment and Development

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Ethiopia's Hydroelectric Program

http://oilprice.com/Alternative-Energy/Hydroelectric/Ethiopias-Hydroelectric-Program-Boon-Or-Folly.html December 07, 2014

Ethiopia's plans for two massive hydroelectric dams could have a major environmental impact. Downstream neighbors such as Egypt and Kenya

Developing countries worldwide view the construction of power facilities as integral to their economic development to lift their populations out of poverty. Ethiopia has now embarked on massive hydroelectric schemes currently involving the construction of two large dams, but the Ethiopian government's obdurate refusal to consider the potential environmental and political impacts of its efforts to become the "energy hub" of East Africa have generated rising concerns not only in Ethiopia but neighboring nations depending on the country's water flows.

Two projects have elicited local, regional and international concerns. The first is the 1,870 megawatt $2.2 billion Gilgel Gibe III dam on the Omo River, which threatens the unique ecology of Lake Turkana on the Kenyan-Ethiopian border, a UNESCO World Heritage Site.

The second is the projected 5,000 megawatt $5 billion Grand Ethiopian Renaissance Dam, formerly known as the Millennium Dam, on the Blue Nile, which the Ethiopian government is pressing forward despite rising concern in downstream states Sudan and Egypt about the potential impact of the facilities on the lower Nile's water flows.

In its rush to construction, in 2009 Addis Ababa issued an environmental impact assessment (EIA) statement for Gilgel Gibe III on the long-term consequences of the dams' construction, but only two years after construction began. The resultant report was regarded as so flawed that the World Bank, European Investment Bank, and the African Development Bank abandoned the project.

Ethiopia more recently has not even bothered to issue an EIA evaluation report for the proposed Grand Ethiopian Renaissance Dam, despite the fact that such evaluations are critical for assessing the potential impact of the hydroelectric cascades and remain an essential element in securing international funding.

Italy's Salini Costruttori was awarded no-bid contracts to build both the Gilgel Gibe III and the Grand Ethiopian Renaissance Dam and a Chinese state-owned bank has approved funding for Gilgel Gibe III despite the project being dogged by controversy from the outset. A 2009 independent feasibility study submitted to the African Development Bank questioned the structural stability of the dam, saying that the risk of a catastrophic failure was "not insignificant."

Last July the UN's World Heritage Committee said that the Gilgel Gibe III dam, Ethiopia's largest investment project, would endanger the existence of Lake Turkana, which receives up to 90 percent of its water from the Omo River, by lowering its water level by up to sixty feet, affecting more than 300,000 people downstream from the facility as well as increasing salinity and wreaking havoc on the lake's unique flora and fauna. In 1997 the Omo River basin and Lake Turkana received UNESCO World Heritage Site listings. The UN's Committee on the Elimination of Racial Discrimination has also urged Ethiopia to suspend the project, fearing its impact on local communities. Experts fear that the the Gilgel Gibe III dam could suffer 50-75 percent leakage of waters from its reservoir due to multiple fractures in the basalt rock at the planned reservoir site and note that the area is also seismically active. Nevertheless, the project is moving forward.

Ethiopian Prime Minister Meles Zenawi is brazening out public criticism, promising to complete Gilgel Gibe III the facility "at any cost," complaining that his critics "don't want to see developed Africa; they want us to remain undeveloped and backward to serve their tourists as a museum." Upping the ante, three months ago Ethiopia announced that it would build four additional dams on the Blue Nile that will work in conjunction with the Gilgel Gibe III and Grand Ethiopian Renaissance Dam to generate more than 15,000 megawatts of electricity and last month Ethiopia's Ministry of Water and Energy announced that Gilgel Gibe III facility is now 46 percent complete.

If Gilgel Gibe III threatens the Omo River and Lake Turkana and Ethiopian and Kenyan water flows, it is the $5 billion Grand Ethiopian Renaissance Dam, whose cornerstone was laid last March, that could unsettle Ethiopia's relations with its downstream neighbors down to the Mediterranean, Egypt most of all.

Egypt relies on the Nile for most of its water supply and Ethiopia's Lake Tana is the source of the Blue Nile, which contributes 86 percent of the water arriving at Egypt's Aswan High Dam. The White Nile's main source is Lake Victoria, whose shoreline is shared by Uganda, Tanzania and Kenya and which joins the Blue Nile south of Khartoum.

Nile water access issues are rooted in history, as 82 years ago Britain as East Africa's dominant colonial power effectively handed Egypt the lion's share of Nilotic waters in a 1929 accord. Under terms of the agreement Egypt had and currently maintains its historic right to three-quarters of the Nile's water, 55.5 billion cubic meters that it annually diverts of the Nile's total flow of roughly 84 billion cubic meters. Under the 1929 agreement Sudan, before South Sudan became independent in July, was apportioned a further 11 percent of the Nile's waters, leaving the other littoral states to share the remainder. Under terms of the accord Egypt has persistently vetoed neighboring countries' rights to build dams or irrigation projects upstream which might affect the river's flow.

In 1959, when Egypt and Sudan were independent but all Nile upstream states except Ethiopia were still colonies, Egypt and Sudan signed a bilateral convention that essentially reaffirmed the 1929 accord and left only 10 percent of the Nile's water to the seven upstream countries, arguing that upstream nations had significant rainfall, unlike Egypt or Sudan. Instability, poor governance, lack of finances and the availability of other water sources left the issue largely dormant until the 1990s, when Nilotic governments seriously started to consider using their Nile Basin waters to generate energy and irrigate crops.

In the 1999 Nile Basin Initiative (NBI) emerged as a basin-wide program between Egypt, Sudan, Ethiopia, Uganda, Kenya, Tanzania, Burundi, Rwanda and the Democratic Republic of Congo to modify the terms of the 1929 agreement, but it has thus far failed to achieve any significant progress.

Given the lack of NBI progress, on 14 May 2010 Ethiopia, Tanzania, Uganda, and Rwanda signed a new water-sharing proposal, the "River Nile Basin Cooperative Framework," also known as the Entebbe Agreement, which both Egypt and Sudan rejected. Until recently Cairo continued to demand a veto power over any projects implemented upstream in southern Nile nations and pushed international donors such as the World Bank, NBI's main fiscal backer, to cut funding to the renegade Entebbe Agreement signatories.

As an indication of how seriously the Egyptian government took the Entebbe Agreement, the same month that it was signed responsibility for the Nile basin dispute was removed from Egypt's Water and Foreign Affairs Ministries and given to Egypt's intelligence and security chief Omar Suleiman, who in February handed over power to the military after Mubarak resigned. Scrambling to utilize its Nilotic waters more efficiently, Egypt has succeeded over the last several decades in increasing its arable land by 25 percent only through extensive and expensive canal systems and increasing use of expensive imported fertilizers, which any diminution of flow would threaten.

As for Egyptian concerns about the Grand Ethiopian Renaissance Dam diverting downstream flows, they are well aware of such issues, as it took 12 years beginning in 1964 to fill the Aswan High Dam's Lake Nasser reservoir with 11 cubic kilometers of waters, which now drive 12 turbines generating 2,100 megawatts, less than half the power output of the proposed Grand Ethiopian Renaissance Dam.

Far from addressing Egyptian environmental concerns, the Ethiopian government has not even bothered to issue an EIA for the Grand Ethiopian Renaissance Dam, which some hydrological specialists predict that in filling its reservoir will cause a 25 percent annual reduction in river flow to Egypt, as the Grand Ethiopian Renaissance Dam reservoir's volume would be about equivalent to the annual flow of the Nile at the Sudanese-Egyptian border, roughly 65.5 billion cubic meters.

The "Arab Spring" that overthrew the regime of Egyptian President Hosni Mubarak in February has resulted in Egypt's interim government showing new signs of flexibility on Nile water issues. Last month Egyptian Interim Prime Minister Essam Sharaf met with Zenawi in Cairo and agreed to set up a technical team to study the impact of the Grand Ethiopian Renaissance Dam while Zernawi, on an obvious charm offensive to secure international financial backing, agreed to host Egyptian and Sudanese officials to prove that the Grand Ethiopian Renaissance Dam will not be used to irrigate any of the large corporate farms the Ethiopian government has leased to foreign investors in recent years, but instead be used solely to generate electricity, adding that his government will delay ratifying the 2010 Entebbe Agreement. Several months ago Ethiopia said it would be forced to finance the Grand Ethiopian Renaissance Dam itself and from the sale of government bonds because Egypt was pressuring donor countries and international lenders not to fund its dam projects.

And both structures are largely about electricity exports. If completed, Gilgel Gibe III alone will double Ethiopia's hydroelectric total installed capacity from its 2007 level of 814 megawatts. In April Zenawi announced that Ethiopia plans to produce as much as 8,000 megawatts of additional electricity from hydropower sources by 2016 as various projects come online.

While Ethiopia reportedly has "initial agreements" to export electricity to Sudan, Dijibouti, and Kenya, critics of the hydroelectric projects emphasize that the majority of Africans are not connected to the power grid, and that Ethiopia will be generating far more electricity than it or its neighbors can currently utilize.

The projected future environmental water stresses of the Nile basin's population make for grim reading. Washington DC's Population Reference Bureau has developed some unsettling statistics for countries along the Nile, estimating that Egypt's population of 80 million is expected to reach 122 million by 2050. During the same period Ethiopia's 83 million population will soar to 150 million and in Uganda, with one of the highest birthrates in the world, the population is expected to more than triple from its current level of 32 million to 97 million.

While East Africa's efforts to improve their standards of living with increased electricity resources, it is questionable whether a massive commitment to hydroelectric power is the only option. The surging demographics of the region combined with the potential environmental impacts of massive hydroelectric projects along the world's longest river, combined with Ethiopia's refusal to provide EIAs should give all international investors pause before underwriting such massive undertakings. The waters of the Nile are finite and will soon support a population greater than the United States, and water diversions for such projects can only increase national and regional tensions.

It is good that Egypt is now willing to talk, but even more important that Ethiopia be willing to listen. If the international community wishes to support Ethiopia's efforts to become East Africa's energy "hub," then it should request transparency about the environmental consequences of such extravagant hydrological projects and their impact not only in Ethiopia but their neighbors along the shared river basins which geography has bequeathed them.

Small Hydropower's Negative Impact on The Environment

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A belief that 'small' hydropower systems are a source of clean energy with little or no environmental problems is driving the growing interest in mini ...

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A belief that 'small' hydropower systems are a source of clean energy with little or no environmental problems is driving the growing interest in mini, micro, and pico hydro systems that generate from less than 5 kilowatts up to 10 megawatts of energy.

Hydropower appears to be the cleanest and most versatile of renewable energy sources. But experience shows that optimism about its potential can be misplaced.

Hydropower uses water and gravity (a totally carbon-free and inexhaustible resource) to drive turbines and generate electricity.

Unlike fossil-fuelled power plants, hydropower plants produce no gases or fly ash emissions (fine particles generated by burning coal). And, unlike nuclear power plants, there is no radioactive waste to contend with. Nor is any resource consumed, because water is neither lost nor polluted. Reservoirs can also enhance the scenery, attracting picnickers and tourists.

As soon as the world took note of these virtues in the 1950s, hydropower became popular. Developing countries including Brazil, China, India, Malaysia, Thailand, and Turkey built increasingly larger dams, generating anywhere from a few hundred megawatts to more than 10 gigawatts.

Egypt's High Aswan Dam has become an iconic symbol of these projects — and their environmental impacts.

Projects like these fundamentally altered river ecosystems, often fragmenting channels and changing river flows. Natural lakes take hundreds of years to evolve from oligotrophic (low in nutrients) to eutrophic (rich in nutrients) status. But man-made reservoirs underwent this transition within a few years, degrading water quality, harming fisheries, bringing siltation and invasion by weeds, and creating environments suitable for mosquitoes and other disease vectors.

And where reservoirs displaced people or suddenly changed resource availability or agricultural capacity, they brought major socio-economic problems.

It was during the mid-1970s, some 20 years after a number of major hydropower projects had been commissioned, that reports of their adverse environmental impacts began to emerge.

By the end of 1970s it had become clear that the very optimistic, almost reverential, attitude towards hydropower projects that had prevailed during the early 1950s was misplaced. These projects damaged the environment as seriously as fossil-fuelled power projects.

The mistake had been to see only the virtues, and to not prepare for possible problems, some of which surfaced only once a large number of projects had been commissioned at different locations.

The big question is: are we set to repeat the same mistake with 'small' hydro?

Nearly everyone seems to believe that small hydro is a safe substitute for large hydro. Some assert it is entirely benign; others acknowledge some problems similar to the ones associated with large hydropower, but say these are too small to be of concern.

In a report on the environmental implications of renewable energy sources, the International Energy Agency (IEA) notes: "Small-scale hydro schemes (SHS) tend to have a relatively modest and localised impact on the environment. These arise mainly from construction activities and from changes in water quality and flow on ecosystems (aquatic ecosystems and fisheries) and on water use".

After the reassuring first sentence, the IEA goes on to list a number of environmental impacts and concludes: "The impacts of small-scale hydro schemes are likely to be small and localised, providing best practice and effective site planning are used".

But the fact is, it gives no evidence whatsoever to support the conclusion that the impacts will be "small and localized".

So far, the world has not experienced any major problems from 'small' hydro simply because the world has used 'small' hydro very sparingly.

A turbine here or there may not affect the river noticeably; but if we are to use the technology extensively and put turbines in every other waterfall in a river, and make small dams on most of its tributaries or feeder streams, the environmental degradation — per kilowatt of power generated — will likely be much higher than that caused by large hydropower systems.

The factors that harm a river habitat with large hydropower projects are also at play with small projects: interrupted water flow, barriers to animal movement, water loss from evaporation and loss of biodiversity from the sacrificed portion of river are some examples.

With smaller dams, storage is an increasingly important problem that may require construction of more low-head systems (hydraulic heads that require a fall of water less than 5 metres) than anticipated. Reservoirs silting up or becoming overloaded with nutrients are common problems with major reservoirs that could be at least as serious where smaller and shallower bodies of water are created — the shallower a water-body, the more easily eutrophic it can become.

Likewise, methane generation occurs largely where water and sediment meet, and this means that a shallower water body is likely to release more methane per unit area than a deeper water body. Shallow reservoirs are not unlike paddy fields which are known to contribute substantially to methane emissions, a greenhouse gas 25 times more potent than carbon dioxide.

Disruption from building roads and power lines is less for small hydropower than for large hydropower projects in absolute terms — but on the basis of disruption per kilowatt of power generated, the impact may be at least as severe, if not more severe.

By using small hydro extensively we could be on course to repeat the environmentally damaging history of large hydropower projects. Countries considering the technology should invest in research into the potential problems, and proceed with caution.

Tasneem Abbasi is assistant professor and S. A. Abbasi is head of the Centre for Pollution Control and Environmental Engineering, Pondicherry University, India. More information about their work is available at www.prof-abbasi.com

POSITIVE AND NEGATIVE IMPACTS OF DAMS ON THE ENVIRONMENT

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POSITIVE AND NEGATIVE IMPACTS OF DAMS ON THE ENVIRONMENT M. Sait TAHMİSCİOĞLU Deputy of the Head of Department, State Hydraulic Works General Directorate,

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M. Sait TAHMİSCİOĞLU
Deputy of the Head of Department, State Hydraulic Works General Directorate,
Department of Investigation and Planning, saitt@dsi.gov.tr,
State Hydraulic Works General Directorate 06100 Yücetepe/Ankara.

Nermin ANUL
Biolog, State Hydraulic Works General Directorate, Department of Investigation
and Planning, nerminanul@dsi.gov.tr,
State Hydraulic Works General Directorate 06100 Yücetepe/Ankara.

Fatih EKMEKÇİ
Environmental Engineer, State Hydraulic Works General Directorate,
Department of Investigation and Planning, fekmekci@dsi.gov.tr,
State Hydraulic Works General Directorate 06100 Yücetepe/Ankara.

Nurcan DURMUŞ
Environmental Engineer, State Hydraulic Works General Directorate,
Department of Investigation and Planning, ndurmus@dsi.gov.tr,
State Hydraulic Works General Directorate 06100 Yücetepe/Ankara.

ABSTRACT

The human being has been struggling in order to shape the ecosphere in a manner he wants since the first day. The period in which this struggle was observed most intensively was the period covering the transition from a migrant and primitive hunter society to a resident life and farming. The most deep-seated environmental modification against the nature that had been realized in the history of the human being has started at this time. Even the development and downfall of civilizations are correlated to this interaction between the human being and nature.

Dams have one of the most important roles in utilizing water resources. They were started to construct long years before gaining present information about hydrology and hydromechanics.

Dams have a great deal of positive and negative effects on the environment besides their benefits like controlling stream regimes, consequently preventing floods, obtaining domestic and irrigation water from the stored water and generating energy. Wherever the location of a dam is, its ecological results are the same. The environmental impacts of dams can be classified according to different criterions as long term and short term impacts, the impacts on the close area and the impacts on the

regions where the dam services, social and unsocial impacts, beneficial and harmful impacts .These effects may be ordered in an intensive and complicated manner like climatic, hydraulic, bioligic, social, cultural, archaeological etc.

In addition to their very important social and environmental benefits, it is important to minimize the negative effects of dams on the environment regarding sustainable development.The mentioned effects and their solutions have taken into account in the environmental impact assesment concept.

Key Words: Dam, environment, ecology, water resources.

INTRODUCTION

Dams have one of the most important roles in utilizing water resources. They were constructed long years before gaining present information about hydrology and hydromechanics. They are not ordinary engineering buildings. Dam projects, which are useful in meeting the demand for water in desired times and in regulating stream regimes, have undertaken an important function in the development of civilization.

Dams have been constructed in order to prevent floods, to supply drinking and domestic water, to generate energy and for irrigation purposes since the old-times.

Dams have a great deal of positive and negative effects on the environment besides their benefits like controlling stream regimes, consequently preventing floods, obtaining domestic and irrigation water from the stored water and generating energy. Dams hold possibilities of considerable harm for living beings in addition to their advantages such as meeting basic requirements of the society and increasing living standarts.

Nearly 700 dams were built every ten years up to 1950s. This number grew rapidly after 1950s. While the dams were built and completed it was observed that there was something missing and detrimental. Although the effects of water on human life and the development of civilizations are well-known all over the world, it is claimed that the economical benefits expected from the projects designed to utilize water resources could not be gained and also necesarry precautions to decrease the environmental, economical and social losses were not taken. Even some studies aiming to block these water supply projects of the developing countries are carried out by some international organizations. Because of this, in the sustainable management of the water, taking into account the economical, social and cultural development and the environmental impacts which came out as a result of the mentioned studies, has gained an increasing importance.

Therefore, it is esential that these water resources development studies have a legal background to ensure sustainable development. During these water resources

planning studies, the law related to the tasks and authorities of the govermental institutions and establishments, contradicts sometimes with the law directly related with environment. These laws should not be neglected while the planning studies.

Naturally current laws always age and change depending on the improvements and technology. The point that should not be overlooked is to make the changes by relying on the scientific, technological and educational studies. The only way to minimize the contradictions between the laws is to make investigations. The investigations must be continuous. It is definitly necessary to put the blameless responsibility principle into practice.

Plants, animals and people have begun to be damaged from 1960s up today, as a result of uncontrolled extreme population increase, air, water and soil pollution caused by wastes as well as the changes in the ecosystems in parallel. Population increase, technological improvements, the expansions in cities, ways, dams and other engineering studies have disordered the natural balance and the natural body has changed drasticly as a consequence of these activities. Meanwhile environment as a subject became popular and has begun to gain imporatance day by day.

The raising interest against environment cause contradicitons between the planners, engineers and some groups in the society who are against all engineering buildings especially dams. On the other hand, it becomes unavoidable to construct the mentioned plants and buildings to enhance the prosperity of the country by realizing socio-economic and technological developments.

Nowadays living cultural, social and environmental values must be taken into consideration in the planning studies which are done based on this new understanding, as well as technical standarts and economical values. At this stage, water resources planners have to give more importance to environmental problems in their plans.

The planners should be reformist, broad-minded, sufficient in evaluating critical needs. This innovation is necessary for alternatives such as designing less water demand, encouraging solutions which are not structural in flood controll, finding better methods to process wastes and purification of waste water.

The relations between water pollution, air pollution and solid wastes must be known very well from a broad perspective. There is need to evaluate the real necessity that means the parallelism between the water supplied and the population distribution. Moreover, the importance of water projects in ecological relations and the effects of the projects on water pollution should be kown. The most important between these is the evaluation of real necessity.

Water projects and acceptable public studies will continue to provide public health and security. Some projects may exchange alternatively. Hydroelectric pro-

jects may take the place of insufficient fuel oil. Purposes like hydroelectric, irrigation, flood and recreation spots should be thouht all together. Storage pollution changes when better treatment serves more effectively.

In case of a need for a new project arise, the planner has to assess the ecological impacts in and around the stream carefully and he/she has to improve his project in a manner that it will have the least hazardous impacts.

Whereever the location of a dam is, its ecological results are the same. The environmental impacts of dams can be classified according to different criterions as long term and short term impacts, the impacts on the close area and the impacts on the regions where the dam services, social and unsocial impacts, beneficial and harmful impacts. These effects may be ordered in an intensive and complicated manner like climatic, hydraulic, bioligic, social, cultural, archaeological etc.

THE POSITIVE AND NEGATIVE IMPACTS OF DAMS ON THE ENVIRONMENT

While preparing the water resources projects, it is important to make clear what the environmental impacts of the project may be when it is executed. The environmental impacts of the dams have been written down below in numerical order. These are;

1. As a result of dam construction and holding of sediments in reservoirs, sediment feeding of downstream channel or shore beaches is prevented. Corrosions may ocur. As the transfer of sediments is avoided by this way, the egg lying zone of the fishes living in the stream ecosystem is restricted, too.
2. Archaelogical and historical places in company with geological and topographical places that are rare with their exeptional beauties, disappear after lying under the reservoir.
3. Reproduction of migrating fishes is hindered by the floods that harm the egg beds. Or the egg gravel beds can be destructed while the excavation and coating works in the stream beds.
4. Temprature of water, salt and oxygen distribution may change vertically as a consequence of reservoir formation.This may cause the generation of new living species. (International River Network, 2001; Canadian Dam Association, 2001).
5. Normal passing ways of territorial animals are hindered since the dam works as a barrier. Meantime the upstream fish movement aiming ovulation and feeding is prevented and thus fish population dicreases significantly (Stott and Smith, 2001).
6. The fishes can be damaged while passing trough the floodgates, turbines and pumps of the high bodied dams. Drainage of marshs and other water

accumulations and the excavation works causing changes in the stream bed structures affect the creatures living here negatively; even result in their death.

7. There will be serious changes in the water quality as a result of drainage water returning from irrigation that was done based on the irrigation projects. In other words, overtransfer of food and the increase in salt density can raise water lichens and may change water living species.
8. The species may change parallel to the erosion caused by the human activities or the permanent increase in the water turbidity as an outcome of the dam construction.
9. Discharge of toxic matters (pesticides, toxic metals etc.) and their condensation in food chain may affect sensitive animals immadiately; all living organisms may expire when the stream becomes unable to recover itself.
10. The water regime may change as a result of destruction of nature, unexpected floods may occur and consequently vegetation and natural structures in the riverbanks can be damaged.
11. Some increase in earthquakes may occur because of filling of big dam reservoirs.
12. Rise in evaporation loses may be expected as a result of the increase in the water surface area.
13. Microclimatic and even some regional climate changes may be observed related to the changes in air moisture percentage,air temprature, air movements in big scale and the changes in the region topography caused by the stagnant, big scaled mass of water.
14. Water-soil-nutrient relations, which come into existence downstream related to the floods occuring from time to time in a long period of time, change. Depending on this fact, compulsary changes come into existence in the agricultural habits of the people living in this region and also in the flora and fauna.
15. Dams may cause increases in water sourced ilnesses like typhus, typhoid fever, malaria and cholera.
16. Dams affect the social, cultural and economical structure of the region considerably. Especially forcing people, whose settlement areas and lands remain under water to migrate, affect their psychology negatively.

Numerous other effects can be added to this list. The most important point that must be considered here is to distinguish the temporary harms from the long term and irreversible harms clearly. It is compulsary that the groups consisting of biologs, engineers, hydrologists, social scientists and other profession groups attend the environmental impact assesment studies and that the alternatives do their duty in the estimation of environmental effects.

Dams, which contribute to the national economy from many aspects like irrigation, drinking water supply, flood control, electricity generation, fishing, tourism, are also effective in increasing the living and cultur level of the region that they were constructed. Meanwhile, the new environment created by the dam also supports the arriaval of different species to the area. Dams are not only important in economical growth, but also in overall economical and moral development.In many developed countries, dams have performed a key role in the development of the underdeveloped regions.

PRINCIPAL BASIC BENEFITS THAT WILL COME INTO EXISTANCE AFTER THE DEVELOPMENT OF WATER SOURCES

1. Flood control benefits; it decreases and remove the flood effects.
2. Land improvement benefits; are the extra benefits that will occur after an increase in the soil productivity because of drainage and land improvement pecautions.
3. Electricity energy benefits; are the energy benefit value of the more economical project out of two alternative projects.
4. Transportation benefits;are the benefits that will happen in case of there is waterway transportation in the project.
5. Providing drinking water and domestic water benefits are different from each other and should be investigated one by one.
6. Irrigation benefits; defines the distinction benefits between dry and irrigated positions.

EFFECTS OF DAMS ON HYDRAULIC SYSTEM

The main hydraulic effect is the discharge of the collection basin to a stationary reservoir instead of a stream bed. Therefore, an instant change will start downstream; downstream of a stream dries partially or totally whenever the reservoir begins to accumulate water. During this temporary or periodically repeating time interval, the hydrological balance can collapse; Irreversible death, disapearance and structural jumps are observed in the water depandent ecosystem. Decay of dead flora and fauna in the new coming water body speeds up. So, upstream water flows polluted, without oxygen in deeper parts, dark coloured for a long time and usually smells rotten because of sulphurous hyrogen disposal. Although after this process the stream forms a new and healty ecosystem in this part of it, neither this new aqua balance nor the terrestrial ecosystem and even the sea environment that the stream joins the sea have the chance to join their previous health.

Assuan Dam is a good example for this case. This dam has changed the feeding charateristics of the Eastern Mediterranean besides the Nile River ecosystem. It is possible to correlate these changes to 6 different factors listed below:

- Flow speed of the river becomes stationary in its downstream part since the water level in the stream bed does not change significantly. Therefore, energy flow characteristics modify in the living ecosystem.
- Positive variations may occur as a result of the incrasing leakage into the groundwater (It has been calculated that it will be possible to supply water for Nubian Desert from the river for domestic and agricultural purposes, with the help of the water leaking from the Lake Nasır which is over the Nil River).
- As the reservoir works like a big settlement basin, turbidity in the water flowing downstream decreases and erosion around the lake deceases slowly.
- Increases in the evaporation losses because of the enlargement in the water surface can be observed.
- The varions in the teprature regime of the water environment can be classified in two groups:
    1. Thermal variations that may end in seasonal thermal layer formations depanding on the water depth in the dams,

2. The variations that happen in the water temprature inside the reservoir related to the water depth that was able to leak trough the downstream gates and the exchange of water with constant temprature. The river will behave like a cold climate river from chemical and biological qualifications point of view, as the water will be always cold even in summer, if the gate depth lies below the thermocline of the reservoir. On the contrary, it will behave like a hot climate river if the flowing water is at surface water temperatures. Effects similar to these can continue kilometers along the downstream.

♦ Serious changes occur in the chemical qualifications of the river water similar to temprature variations. Depanding on the reservoir depth, water that is suffering from oxgen and even includes sulphurous hydrogen may take part in the deeper parts of river. When water flows downwards, very important vital changes may occur in the downstream part, related to the depth of dam Gates. The decomposition products of the organic matters accumulated in deeper parts of the river where oxgen is in limited amounts may come up to the surface accompanied by sudden gas releases. This results in a sudden addition of different chemical nutrient substances to the biosystem and be-

sides a frequently fluctuating water quality. Furthermore, it has been observed that nitrogen in the air was dissolved in extreme saturation levels in the downstream part of the falling water. By this way, water that is saturated approx. 150% to nitrogen can be fatal for fishes.

EFFECTS OF DAMS ON THE ATMOSPHERIC SYSTEM

Variations in moisture percentage, temperature and air body movements of air caused by the big stationary water body differentiate microclima related to region topography. In addition, regional scaled climatic changes can be observed. These alterations may seem not very harmful for human health, but they are notable fro many plants and animals. Their secondary effects influence human being.

EFFECTS OF DAMS ON THE EARTH'S CRUST

Eventhough it is claimed that the dam reservoirs have some seismic effects, it must be stated that this is not proven scientifically.

EFFECTS OF THE DAMS ON TERRITORIAL BIOLOGICAL SYSTEMS

Biological life of the river changes fast both in the reservoir and in downstream. The parts of the biosystem that are affected from the dam are the watered parts on the shore.

During the filling works of the dam, while the lands remain under water the land part of the region decreases. However, the water-land boundary extends. Thus, plant, animal or human being settlement areas change. Forests, agricultural areas may come under water.

As the water level differenciates periodically, some species begin to live under water from time to time, in the tide zone. This area may turn to marshy land or reedbed depanding on the soil structure.

Water-soil-nutrient relations, which were settled after floods in the downstream of the dam, change in a long period of time. Furthermore, compulsory changes occur in flora, fauna and the agricultural traditions of people in the region. This effect can extend for kilometers.

EFFECTS OF DAMS ON AQUATIC ECOSYSTEMS

At the beginning, the decomposing organisms cause an increase in the nutrient substances in water in a short period of time. Therefore, BOD (Biological Oxygen Demand) value of water rises. An anaerobic decomposition media is performed with the help of the stationary layers along the resevoir depth. This results in a dark col-

oured lake smelling badly. Afterwards, an enormous incrase in phytoplanktons feeded by the increased amount of nutrients is observed. Besides the plants covering the water surface as large green-dark coloured bodies, macroflora grow up on water surface. These events can be harmful both for the live of the lake, and also for the people fishing, taking a boat-trip and even for the dam gates and turbine propellers. Sometimes, macroflora created here acts like a source for disease vectors. Separatly, this increase in water plants cause more evaporation losses than it happens by evapotranspiration normally.

The dam is a real obstacle for the animals swimming from one end of the river to the other end. The existance of the dam means death for the fish species spending certain parts of their life in the spring or in the flood water and other parts in the crossection where the river joins sea. We know that some sea fishes come to fresh water and swim up to the spring in order to lay eggs. Later on, they return to sea with new young fishes. A dam that will be built on this way will interrupt the life cycle of these creatures and cause deaths in a mass. It has seen that by-pass flows are designed for this purpose.

EFFECTS OF DAMS ON HUMAN LIFE

Inspite of the fact that the dams are an important target for development; they are not easly acceptable for the people whose agricultural areas, houses and the environment they are living in go under water. For example, when the Volta Lake was created in Ghana in 1969, although a much better settlement area was provided for 80 000 people in another location, these people have returned as 100 000 people and have built their own houses unplanned on the lake shore. Such an unsuccessful experience caused by the social-psychology can be very dangerous for the biosystems in the region and for the reservoir itself.

There are changes in the employment and production systems starting before the construction of the dam including expropriation of the land, employment of construction workers and the transport of construction material with the machines to the site. Unqualified workers are employed from the site; however the technicians and experts come from other places. Generally settlement areas, social buildings, hospitals, schools etc. are built for the people coming from outside at the site. The more these facilities can be hold open for public usage the more the dam becomes a kind of symbol for development. The new settlements improve by this way and result in second ecological needs and changes. For example, drinking water, domestic waste water, waste water treatmant etc. Moreover, the social life becomes active, trade increases, cultural activities rise. Important alterations are observed in the transportation system. The ways lying under water and their surrounding area are

important from this point of view. The new roads that were constructed to prevent any break down in the transportation services result in additional expenses and additional environmental costs.

At the same time dams decrease the pollution effect considerably in the downstream part by lowering the pollution load coming from the source, thanks to their big storing reservoirs. In addition, they decrease the pollution load again by containing water continuously in their beds during dry periods.

Dams decrease the flood risk in the downstream, by their storing opportunity in their reservoir.

Undoubtly there are real and potantial benefits obtained from these projects. Industrial development has gained speed; irrigation channels and food production have improved as a result of the increase in electricity generation. Meanwhile, dams protect the people living downstream from floods. After comparing harms and benefits for a long period of time, a decision can be given about dams. May be the unwanted side effects of dams will be no longer in force because of the benefits in the future. But these big engineering structures should remind us that we are not able to change only a part of the ecosystem. Because whole chains are connected together in the ecosystem. Even only a link breaking out of the chain or a piece coming out of the cog will destroy the whole system. So, the environment subject should be examined in detail at the planning stage. Precautions should be taken beforehand to big hazards caused by the most little sensitive responses.

In addition to their very important social and environmental benefits, it is important to minimize the negative effects of dams on the environment regarding sustainable development.The mentioned effects and their solutions have taken into account in the environmental impact assesment concept.

In summary, the environmental changes coming out of damsa are in various amounts and in different importance degrees. It is difficult to consider the relations between these effects beforehand and determine which positive and negative effects will come up. This estimation shoud be made separately for each dam and reservoir. On the other hand, it is false to comprehend the effects totally negatively. The important point is who will do the assesments and from whose point of view. Will they be based on the fisherman, based on the industrialist or the farmer whose field will be under water? No matter who has taken the decision or whom the decision will take into centre, as long as whole environmental effects are explained totally according to their importance level.

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Environmental and Social Impacts of Hydro-Electric Dams in Chamba Di…

http://www.slideshare.net/harjjumend/environmental-and-social-impacts-of-hydroelectric-dams-in-chamba-district-of-himachal-pradesh December 07, 2014

Environmental impacts of hydroelectric power mrshansen ... We appeal for collaborationsEnvironmental and Social Impacts of Hydro-Electric Dams ...

Having 4300 large dams already constructed and many more in pipeline, India is one of world's most prolific dam-builders. Large dams in India are estimated to have submerged about 37500 km2 land......

Having 4300 large dams already constructed and many more in pipeline, India is one of world's most prolific dam-builders. Large dams in India are estimated to have submerged about 37500 km2 land area and displaced tens of millions of people. Himachal Pradesh is proceeding towards power-surplus state and there are as many as 401 projects of different magnitude in different stages of installation on 5 river basins of the state i.e. Satluj, Beas, Ravi, Chenab and Yamuna. State has identified its hydropower generation potential at 23,000 MW. The ecological devastation caused by various projects at lower altitudes of Himachal Pradesh has been alarming; while the prospect of what will happen to the fragile alpine ecosystem is frightening. These projects will change the microclimate that will result in accelerated melting of the snow and glaciers at high altitudes. Like other river basins of the state, hydro-electric power generation in Chamba district was started in 1980s, with 117 mini & micro power projects in different stages of execution at present. Having the special focus on Hul projects the present paper explores the impacts of various dams on environment and local people in Chamba district of Himachal Pradesh. About 6000 local people are being affected by Hul-I project only. The consequences to nature and wildlife will also prove disastrous. As of now, the wildlife such as deer, bear, goat, tiger and peacock do not enter the fields of farmers. Deforestation and soil erosion are even more devastating. Making the situation even more absurd is that the benefits of these power plants do not go to the community suffering the consequences. Gujjar and Gaddi tribes in the state of Himachal Pradesh have been agitating against 4.5 MW hydropower plant from diverting the entire flow of the Hul stream, on which their lives depend. These communities have for more than two decades protected and preserved the forests from which Hul stream originates. The project’s pipeline is said to destroy about 2000 of slow-growing oak trees. Livelihood and social impacts of poorly planned mini-hydel projects can be thus devastating, as exemplified in this case.

Negative Impacts of Hydroelectric Dams

http://www.civilengineeringgroup.com/negative-impacts-hydroelectric-dams.html December 07, 2014

he negative effects of building large hydroelectric dams are commonly known and environmentalists are at loggerheads with governments

Dams are built worldwide to store water for irrigation, flood control, and to generate electricity. The negative effects of building large hydroelectric dams are commonly known and environmentalists are at loggerheads with governments. Since electricity is also needed, what is the best solution?

Dams are built all over the world due to the needs of controlling floods, storing water for irrigation during dry months, for drinking water, navigation, and for the generation of electricity. Earlier dams were being built at such a speed that every day a dam would be commissioned somewhere in the world. Until now some 800,000 dams have been constructed worldwide. But now the negative effects of large hydroelectric dams have been studied and much caution is being taken before planning and constructing them.

Not all dams are constructed for the generation of electricity. Some of them are just for the storage of water for the dry months. Hydroelectric power plants are of different types, and not all require a reservoir of water to be built. There are different types of hydroelectric power plants which are as follows:

In spite of all the hue and cry about the negative effects of dams, they have lots of advantages, too. The advantages of the hydroelectric dam are as follows:

The negative effects of large hydroelectric dams are as follows:

Dams will be built in future as the demands for electricity are increasing, however the negative effects of the dams on the flora, fauna, and the local population can be reduced by the following methods:

If the political will to change and do a good job is there a dam can be constructed by minimizing its effects on the people and the environment. By proper planning and suitable selection of site for the dam building the environmental effects can be minimized and still the much needed electricity can be generated.

How a Hydroelectric Project Can Affect a River - FWEE

http://fwee.org/environment/how-a-hydroelectric-project-can-affect-a-river/how-a-hydro-project-affects-a-river-print/ December 07, 2014

Foundation for Water & Energy Education. Return to Previous Page How a Hydroelectric Project Can Affect a River Overview. Hydropower has traditionally been considered ...

Hydropower has traditionally been considered environmentally friendly because it represents a clean and renewable energy source. The term renewable refers to the hydrologic cycle that circulates water back to our rivers, streams, and lakes each year. At hydroelectric projects, this water is used as fuel to generate electricity. In contrast, fossil fuels like coal, natural gas, or oil must be extracted from the earth and burned to produce electricity. The term clean is also used because production of electricity with hydropower does not pollute the air, contribute to acid rain or ozone depletion because of carbon dioxide emissions, or (like nuclear power) leave highly toxic waste that is difficult to dispose of.

As the section Hydropower Facts graphically illustrates, hydropower accounts for 98% of renewable energy in the United States. Wind, solar and other sources account for the other 2%. And while there are many benefits to using hydropower as a renewable source of electricity, there are also environmental impacts. These impacts generally relate to how a hydroelectric project affects a river’s ecosystem and habitats.

Because there are over 250 hydroelectric projects in the Northwest, understanding such ecosystem and habitat issues is vitally important. Examining these issues, however, needs to be done in a broad context for three reasons. First, no two hydroelectric projects are exactly alike, and many are very different. Thus, while issues can be examined in general terms, one should not draw conclusions that all or even most projects have similar environmental impacts.

Second, while this discussion focuses on hydroelectric projects, one should not conclude that all dams are used to produce electricity. Nationally, for instance, only three percent of the nation’s 80,000 dams are used to produce electricity. Most dams are used for purposes such as irrigation, flood control, and water treatment. Further, many dams support a combination of activities. For example, dams on the mainstem of the Columbia River are used for irrigation, flood control, transportation, recreation, and the production of electricity.

Third, this section does not provide detailed information about a host of other activities that can significantly impact a river’s ecosystem and the species that rely on it for survival. Examples of other non-hydropower related impacts include grazing, logging, agricultural activities, mining, land development, and the harvesting of fish. Determining the relative impact of these activities versus hydroelectric projects is very complex and the subject of ongoing debate.

For information about the many steps that are being taken to reduce or eliminate ongoing impacts, refer to the Protection, Mitigation, and Enhancement Strategies At Hydroelectric Projects. Reviewing possible changes to a river’s ecosystem is a good place to begin considering the environmental impacts that a hydroelectric project may cause. From this understanding, possible changes to fish and wildlife habitat can be explored.

Specific ecosystem impacts caused by a single hydroelectric project largely depend on the following variables: 1) the size and flow rate of the river or tributary where the project is located, 2) the climatic and habitat conditions that exist, 3) the type, size, design, and operation of the project, and 4) whether cumulative impacts occur because the project is located upstream or downstream of other projects.

The first two variables depend on a complex set of geologic, geographic, and weather conditions. For the Northwest, the bounty and beauty of these phenomena are described in the sections What Makes The Columbia River Basin Unique, and The Columbia River Basin and Its Ecosystems.

Engineers typically determine the type, size, design, and operation of a project based on these natural dynamics. As described in the section “How The Northwest Hydroelectric System Works,” the two most common hydroelectric facilities are storage projects and run-of-the-river projects.

Storage projects hold water in a reservoir or lake to adjust a river’s natural flow pattern to release water when the demand for electricity is highest. In addition, more energy can be produced from water falling 100 feet above a turbine than from 10 feet. This height is called “head.” Thus, it is not surprising that the hydroelectric projects producing the most electricity also have the tallest dams and the largest reservoirs.

Run-of-the-river projects allow water to pass at about the same rate that the river is flowing. Generally, the river level upstream of the project is fairly constant, with daily fluctuations limited to only three to five feet at the largest projects.

Although no two storage or run-of-the-river projects are the same, let’s take a look at some of the ecosystem changes that may occur because of their presence.

Reservoirs, also called lakes, are created when storage projects are built. Reservoirs can significantly slow the rate at which the water is moving downstream. Surface temperatures tend to become warmer as the slower moving or “slack” water absorbs heat from the sun.

In addition to surface water warming, the colder water sinks toward the bottom because of its higher density. This causes a layering effect called stratification. The bottom layer is the coldest and the top layer the warmest.

When stratification occurs, there is also another ecosystem effect. Specifically, the colder water that sinks toward the bottom contains reduced oxygen levels. Further, at some sites when water is released from the colder, oxygen-depleted depths, downstream habitat conditions change because of the reduced oxygen level in the water.

Supersaturation occurs when air becomes trapped in water spilled over a dam as it hits the pool below, creating turbulence. Because air is comprised of 78% nitrogen, the level of nitrogen dissolved in the water can increase dramatically. The affected water does not lose the excess nitrogen quickly. For fish and other species, supersaturated water can enter tissues. If fish swim from an area supersaturated with nitrogen to a lower pressure area, a condition similar to “the bends” in scuba diving can occur. This effect causes injury and can even cause death to fish.

Building a storage project can raise the water level behind a dam from a few feet to several hundred feet. When stream banks and riparian areas become covered by the reservoir’s higher water level, the result is called inundation. Habitat conditions change and a new equilibrium emerges. As this occurs, a different set of dynamics begin impacting species that traditionally grow, nest, feed, or spawn in these areas.

Once built, storage projects can also raise and lower the level of water in a reservoir on a daily, weekly or seasonal basis to produce electricity. One term used to describe this process is “power peaking.” This occurs when, for instance, more water is released in the morning because electricity demands increase as people wake up and begin taking hot showers, using kitchen appliances, etc. In a riparian zone, (the area where moist soils and plants exist next to a body of water) this may result in shoreline vegetation not being effectively reestablished.

Sediments, which are fine organic and inorganic materials that are typically suspended in the water, can collect behind a dam because the dam itself is a physical barrier. From the time a project is built, man-made and natural erosion of lands adjacent to a reservoir can lead to sediment build-up behind a dam. This build-up can vary based on the ability of a river to “flush”the sediments past the dam. It can also vary based on the natural conditions specific to the river and its upstream tributaries.

When sediments collect, the ecosystem can be affected in two ways. First, downstream habitat conditions can decline because these sediments no longer provide important organic and inorganic nutrients.

Second, where sediment builds up behind a dam, an effect called “nutrient loading”can cause the supply of oxygen to be depleted. This happens because more nutrients are now available, thus more organisms populate the area to consume the nutrients. As these organisms consume the nutrients, more oxygen is used, depleting the supply of oxygen in the reservoir.

Similarly, gravel can be trapped behind a dam in the same way as sediment. In cases where the movement of gravel downstream is part of establishing spawning areas for fish, important habitat conditions can be affected.

Changing water levels and a lack of streamside vegetation can also lead to increased erosion. For example, the lack of vegetation along the shoreline means that a river or reservoir can start cutting deeply into its banks. This can result in further changes to a riparian zone and the species which it can support. Increases in erosion can also increase the amount of sedimentation behind a dam.

Just as the changes that occur to ecosystems vary greatly from project to project, so do changes in habitat. Indeed, painting a picture of all or even most hydroelectric projects as having more or less the same impacts is a serious mistake. For a given project, learning what habitat conditions exist and the extent of ongoing impacts requires a good deal of investigation. Likely sources of information include the project owner, information provided to the Federal Energy Regulatory Commission, state and federal fish and wildlife agencies, and local environmental groups.

When ecosystem changes occur at a project, a new pattern of biological activity and equilibrium is likely to emerge. As this happens, a new and dynamic equilibrium takes hold. With this new equilibrium comes changes to the plants, fish, and wildlife that populate these areas.

Over time, observation indicates which species continue to do well, which ones become attracted or more attracted to the area around a hydroelectric project, and which species begin a gradual, sharp, or complete decline.

To examine these possible habitat changes, let’s begin with fish.

Salmon are the most well-known species of fish that migrate up and down streams. As a species, salmon are called anadromous because they migrate from fresh water to the oceans and then back again. Resident fish, on the other hand, spend their entire lives in fresh water streams, tributaries, and rivers. Some migrate from streams to lakes (adfluvial), others migrate from streams to rivers (fluvial), and some remain in the same reach of water. Brook trout and bull trout, for instance, are well-known resident fish that migrate up and downstream.

Depending on the species, these migration patterns can vary dramatically. In the case of salmon, for instance, coho tend to spawn in small streams and prefer shaded pools with overhanging trees and shrubs; sockeye salmon can migrate hundreds of miles to spawn in large lakes where, as fry, they live for two years before migrating to the sea; and chinook can spawn in large rivers like the mainstem of the Columbia River.

Salmon are called “fry”when they emerge from their spawning area and begin swimming freely and feeding in the stream. As they increase in size and maturity, they become “smolts”or “juveniles.”During their time in the ocean, they become “adults.”As a result, adults only exist in the river when they are migrating upstream to their spawning grounds.

Based on their life cycle and migration and spawning patterns, fish can face a number of different and changing ecosystems. Listed below are the most common and serious fishery impacts that relate to hydroelectric projects.

There can also be effects to fish from loss of riparian vegetation, sedimentation, erosion, and temperature changes. Unlike the impacts listed above, however, these effects are also caused by non-dam activities such as farming, logging, and land development. As a result, when studying the health of habitat along a particular reach of river or tributary, all sources of environmental impacts must be reviewed.

Further, while fish migrating down and upstream may encounter altered ecosystems and barriers that impact their ability to survive, predation from other species also has an impact. Squawfish, for instance, live below a dam where (as predators) they can easily feed on smolts as they come through the tailrace of the dam’s powerhouse.

Likewise, slower moving waters and temperature changes caused by reservoirs can provide improved environments for warm water fish such as smallmouth bass and walleye. These resident fish also prey on salmon smolts moving downstream. And as smolts enter the ocean, the increased presence of sea lions makes survival more difficult.

The introduction of non-native fish to Northwest rivers further complicates the situation. Warm water fish such as smallmouth bass and walleye are examples of non-native species introduced to Northwest rivers by humans. Examples of non-native trout include brook and rainbow trout. While many anglers enjoy catching these fish, it is important to note that their improved conditions are at the cost of poorer conditions for native stocks of salmon and trout.

Riparian vegetation and its bordering waters provide critical habitat for birds, waterfowl, and small and large mammals. When a hydroelectric project results in inundation of a free-flowing river, the nesting, forage, and cover provided by these areas is temporarily or permanently lost.

When habitat is lost, animals are forced to move to higher ground or other areas where habitat conditions may be less suitable, predators are more abundant, or the territory is already occupied. As an example, ground birds like pheasant and grouse require cover and cannot successfully move to higher, more open, ground.

In cases where water levels stabilize at a new height, vegetation in riparian zones can re-emerge and species can re-populate an area. With storage projects, the riparian zone that re-emerges has conditions that now reflect that of a reservoir or lake rather than a free-flowing river. When such conditions occur, certain species will begin to decline, others will become more abundant, and some will populate these areas for the first time.

Ducks and geese are examples of waterfowl that are strongly attracted to the habitat conditions found in reservoirs. For some of these species, reservoirs are providing an important alternative to the wetland areas that they formerly occupied. Canada geese are one example of birds that now frequent reservoirs as part of their migration pattern.

Hydroelectric projects do affect the ecosystems of rivers and their surrounding areas. The degree, however, to which any one project affects a river varies widely. As discussed, one of the most important variables is whether a dam is part of a storage or run-of-the-river hydroelectric project. Other variables include the size and flow rate of the river or tributary where the project is located; the existing habitat and climatic conditions; the type, size, and design of a project; and whether a project is located upstream or downstream of other projects.

As changes in habitat occur, observation and time make it increasingly clear which plants, fish, and wildlife are affected. Some species end up doing quite well, others sharply or completely decline, and some are minimally affected.

The section Protection, Mitigation and Enhancement Strategies At Hydroelectric Projects reviews measures being taken to address continuing environmental impacts. It is important to remember these measures are part of a much larger and complex whole. As such, their perceived success or failure is often dependent on a number of non-hydroelectric project activities.

For instance, there are natural conditions that can dramatically affect the health of a river's ecosystem and habitat. As an example, drought years at the beginning of the decade impacted critically important stream flows.

For salmon, the most important natural change relates to ocean conditions. Specifically, the effect called El Nino has resulted in higher sea levels and warmer surface temperatures. These conditions are being shown to greatly affect salmon survival and abundance.

Beyond these natural conditions are a host of man-made conditions. Such conditions include but are not limited to:

While this section focused on impacts from hydroelectric projects, understanding how to maintain the health of rivers and tributaries throughout the basin requires investigating these much broader impacts as well. Additional sources of information on these impacts and what is being done to mitigate them include federal, state, local, and tribal agencies; public and private organizations that contribute to these impacts; and non-profit groups interested in these environmental issues.

Environmental Impacts of Increased Hydroelectric ...

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Hydroelectric Development
at EXisting Dams

S. F. Railsback
G. F. Cada
C. H. Petrich
M. J. Sale
J. A. Shaakir~Aii
J. A. Watts
J. 'Iv. Webb

Environmental DiViSion)
Publication No. 3585

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Environmental Sciences Division

ENVIRONMENTAL IMPACTS OF INCREASED HYDROELECTRIC DEVELOPMENT AT EXISTING DAMS

S. F. Railsback
G. F. Cada
C. H. Petrich [1]
M. J. Sale
J. A. Shaakir-A1i [2]
J. A. Watts
J. W. Webb

1. Energy Division
2. Computing and Telecommunications Division

Environmental Sciences Division

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Prepared by the

OAK RIDGE NATIONAL LABORATORY

Oak Ridge, Tennessee 37831-6285

managed by

MARTIN MARIETTA ENERGY SYSTEMS, INC.

for the

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SUMMARY

This report describes the environmental impacts of a proposed U.S. Department of Energy (DOE) initiative to promote the development of hydropower resources at existing dams. This development would include upgrading existing hydropower plants and retrofitting new projects at dams where no hydropower currently exists. It is estimated that by the year 2020 the following increases in the nation's hydropower capacity would result from the proposed initiative:

	Capacity increase (OW)	
	UP&rades	Retrofit~
At nonfederal dams	2.2	5.8
At federal dams	-U	~
Total	5.1	10.6

The plant factors (the percentage of the capacity that would actually be generated, averaged over time) for hydropower upgrades and retro· fits are assumed to be 14% and 50%, respectively. Assuming that fossil-fueled plants have a plant factor of 65%, the power provided under the proposed hydropower initiative could replace approximately 9 GW of fossil-fueled capacity, or approximately 18 large (SOD-MY) coal· fired power plants.

Existing hydropower plants can be upgraded by (1) increasing the efficiency of the turbines and generators and (2) increasing the flow or head used by the plant. These two methods of upgrading plants cause different environmental impacts.

The efficiency of a plant can be improved by replacing obsolete or worn turbine or generator parts with new equipment, fine-tuning performance, reducing friction losses of energy, and automating opera tions. These efficiency improvements are expected to have only very minor and short-term environmental impacts. Replacement of turbine gates and runners (the surfaces against which water is impinged) can be environmentally beneficial because more efficient turbines generally kill fewer fish, and because new turbine parts can be designed to facilitate aeration at dams that release water with low dissolved oxygen (DO) concentrations.

Upgrading an existing plant to increase its flow or head can be

accomplished by adding more turbines or replacing turbines with larger units, raising the reservoir level to increase head and storage capacity, or by reallocating the storage in a reservoir to increase the flow available for hydropower. The potential adverse effects of flow and head increases include (1) changes in downstream water quality (especially DO concentrations and temperatures) resulting from altered reservoir release patterns or from decreases in the amount of flow that is aerated when spilled from the dam, (2) changes in reser voir water quality from changes in the volume and the quality of water released, (3) reduced fish populations or growth because of water

quality changes, (4) increased entrainment and mortality of fish in turbines, (5) effects of altered reservoir levels on the terrestrial environment, and (6) altered availability of recreation. These impacts are expected to be minor in most cases, but the extent of impacts will depend on the kind of upgrade and the local environment. Most impacts would be local and could be adequately mitigated with available technology.

Retrofitting existing dams with new hydropower plants provides the benefits of new hydroelectric capacity without many of the environ mental impacts of constructing new dams. New hydropower can be installed at existing storage and flood control dams, navigation dams, other kinds of impoundments, and water works such as canals and pipe lines. The potential adverse environmental effects of retrofits include (1) changes in water quality (both in tailwaters and in reservoirs) resulting from changes in reservoir release volumes and qualities, (2) reductions in DO resulting from decreases in aerated spill flows, (3) mortality of fish that pass through turbines, (4) minor changes in recreational uses, and, (5) in some cases, small changes in flood elevations. As with the upgrading of existing plants, most of these impacts are local and can be adequately mitigated.

Increased hydropower capacity offers many ene~gy security bene fits. This resource is domestic and renewable. The environmental impacts of most hydropower development at existing dams are minor, so environmental concerns should not prohibit the development of most sites. However, the plant factors for projects developed at existing dams under this initiative may be lower on average than for existing operations, since the most reliable hydropower resources in the United States will have already been developed. Many new hydropower projects at existing dams may not be allowed to alter daily or seasonal flow release patterns and so may not be useful in following peaks in power demands.

The environmental impacts of fossil-fueled power generation, which would be reduced by the DOE initiative, are of greater regional and global significance than those of hydropower. These impacts include the negative effects of extraction and transportation of fossil fuels, emissions of acid-producing compounds, emissions of greenhouse gases, and disposal of large volumes of solid waste. The hydropower initia tive is estimated to reduce the sulfur dioxide emissions from coal fired generation by up to 1.3% by the year 2020. However, reductions would be less than 1% for nitrous oxides and less than 0.1% for particulates and carbon dioxide. (Hydropower would replace older fossil-fueled plants that emit more sulfur than do newer plants, which is why reductions in sulfur are predicted to be greater than reductions in other emissions. Newer plants do not generally emit less nitrous oxide or carbon dioxide than do old plants. Reductions in particulate emissions are low because almost all fossil-fueled plants currently have adequate particulate emission controls.)

Development of new hydropower capacity at new dams is a renewable energy resource that could also be partially replaced by the power resulting from the DOE initiative. Development of hydropower at new

dams has impacts similar to, but of greater magnitude than, develop ment at existing dams.

Hydropower development at existing dams has, in general, fewer impacts than development of additional fossil-fueled resources or hydropower at new dams, although potential cumulative impacts of developing multiple hydropower projects have not been explicitly addressed. Environmental review of project impacts and mitigation needs can ensure that additional hydropower development at existing dams can provide a renewable, domestic energy resource with fewer impacts than alternative resources.

1. INTRODUCTION

This report has been prepared in support of the National Energy Strategy (NES) to examine the potential environmental effects of an initiative to enhance the development of hydropower at existing dams. This initiative is being considered by the U.S. Department of Energy (DOE) as a way to increase energy resources that are domestic, renew able, and environmentally acceptable. The initiative would promote both the upgrading (increasing the capacity and energy production) of existing hydropower projects and retrofitting hydropower (constructing new projects) at existing dams. The hydropower development that would result from this proposed initiative would be in addition to the growth in hydropower production that is expected to occur without it. This report compares the environmental effects of the proposed hydro power initiative with the effects of producing the same amount of power using the energy sources that the additional hydropower would likely replace.

The regions where additional development at existing dams is most likely to occur can be predicted from data on the location of suitable dams. However, the exact sites where additional development would occur with and without the initiative are urknown at this time. Therefore, this report discusses environmental effects qualitatively, noting regional differences in impacts where they occur. Site specific impacts of projects developed under the proposed initiative would be assessed before such projects would be (1) licensed for construction by a nonfederal entity or (2) constructed by a federal agency. This report covers only the development of additional conven tional hydropower resources; it does not consider pumped storage projects.

The impacts of increased power production at existing dams are compared with impacts of two likely alternative electric power sources. Because the hydropower resulting from the proposed initia tive is most likely to offset use of new or existing fossil-fueled generation and hydropower at new dams, the impacts of these other energy sources are compared with the impacts of the initiative.

2. DESCRIPTION OF PROPOSED INITIATIVE AND ALTERNATIVES

The hydropower initiative being considered by DOE would promote the upgrading of existing hydropower projects by increasing efficiency and by increasing capacity and energy production to the extent possible without unacceptable environmental impacts. The initiative would also promote the development of hydropower at existing dams where no power is currently generated. This section describes the proposed initiative and the kind of development that would occur under it. This section also briefly describes the power resources that are expected to be replaced should the hydropower initiative be implemented.

2.1 UPGRADING EXISTING HYDROPOWER. PLANTS

There are many ways to increase power production at existing hydropower projects. These can generally be classified as (1) methods to increase the efficiency of power generation [producing more power per unit of flow and head (elevation difference) 1 and (2) methods to add to the amount of water flow or head that can be used.

Methods of increasing efficiency include

1. replacing old turbine gates (the surfaces which control the flow and direction of water entering the turbine) and runners (the turbine blades) with newer, more efficient designs;
2. replacing turbine runners with new ones of the same design to eliminate cavitation or other imperfections;
3. rewinding generators to make them more efficient;
4. fine-tuning turbine performance (e.g., gate and blade angle settings) to maximize efficiency;
5. eliminating leakage of water through gates or other structures,
6. improving trash rack cleaning to reduce friction losses of energy from them;
7. using coatings to reduce friction losses of energy in flow passages; and
8. installing automated diagnostic data collection and analysis systems.

Methods being considered by DOE to increase usable flow and head include

1. adding more turbines to utilize flow that otherwise would be spilled,
2. replacing turbines and generators with new equipment that can use a wider range of flows,
3. raising the elevation of a dam to increase its storage capacity and head, and
4. making other changes in the allocation of reservoir storage and releases.

DOE predicts that, between the years 1990 and 2020, its initi ative to upgrade existing projects would result in the development of approximately 2.2 GW of generating capacity at nonfederal projects (in addition to development that would occur without the proposed initiative) and approximately 2.6 GW at projects operated by federal agencies.

The Federal Energy Regulatory Commission (FERC) Hydropower Resources Assessment data base was used to determine the location of projects most likely to benefit from upgrades. Existing hydropower projects (federal and nonfederal) that were constructed prior to 1940 and those constructed between 1940 and 1970 were identified. Projects constructed prior to 1940 are considered most likely to benefit from upgrades, but projects built between 1940 and 1970 may also gain improved power generation through upgrading. The type of turbine used at a project also affects how beneficial an upgrade could be. Figure 1 shows the locations of existing hydropower projects that may be candidates for upgrade projects because they were constructed before 1940 or between 1940 and 1970. The figure also shows whether the projects use Francis or propeller turbines. (Figure 1 includes only

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• Francis turbines installed before 1940

t:, Francis turbines installed 1940-1970

* Propeller turbines installed before 1940

* Propeller turbines installed 1940-1970

Fig. 1. Existing hydropower projects that may have upgrade potential.

the 186 projects for which adequate data were available; there are additional existing projects where either the age of the plant or the turbine type is missing in the data base. The 186 mapped projects include 95 built before 1940 with Francis turbines, 41 built between 1940 and 1970 with Francis turbines, 31 built before 1940 with propeller turbines, and 19 built between 1940 and 1970 with propeller turbines.)

2.2 RETROFITTING DAMS TO DEVELOP NEW HYDROPOWER

Testimony presented at public hearings for the NES indicated that only about 5% of 67,000 existing dams in the United States have hydropower capacity. Many of these dams are unsuitable for hydropower development because they are too small, too remote, or do not meet safety criteria. However, DOE (1990a) estimates that there are 2600 dams at which conventional hydropower could be developed. These dams include flood control and water supply reservoirs, navigation dams, abandoned or retired hydropower facilities, dams developed to provide industrial water power, and others. Some of these sites are currently being developed privately without DOE's proposed initiative, but many others are not being developed because of a combiuation of high development costs, relatively low energy prices, and regulatory problems (DOE 1990b).

Retrofitting a dam to generate hydropower (Fig. 2, an example at a navigation dam) usually involves (1) construction of intakes, penstocks, and a powerhouse that either replaces part of the existing structure (at low-head dams) or is located downstream (at high-head dams); (2) diversion through the turbines of water that previously was spilled through gates or over a fixed-crest or spillway; (3) construction of power lines to tie the project into the existing power grid; and (4) implementation of mitigation measures to reduce the impacts of the project. Mitigation measures may include flow release requirements, construction of fishing facilities, use of screens to keep fish out of the turbines, and water quality monitoring.

DOE predicts that its proposed initiative will result in the development. through new projects to retrofit dams between the years 1990 and 2020, of 5.8 GW of new capacity at nonfederal dams (in addition to development that would occur without the proposed initiative) and 4.8 GW of new capacity at projects operated by federal agencies.

The locations of approximately 2400 existing dams with hydro-power development potential included in the FERC Hydropower Resource Assessment data base are shown in Fig. 3. The proposed DOE initiative would result in the development of less than half of these sites (some sites are expected to remain undeveloped, and others will be developed even without the DOE initiative), but Figure 3 can be used to determine the geographic regions where dams could most likely be retrofitted to generate hydropower.

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Fig. 2. Proposed retrofit of hydropower at an existing navigation dam. Source: Application for license to the Federal Energy Regulatory Commission, Allegheny River Lock and Dam No.4 Project, FERC No. 7909, Allegheny County Hydropower Programs.

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Fig. 3. Existing dams with hydropower development potential.

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50

Oil

40

Gas

Coal

Nuclear

30

Renewable

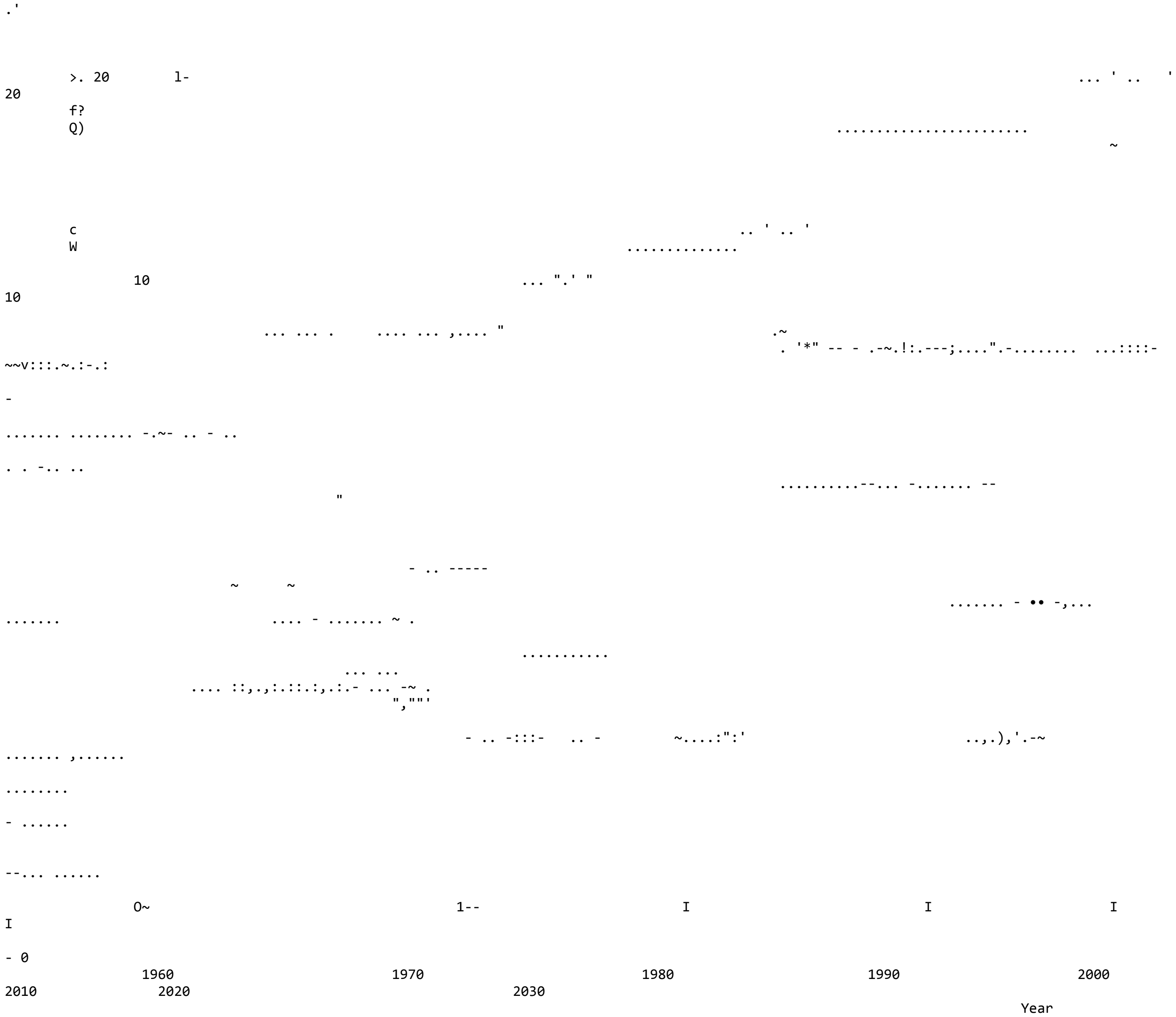

Fig. 4. Energy sources for electric power generation under the National Energy Strategy reference case.

2.3 ALTERNATIVES TO HYDROPOWER. DEVElDPKENT AT EXISTING DAMS

For this report, it is assumed that energy not produced through additional hydropower development at existing dams would be provided by the mix of electric energy sources in the NES reference case. The NES reference case is DOE's prediction of the future mix of energy sources in the United States without additional policy changes. This mix is illustrated in Fig. 4, which shows U.S. energy consumption for electric power generation, from the sources oil, gas, coal, nuclear, and renewables, in units of quads (10^{15} Btu) as it is predicted to change over time.

The development of additional hydroelectric generating capacity through the DOE hydropower initiative can be assumed to replace (1) new capacity that has greater costs (including capital costs and environmental impacts) than hydropower development at existing dams or (2) existing capacity that is expensive to operate, such as obsolete plants or plants using expensive fuel. The exact mix of capacity that would be replaced by hydropower under the proposed DOE initiative can be predicted only with detailed consideration of future energy costs, the types and locations of existing and future power plants, and site specific environmental considerations. The predicted generating capacity provided by the initiative would not have major effects on generation in any region of the United States but would probably make subtle changes in the power resources of several regions.

Figure 4 shows that most future power production under the NES reference case will be from fossil fuels, mainly coal, and that fossil fuels are also expected to provide the most growth in capacity. Therefore, it Is assumed that the hydropower resulting from the DOE initiative would most likely replace additional power generation at fossil-fueled thermal electric plants. The generating capacity resulting from the DOE hydropower initiative is uncertain, but, for purposes of comparison with alternative power sources, it is assumed that the new hydroelectric capacity developed by the year 2030 under the initiative would replace 9 GW of thermal electric capacity.1 This capacity is that of approximately 18 large coal-fired generating stations.

As discussed previously, the NES reference case includes substantial increases in hydroelectric power, including the development of new dams. Hydroelectric power is the largest component of renewable energy capacity under the NES reference case, which includes the growth in hydroelectric power generating capacity illustrated in

lThis estimate is based on (1) a total of 5.1 GW of capacity, with a plant factor of 14%, for upgrades at existing hydropower projects; (2) a total of 10.6 GW of capacity, wi th a plant factor of 50%. for new hydropower projects at retrofitted dams; and (3) a plant factor of 65% for fossil-fueled thermal electric generation. The plant factor for upgrades is taken from DOE (1990a). The plant factors for retrofits and for fossil-fueled plants are approximate national averages.

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Fig. 5. Hydroelectric development predicted under the National Energy Strategy reference case, with and without the DOE initiative promoting development at existing dams.

Fig. 5 (which illustrates the growth in hydropower capacity predicted to occur with and without the proposed DOE initiative). Because additional development of hydropower at existing dams resulting from the initiative may offset some of the hydropower expected at new dams in the NES reference case, additional hydropower at new sites is discussed here as an alternative to the DOE initiative. (New hydro electric power projects in Canada are currently an important and growing power resource, especially in the northeastern United States, where contracts for firm Canadian power supplies have recently been executed. Many Canadian hydroelectric projects are large and have had significant environmental impacts. However, the impacts of new Canadian hydropower development are not considered in this document.)

Under the NES reference case, nuclear power capacity is expected to decrease as existing plants reach their design lives and as their operating licenses expire. Therefore, additional nuclear power development is not discussed as an alternative power source.

3. ENVIRONMENTAL IMPACTS OF THE PROPOSED INITIATIVE AND ALTERNATIVES

This section discusses the environmental impacts of the hydropower development that would result from the proposed initiative and the impacts of developing the power through other means. The discussion is most detailed for hydropower development and for fossil fueled generation, the most likely alternative. Measures to mitigate the impacts of hydropower development at existing dams are also presented. Mitigation can be costly in some cases, but the costs of mitigation and their effects on the economic viability of projects are not evaluated here.

3.1 IMPACTS OF UPGRADING EXISTING HYDROPOWER PlANTS

The environmental impacts of upgrading existing hydroelectric plants are generally minor compared with the impacts of other energy development. The impacts depend on the kind of upgrade made. Upgrades involving only replacement of turbines or generators, without changes in the volume or timing of reservoir releases, are expected to cause only minor and short-term impacts and could have some long-term environmental benefits. Upgrades that include increases in reservoir storage capacity or changes in the volume or timing of releases could have some long-term impacts.

3.1.1 Water Resources

3.1.1.1 Construction Impacts

Upgrades involving only replacement of turbines or generators, without alterations in intakes, draft tubes, or other structures, can be completed with little or no effects on water resources. Such

upgrades require little outdoor work, so impacts such as erosion, disturbance of the riverbed, or fuel spill risks should be minimal. Reservoir levels and streamflows would not be changed by such upgrades.

Upgrades to install larger turbines or more turbines require more extensive construction and therefore have greater potential for impacting water resources. Such upgrades may require installation of cofferdams, dredging or excavation upstream or downstream of a dam or powerhouse, and the use of heavy machinery and outdoor storage areas. These kinds of activities can increase the local erosion of banks and streambeds during construction, resulting in increased sediment loads and potential deposition downstream. Sediments at a dam may be disturbed and redistributed by construction; if sediment contamination occurs locally then sediment redistribution may have adverse effects. The use of machinery near or in the waterway presents a risk of small fuel spills. These construction impacts are short~term, occurring only while the upgrade is being completed. It is unlikely that Significant impacts on water quality (i.e., impacts that could have long~term effects on aquatic life) would occur during construction.

At upgrade projects involving extensive construction, .or at simpler upgrades at projects with only one turbine, river flows in the tailwaters may be stopped for longer periode than would otherwise turbines and generators requires that there be no flow through the turbine, and at projects with storage capacity there may be no releases if the nature of the upgrade requires that all turbines be shut down. Shutting off releases to the tailwater could result in temporary dewatering and stagnation of the tailwater, contributing to high algal growth and low or highly fluctuating dissolved oxygen (DO) concentrations with consequent adverse effects on aquatic organisms.

Mitigation can be implemented to minimize or avoid most construction impacts. At multiturbine projects, normal flows in the tailwaters can be maintained by operating other turbines when one is shut down for upgrading. At some single-turbine projects, tailwater flows could be maintained, if necessary. with nongenerating releases from gates or spillways, although prolonged nongenerating releases may offset much of the benefit of upgrading. Construction impacts such as erosion and fuel spill risks are typically addressed in the licensing and permitting process for hydropower upgrades. Projects involving disturbance of the streambed or adjacent riparian zones or wetlands require permits from the U.S. Army Corps of Engineers and may also require water quality certification from the appropriate state water resources agency. These permits (which are issued under the Clean Water Act) and FERC license amendment orders for project upgrades are designed to mitigate construction impacts. Requirements of permits and FERC orders typically include development and approval of plans for (1) prevention of erosion, (2) prevention of fuel spills, and (3) deposition of dredged material. Compliance with permit and FERC licensing requirements should adequately mitigate construction impacts of major plant upgrades.

3.1.1.2 Decreased Aeration

Project upgrades can include installation of turbines capable of using higher flows at sites where some flow is otherwise spilled through gates or over spillways. Flows in excess of turbine capacity are spilled at such projects, because the existing turbines are too small to use all of the flow. The flows that are spilled may be aerated to some degree (i.e., the DO concentrations increased) during spillage. Increasing the capacity of the turbines would result in a higher percentage of the flow passing through the turbines, where little or no aeration occurs. At projects where DO concentrations are low (because of either upstream water quality impacts or impacts of the project itself), and where upgrading would result in less flow being aerated during spillage, there would be a net decrease in DO concentrations downstream. At sites where spillage occurs only during times of high flows (when DO concentrations do not tend to be low). impacts of using the spillage for power generation may not be significant. This impact tends to occur at low-head dams where the original project purpose was not hydropower and is less likely to be important at upgrades than for new hydro retrofits.

Decreases in downstream DO reSUlting from reduced spillage can be mitigated when necessary by requiring the projec~ to spill flows through gates or over spillways, where aeration occurs. Such spill flows may be required during periods of low flows or high water temperatures, when DO concentrations tend to be low. Mechanical aeration processes (such as pumping air into the water as it passes through the turbine) have not yet been shown capable of economically replacing spill flows as a way of maintaining DO concentrations at low-head plants.

3.1.1.3 Improved Turbine Aeration

The replacement of turbines at projects that routinely suffer water quality problems offers the potential to reduce these problems. Many deep reservoirs stratify in summer, with a layer of cold water with low DO concentrations forming on the bottom. When this cold, deoxygenated water is released through the turbines, it provides inadequate DO in the tailwaters. Aerating the water as it passes through the turbine is one way to mitigate this problem.

Experiments with self-aerating turbines have been conducted by the Tennessee Valley Authority, the Army Corps of Engineers, and private utilities (Bohac et al. 1983, Wilhelms et al. 1987). These experi ments indicate that, at some plants, turbines designed to entrain air into the flow as it passes through them could aerate the tai1waters adequately and cost-effectively (although adverse effects such as decreased efficiency and increased fish mortality can result). The upgrade of old turbines at such plants may provide an opportunity to install self-aerating turbines that could increase tailwater DO concentrations, providing a substantial environmental benefit.

3.1.1.4 Changes in Reservoir Storage and Flow Releases

Upgrade methods for existing hydropower projects include increasing or reallocating reservoir storage and increasing the flow rates used by turbines. Increasing storage is accomplished by raising the elevation of the dam. Reallocating storage generally involves changing the times at which water is released throughout the year, with resulting changes in reservoir levels. These changes can affect reservoir and downstream water quality in many of the same ways that changing the release elevation does (see Sect. 3.2.1). These impacts can include changes in water temperature and DO concentrations over time and space, which can be predicted only with site-specific modeling studies. Increased flow capacity of turbines allows the potential to increase daily flow fluctuations, the potential impacts of which are discussed in Sect. 3.2.1.2.

3.1.2 Air Quality

The air quality impacts of upgrading hydroelectric plants are expected to be local. short-term, and minor. Such impacts are likely to occur only as a result of fugitive dust emissions and emissions from machinery and vehicle use at upgrade projects requiring extensive construction. These impacts would occur only during construction and in almost all regions would be very minor compared with other emissions. There are no negative long-term air quality impacts of upgrading hydropower plants. Hydropower development can have positive effects on air quality by reducing fossil-fueled generation and its air emissions (Sect. 3.3.2).

3.1.3 Aquatic Ecosysteas

The impacts to aquatic biota of upgrading existing hydropower plants result primarily from potential changes to water quality during construction and operation (see Sect. 3.1.1). Upgrades involving replacement of equipment inside buildings pose little threat for water quality degradation and subsequent biological impacts. However. substantial work outside of existing structures could lead to soil erosion and sedimentation, disturbance of contaminated sediments, and spills of construction oils and chemicals, all of which could have toxic effects on fish and other aquatic organisms (Miller et al. 1985). All sites could be affected by soil erosion and spills, but effects are readily controlled by proper construction practices. On the other hand, the possibility of encountering contaminated sediments would need to be evaluated at each site.

Changes in flow releases during construction could degrade tailwater quality (e.g., stagnation leading to increased temperatures and decreased DO concentrations). Fish and benthic invertebrates could be impacted not only by these water quality changes but also by the loss of habitat when the river below the dam is temporarily dewatered. Loss of instream habitat could range in severity from minor reduction of shallow riffle areas, which support many benthic

invertebrates and some fish species, to total loss of both riffle and pool areas (Hildebrand 1980b).

Decreased aeration, as a result of passing poorly oxygenated water through a turbine instead of spilling the water over a dam, could impact tailwater biota that require high levels of DO to survive and reproduce. Effects of low DO concentrations could range from decreased growth rates to mortality among sensitive species or life stages (USEPA 1986).

Replacement of older turbines with new designs could change the turbine-passage mortality experienced by fish. Older turbines (e.g., Francis or impulse turbines) often have small passages that may cause considerable injury or mortality (Turbak et al. 1981, Ruggles and Collins 1981). Further, operation of turbines under suboptimal conditions of flow and hydraulic head may lead to high levels of cavitation, which is particularly detrimental to fish (Cada 1990).

Many of the newer turbine designs have large passages and, by adjusting wicket gates and turbine blades, the capability to operate efficiently under a variety of flow conditions (Fig. 6); these improvements could lead to lower turbine-passage mortality. However, at sites where the upgrade adds capacity, passing more water through additional or larger turbines could cause greater mortality among fish that were formerly spilled over the dam.

Most of the potential impacts to aquatic biota can be controlled or mitigated by the same techniques used to protect water quality. If care is taken to minimize soil erosion, spills, and changes in flow releases, construction impacts to aquatic biota within the reservoir and in the tailwaters should be minor. Spill flows or self-aerating turbines designed to ensure adequate reaeration of water would mitigate potential low DO effects on tailwater biota. The use of multilevel intakes to remedy water quality problems may expose differ ent reservoir fish to entrainment in the turbine intake flow. If surface waters of stratified impoundments support more fish than poorly oxygenated deep waters, increasing tailwater DO concentrations by increasing the surface withdrawal rates could exacerbate turbine passage mortality. Considerable effort has gone into the development of fish screens for hydropower intakes (EPRI 1988); although the results have been mixed, some of these devices may be useful for reducing turbine-passage mortality at upgraded sites.

3.1.4 Riparian and Terrestrial Ecosystems

Impacts of upgrading existing power plants on terrestrial resources result mainly from construction-related disturbance to riparian habitats and wetlands. Such impacts are highly site- and project-specific but generally are likely to involve very small areas (e.g., for laydown, access, or larger facilities) and would usually be of little if any significance. In certain regions (e.g., arid land scapes of the western United States, Kondolf et al. 1988) or habitats (e.g., old-growth riparian hardwoods), the issue of construction related disturbance could be significant for particular projects.

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FISH PASSAGE THROUGH WICKET GATES AND TURBINE

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Fig. 6. Turbine passage and mortality of fish.
Source: American Electric Power, Inc.

Enhancements that involve ra1s1ng dam elevations could result in significant loss of upstream terrestrial habitat through inundation (FERC 1988b). Valuable habitats that could be lost through such changes include bottomland hardwoods in the South, emergent wetlands throughout the United States, and riparian zones in semiarid or arid regions. Although such areas may be small (i.e., one to several acres) for individual projects, these habitats are increasingly valued, and the cumulative effect could be significant.

Temporary sedimentation and changes in flow regimes during construction are unlikely to have lasting effects on terrestrial resources. Similarly, replacing equipment inside buildings is unlikely to affect terrestrial resources.

Impacts to terrestrial resources can be mitigated by careful attention to siting of construction activities in relation to more important habitats and by strict adherence to erosion controls and other sound construction practices.

3.1.5 Recreation

3.1.5.1 Construction Impacts

Upgrades involving only replacement of turbir.es or generators without alterations in intakes or other structures would likely have few effects on recreational opportunities or resources except for limited periods during construction. More extensive alterations to dams would cause increased interruptions to normal recreational pursuits on and around hydropower reservoirs and their tailwaters. With the potential for increased sediment loads due to erosion of banks and streambeds, the water quality impacts could affect fishing, swimming, water skiing, hiking, and boating. Isolated small fuel and lubricant spills associated with the operation of heavy machinery could temporarily affect recreational activities. Such impacts would most likely be short-lived and quickly cease after construction and soil stabilization.

If reservoir waters are drawn down during construction, exposed mudflats, reduced swimming and boating areas, changed fishing habi tats, etc., all affect-for the short-term and locally-the recreational opportunities available.

Fishing around tailraces is often a preferred activity for some anglers; such fishing would be affected during construction because of both water quality impacts and modifications in the normally main tained flow regimes. Temporary cessation of flows through turbines and generators during upgrades may be required, resulting in no releases through the tailraces. Potential dewatering and stagnation as a result of such constrained flows could contribute to undesirable algal growths and low DO concentrations. Other aesthetic impacts such as exposed rocks, noxious odors, loud noises, fugitive dust, gaseous hydrocarbon emissions, and eroded banks and exposed mudflats would negatively affect the expected recreational experience. Fishing may be temporarily prohibited near a project during construction.

The mitigation discussed in Sect. 3.1.1 could protect most of the recreational resources to the extent feasible.

3.1.5.2 Long-Term Impacts

Among the potential long-term effects on recreational opportu nities is decreased aeration in waters released below the dams. As described in Sect. 3.1.1, new turbines could cause a decrease in available DO to fish and other aquatic species, potentially affecting the quality of the fishing experience and the aesthetics of fishing (such as through increased odors and algal growth).

At sites where turbines capable of using higher flows are installed (where some flow is otherwise spilled through gates or spillways), new flow regimes for impoundments could affect eXisting recreational activities such as whitewater canoeing or kayaking, swimming, and fishing. Changes in the magnitude or timing of flows downstream could affect aquatic habitats, riparian vegetation, breeding success of aquatic species, etc. All could have at least secondary effects on recreational opportunities, including safety, and the quality of the available recreational experience. Successful exploitation of available flows and head may require an increase in the height of dams and in the size of storage impoundments. Impacts would be comparable to those described in Sect. 3.2.5. The conversion of some primarily flood control dams to increase hydropower capacity could require a less tightly maintained pool, resulting in a smaller reservoir at least seasonally and possibly over the whole year. Recreation impacts would then include inappropriate dock, marina, and boat ramp elevations; exposed expanses of mudflats and/or marshy vegetation; decreased wildlife support area; and decreased fishing, swimming, and boating areas. On the positive side, less severe fluctuations in pool elevations could mean a more pleasing shoreline, less-expensive dock structures in the long term, and potentially more or improved riparian vegetation and fish habitat upstream.

Mitigation for water quality (Sect. 3.1.1) would also eliminate many recreation impacts. Projects that would alter lake elevations could make funds available to modify structures to accommodate less severe fluctuations in reservoir elevations and to relocate structures to new shoreline locations where necessary. Fishing platforms could be installed to facilitate fishing access and safety along tailwater areas, improving the fishing experience.

3.1.6 Daa Safety and Flooding

Plant upgrades that do not include increasing reservoir storage generally pose no dam safety concerns (i.e., concerns about failure of a dam and the reSUlting flooding). When an upgrade includes raising the reservoir levels, there are additional structural loads on the dam, and the overall factor of safety for dam failure may be reduced. The design of such a project must consider dam safety concerns. The FERC license amendment process for such upgrades includes analysis of whether the dam would continue to be safe with the raised reservoir level.

There are generally no flooding concerns at most upgrade projects. However, one way to increase generation at an existing reservoir is to reduce flood storage to provide more water for generation (Sect. 2.1).

Such a reduction in flood storage would increase risks of downstream flooding; the magnitude and impacts of the additional flooding depend on site-specific factors. Any construction work that would place tem porary facilities (such as cofferdams, temporary dams used to dewater construction areas) or permanent structures (such as new powerhouses) in a floodway would increase upstream water levels during floods.

3.1.7 Energy Security Benefits

The energy provided by upgrading existing hydroelectric power projects would be a relatively small portion of the additional U.S, power needs expected by 2030 (less than 1% of the increase in fossil fueled power generation expected between 1990 and 2030 under the NES reference case), but it would be a relatively inexpensive and bene ficial form of energy. Energy from such upgrades would be totally domestic and renewable, so it would not be vulnerable to foreign control or fuel shortages. Because energy from most kinds of upgrades has minimal environmental impact, environmental concerns should not prohibit its development. Energy obtained from efficiency improve ments at existing projects would have the same reliability as the existing hydroelectric power. Energy obtained from increased capacity (the ability to use additional flow) at existing plants would have less reliability than the existing power, since the additional capacity would be lost first in times of low flow or if additional flow releases are needed to improve water quality or aquatic habitat. In fact, DOE (1990a) estimates that the plant factor for upgrade capacity at existing projects is 14% (i.e., energy production over time would average 14% of capacity). The ability of some projects to generate this power during peak demands greatly increases the value of the power.

3.2 IKPACTS OF NEW HYDROPOWER AT EXISTING DAMS

The installation of new hydroelectric projects at existing dams provides the benefits of additional renewable power resources without many of the adverse environmental impacts of hydropower development at new dams. The impacts that result from the impoundment of a stream have already occurred at existing dams; these impacts include altera tion of aquatic habitat from flowing water to slack water in the impoundment, changes in the magnitude and timing of flows downstream of the dam, changes in water quality that occur in the impoundment and affect the tailwaters, blockage of fish migration, and submergence of terrestrial habitat by the reservoir. However, retrofitting a dam to generate hydropower can involve some additional impacts.

3.2.1 Water Resources

3.2.1.1 Construction Impacts

At low-head dams, such as navigation dams, retrofitting usually involves replacing part of the existing dam with a powerhouse or adding a powerhouse to one end of the dam. At high-head plants, such as storage reservoirs, hydropower is usually added by installing penstocks through the existing dam and constructing a powerhouse and tailrace immediately downstream of the dam. Short-term, local impacts of construction on water resources are possible. Sediment loads to the tailwaters can result from erosion at the construction site and the accidental release of excavated materials into the stream. There is a risk of small fuel spills resulting from the use of construction equipment near and in the streambed. Contaminated sediments existing at a dam may be disturbed and distributed by construction. If con struction of the power plant requires temporary cessation of flow releases, the tailwater reach could be dewatered or stagnated, as discussed in Sect. 3.1.1 for hydropower upgrades. Water quality impacts of retrofit hydropower projects are unlikely to persist after construction is complete.

Mitigation to minimize or avoid construction impacts at retrofit projects would be similar to that at upgrades (Sect. 3.1.1.1). Compliance with permit and license requirements should adequately mitigate construction impacts.

3.2.1.2 Changes in Flow Release Patterns

Hydropower projects can generate more valuable power by releasing water during periods of peak daily power demands and storing it during off-peak periods. This peaking mode of operation is possible at retro fit projects built at dams with at least minimal storage capacity. The daily flow cycles that result can have adverse impacts downstream, such as stranding fish (including spawning nests and juvenile fish), posing hazards to recreational users, and increasing bank erosion. These impacts can be mitigated by (1) not allowing daily flow cycles (a common requirement) or (2) building some kind of re-regulation structure (such as another small reservoir or a low-head weir) downstream to even out daily flow cycles. Since such fluctuating flows can have adverse impacts and can conflict with the original uses of an existing dam, they are often not allowed.

Changes in seasonal release patterns would be similar to those discussed in Sect. 3.1.1.4. However, at most dams a retrofit hydro power project would not be allowed to change seasonal flow release patterns because such a change would reduce the ability of the dam to fulfill its original purposes.

3.2.1.3 Changes in Tailwater Quality Due to Changes in Release Elevation

A retrofit hydropower project can withdraw water from elevations different from the withdrawal elevations of the original impoundment.

In the case of a deep storage reservoir, water quality commonly varies with elevation, especially in summer. Thermal stratification results in an impoundment having cold water, often with low DO concentrations, in its lower elevations and warm water with relatively high DO concen trations in the higher elevations. In stratified impoundments where the existing release is from the top (over a spillway or through high elevation gates), the installation of a hydropower plant withdrawing from low elevations would cause downstream water quality to change in summer from high to low temperatures and from high to low DO concen trations. Yater released from low elevations also tends to have high concentrations of heavy metals, which can have toxic effects, and high concentrations of iron and magnesium, which are considered nuisance compounds. Even small changes in the withdrawal elevation can significantly change water quality over a summer season.

Cada et al. (1983) showed that problems with low DO concentrations in reservoir releases are much more common at large reservoirs than at small ones. Problems with low DO in releases at small hydropower projects were shown to be more common in the midwestern, southeastern, and southwestern regions of the United States. Large projects releasing low DO concentrations are most common in the midwestern, east-central, and southeastern states. Low DO problems are uncommon in winter.

In unusual circumstances even shallow impoundments, such as large rivers with low-head dams, can have stratified water quality (such as when thermal-electric power plants or upstream reservoirs contribute to temperature differences). The bulb-style turbines typically installed at low-head dams withdraw water from all levels of the upstream impoundment and eliminate stratification by mixing the water thoroughly; this mixing can actually improve water quality in situa tions where stratification occurs.

The release of deoxygenated water from the bottom of a reservoir can be mitigated in several ways. One way is to construct the hydro power project with a multilevel intake so that water can be withdrawn from the reservoir selectively from different elevations. Such selective withdrawal allows the project operator to release water with acceptable temperatures and DO concentrations (although water quality changes in the reservoir, discussed in Sect. 3.2.1.5, may result). Another way to mitigate the release of deoxygenated water is to aerate the water as it is released through turbines. Numerous other methods have been used to increase DO in turbine releases (Bohac et al. 1983). These methods include venting air into the turbine, with or without air pumps; pumping air or oxygen into either the tailwaters or the reservoir just upstream of the intake; forcing water from the surface layer of the reservoir down and into the turbine intakes; and, where tailwaters are adequately steep (to avoid backpressure on the tur bine), installing of a weir downstream that provides aeration and evens out flow fluctuations. Such a weir is currently being designed by the Tennessee Valley Authority. The installation of a multilevel intake, aerating turbines, or other DO enhancement technologies in a retrofit hydropower project can mitigate tailwater quality problems. In cases where existing DO concentrations were high, some decrease in DO would be expected with the addition of hydropower. However, in

cases where existing DO concentrations were low, better quality releases may be possible with hydropower and DO mitigation than without hydropower.

3.2.1.4 Decreases in Aeration

Installation of hydropower at some existing dams can replace well aerated spill flows with unaerated flows through turbines. This impact is important at many low-head dams, especially navigation dams on large rivers (e.g., 19 dams considered by FERC 1988b, Sale et al. 1989, Thene et al. 1989). At low-head dams without hydropower, flows are spilled over spillways or through gates that may (or may not) provide important aeration (Railsback et al. 1990). Such spill flows may be aerated up to or above the saturation concentration of DO. This aeration can be very important for water quality since impounded rivers receive relatively little other aeration because they are deep and slow. Flows through low-head hydropower turbines receive negli gible aeration. Therefore, when hydropower is installed at a dam that aerates well, the flows through the turbines do not receive the aeration they would receive without hydropower, and a net decrease in downstream DO concentrations results. The magnitude of DO reductions varies between sites and over time and may be sufficient to signifi cantly affect fisheries. Where hydropower is installed at adjacent dams on the same river, cumulative decreases in DO could occur, resulting in DO concentrations low enough to affect fisheries (e.g., FERC 1988b).

A loss of aeration can also occur when hydropower is installed at some high-head mUltipurpose storage reservoirs. Some dams release cold, deoxygenated water from the bottom of a reservoir through gates and energy dissipators that greatly increase DO concentrations. This water, if released through hydropower turbines, would not be aerated, and DO concentrations downstream would be significantly reduced. Reductions in summer DO concentrations to levels harmful to fish could result without mitigation.

Loss of aeration resulting from installation of hydropower can be mitigated at both low-head and high-head plants. At low-head plants, DO concentrations can be maintained during critical periods (e.g., during summer low-flow periods) by requiring some or all of the flow to be spilled for aeration instead of being used for hydropower generation, with a resulting loss of power production. There may be ways to mechanically aerate flows cost-effectively at low-head projects, but none have been demonstrated. (Mechanical aeration is less cost-effective as a mitigation measure at low-head plants than at high-head plants because (1) much more water must be aerated per unit of power generated; (2) low-head turbines are typically designed so that water pressures are never less than atmospheric pressure, so self-aeration by venting air into the turbine at low-pressure zones is infeasible; and (3) very little research on aeration of low-head turbines has been conducted.)

Mitigation for the discharge of low-DO water from high-head plants is discussed in Sect. 3.2.1.3.

3.2.1.5 Changes in Reservoir Vater Quality Due to Changes in Release Elevation

The effects on downstream water quality of installing hydropower that withdraws from different elevations of a stratified impoundment are discussed in Sect. 3.2.1.3. Changes in the elevation of withdrawal from a reservoir can also affect water quality in the impoundment upstream of the dam. For example, replacing a gate release with a turbine intake at even a small difference in elevation could reduce the amount of cold water on the bottom of a reservoir and increase the amount of warmer water in the reservoir in summer. Such changes can affect water temperatures, DO concentrations, algal production, and other water quality parameters at different times and locations in the reservoir. These effects are complex, variable, and site-specific, and reservoir simulation models are used to predict them. In some situations, the alteration of the withdrawal elevation could be bene ficial for reservoir water quality (e.g., if deoxygenated water were flushed from the bottom of a reservoir), and in other situations the effects could be negative (e.g., if the reservoir volume with unsuit ably high temperatures were increased).

In situations where water quality impacts on the impoundment of a proposed retrofit hydropower project were predictud to be negative, a multilevel intake for the project might be able to mitigate the impacts. However, maintaining water quality both in a reservoir and in its tailwaters may in some cases be conflicting objectives, and there may not be selective withdrawal schemes that satisfactorily prevent all water quality impacts. In some cases, water quality problems within an impoundment can be mitigated by reducing upstream sources of pollutants (e.g., wastewater discharges, non-point-source runoff) contributing to the problems.

3.2.1.6 Nitrogen Supersaturation

Nitrogen supersaturation and the gas bubble disease it causes in fish are commonly associated with hydropower projects. Gas bubble disease occurs in fish exposed to water supersaturated with dissolved nitrogen. The disease results in formation of gas bubbles within the fishes' bodies and can cause mortality at nitrogen concentrations as little as 105% of saturation (Norwegian Hydrodynamics Laboratories 1984). Nitrogen supersaturation can occur when air is entrained into poorly designed penstocks, when water saturated with nitrogen deep in a reservoir (where pressure increases the saturation concentration) is released to tailwaters, and when reservoir releases are very highly aerated (Wolke et al. 1975). Nitrogen supersaturation is not commonly found at dams suitable for addition of hydropower, and, although gas bubble disease may occasionally occur because of site-specific conditions, it is not expected to be a significant adverse impact of hydropower development at retrofitted dams.

3.2.2 Air Quality

As with upgrading hydropower projects (Sect. 3.1.2), the air quality impacts of retrofitting. dams with hydroelectric plants are expected to be local, short-term, and minor. Impacts such as fugitive dust emissions and emissions from machinery and vehicle use would occur only during construction and in almost all regions would be very minor compared with other emissions.

3.2.3 Aquatic Ecosystems

Construction impacts to aquatic resources from retrofit hydropower development would be similar in nature to those associated with upgrading existing hydroelectric plants (Sect. 3.1.3). However, because construction is likely to be more extensive under this alter native, the potential for impacts to aquatic resources, especially from water quality degradation, is greater. Also, the mitigative measures needed to control these potential impacts would be similar to those described in Sect. 3.1.1.

Operation of a retrofitted dam could impact aquatic organisms through habitat and water quality degradation. Although the reservoir already exists and the biological communiti~s have adapted to the lake environment, commencement of hydropower production may alter the magnitude and timing of releases. This in turn could result in rapid and more extreme water level fluctuations in both the reservoir and tailwaters, which degrade important shallow-water habitat for aquatic biota (Hildebrand 1980b).

The release of cool, poorly oxygenated, deep water from stratified reservoirs will degrade the water quality of the tailwaters and adversely impact tailwater communities that are adapted to releases of warmer, well-oxygenated surface waters. As with the potential decreased aeration problem described for the upgrade alternative (Sect. 3.1.3), effects can range from decreased growth rates to mor tality. The mitigative measures suggested in Sect. 3.2.1 to enhance DO concentrations of new hydropower releases should also serve to protect tailwater biota. The use of multilevel intakes to correct low DO problems would .need to take into account not only the DO require ments but also the temperature requirements of aquatic organisms below the reservoir. An additional complicating factor associated with the use of multilevel intakes is that withdrawal of water from different levels of the reservoir may expose different reservoir fish to entrainment in the turbine intake flow. If surface waters support more fish than deoxygenated deep waters, correcting water quality problems by increasing the surface withdrawal rates could exacerbate turbine-passage mortality.

Water quality changes within the reservoir reSUlting from new hydropower releases could have either beneficial or adverse effects on aquatic organisms. Releases of poorly oxygenated deep water could increase the amount of well-oxygenated habitat available to both fish and bottom-dwelling invertebrates in a stratified reservoir. On the other hand, releases of surface water, for example to correct tail water quality problems, may reduce the amount of adequately oxygenated

habitat for reservoir biota. Because different release schemes will alter impoundment temperatures as well as DO concentrations, the thermal requirements of reservoir organisms must also be considered. As with water quality considerations (Sect. 3.2.1), such effects are complex, variable, and must be evaluated on a site-specific basis.

Turbine-passage mortality would be a new impact of installing hydroelectric facilities at existing dams. The seriousness of this issue depends on a number of factors, including the species of fish affected; sport fish are generally of greater concern than rough fish. Behavior of the fish has an important influence on turbine passage mortality. Bottom-dwelling species may not encounter surface-level intakes. Anadromous fish such as salmon, American shad, and striped bass must migrate downstream and therefore must pass over the dam either in spill flows or through the turbines; on the other hand, many inland fish species in reservoirs do not move great distances and may not be exposed to turbine intake flows. Finally, the size of the fish entrained in the intake flow is important in that large fish are more likely than small fish to be injured by turbine passage (Cada 1990). Different turbine types cause different mortality rates: in general, the farther apart the blades are, the lower the mortality, although other factors are also important.

3.2.4 Riparian and Terrestrial Ecosystems

The impacts to terrestrial resources from retrofits are similar to those from upgrading existing hydroelectric plants (Sect. 3.1.4). However, because more extensive construction is likely under this alternative (e.g., several to many acres for powerhouse, penstock, access, parking, and transmission lines), the potential for distur bance to riparian habitats and wetlands is greater. The installation of new power lines, in addition to disturbing habitat, may pose collision hazards for birds and bats and electrocution hazards for large raptors. The latter can be mitigated by proper tower design. Other mitigative measures needed to control these potential impacts would be similar to those described in Sect. 3.1.4.

Hydropower production at retrofitted dams may alter flow releases, thereby affecting shallow-water habitat including emergent vegetation in wetlands near tailwaters. Altered flow regimes may also alter reservoir levels enough to affect upstream wetlands and riparian zones. The seriousness of such effects depends on the extent and value of wetlands present; effects would normally be small for indi vidual projects but could be cumulatively significant.

Projects that produce electricity by diverting water through penstocks for significant distances may produce losses or undesirable changes to riparian zones along dewatered reaches. Such damage is particularly serious in semiarid or arid regions where streamside vegetation is particularly important ecologically (Kondolf et al. 1988).

3.2.5 Recreation

3.2.5.1 Construction Impacts

The retrofitting of dams to generate new hydropower will entail many of the same construction effects as described in Sect. 3.1.5.1. Where new penstocks and powerhouses are required downstream of the existing dams (high-head situations), significantly more riparian disturbances are likely. This could affect fishing, hiking, swimming, boating, nature observation. and access to any of these. If construction of the power plant requires temporary cessation of flow releases, the tailwater reach could be at least partially dewatered, and the remaining waters could become stagnant, as discussed in Sect. 3.1.5.1. Fishing in dam tailwaters could be prohibited during construction.

If greater impoundments are needed to accommodate the flow requirements of the new generation capability, a variety of impacts can be expected. Construction could bring erosion and sedimentation impacts to water quality, affecting fishing, swimming, and boating. Recreational activities could be directly affected by construction noises, aesthetic impacts of heavy machinery in a recreational environment, and temporary cessation of activities because of safety concerns.

The mitigation strategies outlined in Sect. 3.2.1 would be appropriate to partially protect water quality-dependent recreation resources. Normal flows should be maintained in tailwaters via use of flows from gates or spillways.

3.2.5.2 Long-Tera Impacts

Retrofitted dams could create local impacts due to the presence of mechanized fish screens in place of simple spillways and gates. These could affect swimmers, scuba divers, boaters, nature watchers, and anglers who normally use the waters near the dam area for their rec reational pursuits.

Sect. 3.2.1 describes the potential reservoir water quality impacts due to changes in release elevation. These possible changes could affect swimming, fishing, and wildlife observation at different times of the year and in different locations around the reservoir.

Long-term effects of expanding reservoir sizes to accommodate new hydropower generation regimes could result in both negative and positive impacts for recreational resources. Increased impoundment size could mean greater expanses of calm water for sailing. rowing. fishing, and swimming. On the negative side, access to the water could be changed due to higher water levels. For example, docks, boat ramps and marinas might have to be relocated or redesigned to accom modate the higher or more frequently changing water levels. Riparian vegetation and riparian aquatic habitat of some sports fisheries could be lost to expanded impoundments. Wildlife, possibly seasonal wildlife, could be affected by changes in the water regime in impound ments. This could affect hunting, fishing, and nature watching.

Anglers accustomed to using tailwaters might have to adjust to the changed water release regimes that would accompany conversion to

hydropower development. There could be safety risks to boaters and fisherman who use the areas immediately downstream of the newly converted dams. The smaller impoundments of the New England area might experience some changes in recreational use or potential with modest augmentation of reservoir size. Similarly, the loss of free flowing upstream waters and their associated recreational resources could mean some loss of recreational and aesthetic resources. On the larger reservoirs used for navigation and flood control in other areas, the increased surface areas would also likely be only modestly increased.

As described in Sect. 3.2.1, the installation of new hydropower facilities at existing impoundments can result in the withdrawal of water from different depths than was the case prior to conversion. The net result can be significant changes in water temperatures and in DO concentrations-potentially negative effects on fishing and swimming.

Mitigation can be provided for many impacts to recreation. Horns or warning whistles could notify recreational users just below retro fitted dams of the dangers of sudden water releases and the associated potential for rapid changes in water levels. Warning signs could also be posted on both riverbanks. Funds could be made available to compensate riparian owners who might have to lose lakeshore property, move docks or boat ramps, or otherwise change or redesign their use of the reservoir area. Fishing platforms could be installed to facili tate fishing access and safety along tai1waters areas.

3.2.6 Dam Safety and Flooding

3.2.6.1 Dam Safety

Some dam safety concerns are associated with retrofitting dams with hydropower. Removal of some parts of existing dams is usually required for installation of powerhouses and penstocks. This demoli tion must be conducted properly to avoid weakening the structure or foundation of the dam. The new structures and cofferdams must be properly designed and constructed to avoid failure.

When a hydropower dam operated by a federal agency (e.g., the Army Corps of Engineers or the Bureau of Reclamation) is retrofitted, the agency reviews the plans prepared by the hydropower developer and oversees all demolition and construction work. The agency retains responsibility for dam safety during construction and operation of the hydropower project. The agency review process and oversight responsibility are designed to prevent hydropower development from significantly increasing risks of dam failure.

When a hydropower project is proposed at a dam not operated by a federal agency, FERC evaluates dam safety as part of the licensing process. If the dam does not meet FERC's safety criteria, the project will not be licensed unless the hydropower proponent agrees to bring the dam into compliance with the safety criteria. If the project is licensed, the licensee assumes responsibility for the safety of the dam. The FERC requirement for a hydropower developer to assume respon sibility for safety of an existing dam may discourage development at

some dams but is designed to prevent hydropower development from significantly increasing the risk of dam failure. In cases where existing dams would be upgraded to meet FERC's safety criteria, an increase in dam safety would result from hydropower development.

3.2.6.2 Flooding

The construction of hydropower projects at low-head dams may, depend ing on design, increase the magnitude and frequency of flooding upstream (Schmitt and Varga 1988). For example, hydraulic modeling studies for powerhouses built at two existing navigation dams on the Allegheny River predicted that water levels during extreme floods would increase by up to 2 ft. as a result of the hydraulic resistance of the powerhouse. (Floodwaters would flow over the powerhouse less smoothly than over the existing dam.) During construction of projects, any obstruction (especially cofferdams) in the path of flood flows would increase the upstream flood elevations.

The potential increases in upstream flooding caused by retrofit hydropower projects can be studied with hydraulic models. Projects can be designed to minimize effects on flood· elevations. At projects where some increases in flood elevation are unavoidable, hydropower developers can avoid the financial impacts of increased flood eleva tions by purchasing flood easements.

3.2.7 Energy Security Benefits

The energy provided by retrofit hydropower projects would be a relatively small portion of the additional U.S. power needs expected by 2030 (less than 1% of the increase in fossil-fueled power genera tion expected between 1990 and 2030 under the NES reference case), but it would be relatively inexpensive and beneficial energy. This hydro electric resource would be totally domestic and renewable, so it would not be subject to foreign control or fuel shortages. Development at many existing dams could have minimal environmental impacts, so environmental concerns should not prohibit it. (However, real and perceived environmental impacts could lead to strong opposition to development at some existing dams.)

Energy obtained from many retrofitted dams, such as storage projects and navigation dams, would be as reliable as that from most existing hydroelectric projects. However, new power capacity at some kinds of dams, such as small projects, may provide less-reliable power because flows too low to generate occur frequently. Few retrofitted dams are expected to be allowed to use peaking operation or to other wise change storage patterns, so the projects would tend not to be useful for following daily or seasonal cycles of demand.

3.3 IMPACTS OF GENERATION USING FOSSIL FUELS

Generation using fossil fuels (coal, gas, and oil) accounts for most U.S. capacity and is likely to provide most of the power that would otherwise be generated by hydropower under the proposed DOE

initiative. The power provided under the initiative could replace the capacity of approximately 18 large (500-MW) fossil power plants. The environmental impacts of fossil-fueled generation have been described in other studies, including Dvorak et al. (1978) and DOE (1989).

3.3.1 Water Resources

Fossil-fueled generation causes a number of impacts to water resources. Fossil plants are generally constructed adjacent to large bodies of water, which provide cooling water and, sometimes, barge transportation of fuel. The construction of plants disturbs large land areas, which can increase erosion and, consequently, stream sediment loads.

Many water resources impacts of coal-fired generation result from coal mining and transportation. Coal mines in humid regions (such as the eastern United States) have historically caused severe degradation of water resources as a result of stream channel alteration (from direct effects of mining, hydrologic changes to watersheds, and increased sediment loads) and acid mine drainage. These impacts can be controlled to some extent but cannot be totally avoided. In arid regions, impacts of mining to water resources are generally less than in humid regions, although some impacts such as changes in groundwater can occur. Transportation of fossil fuels by barge on existing water ways generally has minor impacts on water resources, but some other modes of fuel transportation, such as coal slurry pipelines, can have major effects on local water resources. Coal is often washed at the mine or power plant to improve its burning and emissions qualities; this process consumes and degrades the quality of large amounts of water.

The production and transportation of gas and oil for electric power production also have impacts on water resources. These include impacts of offshore oil development and oil spills during transporta tion and refining.

The operation of fossil-fueled power plants causes a number of impacts to water resources. These plants require cooling water to condense steam prior to its reuse in the boilers. Cooling water can be used either once and discharged to surface waters or recycled using a cooling tower to release the heat to the atmosphere. Once-through cooling can cause significant temperature increases and evaporation in the receiving body of water. Cooling towers consume water by evap orating it and require the release of blowdown water, which has higher-than-natural concentrations of dissolved solids. On average, cooling is estimated to consume 1500 liters of water per megawatt-hour of power generation (DOE 1989). There are other smaller wastewater streams from fossil-fired power plants, such as boiler blowdown and scrubber effluents. Runoff from coal, fly ash, and scrubber sludge storage areas are other wastewater sources which. if not controlled, can release toxic compounds into surface water or groundwater. Water consumption for coal cleaning, scrubbers, and other uses besides cooling is estimated to average 2300 liters per megawatt-hour (DOE 1989).

Air emissions from fossil-fueled power generation have important regional impacts on water quality. Coal-fired power generation contributes large fractions of sulfur and nitrous oxide emissions, which cause acid deposition. The effects of acid deposition (both as precipitation and dry deposition) on water resources is being studied by the National Acid Precipitation Assessment Program (e.g., Malanchuk and Turner 1987, NAPAP 1990). The effects of acid deposition vary regionally with depOSition rates and also depend on local geology. The regions most at risk from acid deposition from U.S. power plants appear to be the northeastern United States and some of southeastern Canada.

Global water resources could be affected increasing carbon dioxide emissions (Waggoner 1990). The effects of increased greenhouse gas concentrations in the atmosphere are poorly understood, but regional changes in the amounts and timing of precipitation, air temperatures, winds, and vegetation types, all of which could result from global warming, would have major effects on water availability and water quality in many parts of the world.

3.3.2 Air Quality

Unlike hydroelectric generation, power generation using fossil fuels is a major source of air emissions. Emissions include fugitive dust releases from coal piles and mines, emissions from vehicles used to mine and transport fossil fuels, volatile hydrocarbon emissions from the storage and handling of petroleum and gas, and combustion emissions.

The air quality impact of fossil-fueled generation that is of greatest concern is the emission of the combustion products sulfur dioxide, nitrous oxides, particulates, and carbon dioxide.. Fossil fired electric power generation produces approximately 70% of U.S. sulfur emissions and 40% of nitrous oxide emissions but only about 10% of particulate emissions (Placet et al. 1986), These emissions are mostly from coal and oil combustion; natural gas-fired plants have significantly lower air emissions.

Sulfur dioxide and nitrous oxides are of concern mainly because they contribute to acidic precipitation and dry deposition, although they may also affect human health. Particulates have adverse effects on human health, weather, and visibility.

Carbon dioxide emissions are also of concern because of their contribution to potential greenhouse warming of the earth. Carbon dioxide emissions have risen steadily since at least the 1950s. It appears that approximately half of the carbon dioxide emitted remains in the atmosphere, where it may contribute to global warming, and the rest is dissolved in the oceans, taken up by vegetation, or otherwise sequestered (DOE 1989). Coal-fired generation in the United States contributes about 8% of the current global carbon dioxide emissions from energy consumption (including transportation). Fossil-fueled power generation in the United States is one of the largest single sources of carbon dioxide emissions but is still a relatively small part of the global emissions and activities that contribute to climate change concerns.

Many technologies (referred to as clean coal technologies) are potentially capable of reducing emissions of sulfur and nitrogen compounds from fossil-fueled plants (DOE 1989). These technologies are expected to be used even more in the future, especially following passage of the 1990 revisions of the Clean Air Act. However, no technologies exist to significantly reduce carbon dioxide emissions of fossil-fueled generation.

The effects on air emissions of replacing 9 GW of coal-fired capacity with hydropower were analyzed. Hydropower would result in greater reductions in air emissions if it were developed quickly, replacing existing conventional coal-fired capacity before most coal fired plants are converted to or replaced by clean coal technologies (DOE 1989). The scenario simulated is the replacement, over the period 1995-2010, of 2.25 GW of coal generation every 5 years. Predictions of air emissions from all electric utilities for 1990 to 2020 without the hydropower initiative are those estimated by DOE for the NES reference case; these predictions are based on actual emissions in 1987. It was assumed that coal-fired plants without clean coal technologies would be replaced by the additional hydro power. Table 1 gives the air emissions predicted under the NES reference case, and Table 2 gives the emissions predicted with the hydropower initiative.

With the hydropower initiative, emissions of particulate matter are predicted to change negligibly from the baseline case. This finding is attributed to the high removal rate of TSP at existing coal plants. The impacts of the hydropower initiative on sulfur dioxide, nitrous oxides, and carbon dioxide emissions are shown in Fig. 7. The predicted reduction in sulfur is 2.2% by the year 2010. Hydropower developed after about 2010 may replace power generated at relatively new plants (built during or after the 1980s) that use clean coal technologies and emit less sulfur. Therefore, hydropower developed after 2010 would be less beneficial in reducing emissions than would hydropower developed before 2010. The hydropower initiative would result in decreases of 2.1% in nitrous oxide emissions and 1.0% in carbon dioxide emissions from electric utilities by 2010.

3.3.3 Aquatic Ecosystems

Many of the impacts to aquatic ecological resources from construc tion and operation of fossil-fueled power plants are much different in kind and magnitude than impacts from the various hydropower alterna tives. Most of the construction of fossil plants occurs on land, and the same mitigative measures discussed in Sects. 3.1.1 and 3.2.1 to control erosion, sedimentation, and construction spills at hydro electric facilities can be employed to minimize aquatic impacts at fossil plants. Unless the fossil plant creates a cooling lake, losses of aquatic habitat are generally relatively small, comparable to those resulting from by upgrading or retrofitting existing reservoirs, and much less than the amount of riverine habitat lost to a new hydroelectric impoundment.

Operation of the condenser cooling system of a fossil plant can impact aquatic organisms through entrainment, impingement, and

Table 1. Predicted emissions from electric utilities under the National Energy Strategy reference case, and 1987 base values

Year	SO2 (10 3 tons/year)	NOx (10 3 tons/year)	CO2 (10 6 tons C/year)
1987	14630	6651	479
1990	14911	6737	495
1995	16426	7524	562
2000	17787	8370	653
2005	18231	8885	752

2010	18730	9496	863
2015	18811	10149	994
2020	17242	10086	1117
2025	15410	9986	1241
2030	13841	9859	1364

Table 2. Predicted emissions from electric utilities with the DOE hydropower initiative, and 1987 base values

Year	SO_2 (10^3 tons/year)	NO_x (10^3 tons/year)	CO_2 (10^6 tons C/year)
1987	14630	6651	479
1990	14911	6737	495
1995	16324	7473	560
2000	17582	8268	648
2005	17924	8732	745
2010	18324	9292	854
2015	18405	9945	985
2020	16836	9882	1108
2025	15004	9782	1232
2030	13435	9655	1355

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Sulfur Dioxide

36
34
32
30
28
26

1990 1995 2000 2005 2010 2015 2020

Year

Nitrous Oxides

30
28
26
24
22
20
18
16

1990 1995 2000 2005 2010 2015 2020

Year

Carbon Dioxide

11,000
10,000
9,000
8,000

Without hydro,Egwer initiative

With hydroP?Y'er initiative

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Year

Fig. 7. Air emissions from electric utilities with and without hydropower from the DOE initiative.

chemical and thermal discharges (Langford 1983). The amounts of water used to cool the power plant condenser can be large; a 1000-MW power plant with once-through cooling discharges about 48 cubic meters of water per second (761,000 gallons per minute) at a temperature ele vated 10°C (18°F) (Coutant 1981). Large numbers of aquatic organisms may suffer mortality as a result of being drawn through the cooling system (entrainment) or being trapped against the fine-mesh debris screens in the intake (impingement). Periodic discharge of chlorine or other chemicals and continuous discharge of heat can affect aquatic life in the receiving water.

Coal-fired power plants produce large amounts of solid waste (e.g., combustion ash and scrubber sludges). Leachates from both coal and ash piles can degrade water quality and have toxic effects on aquatic biota if not controlled. In addition to effects at the power generation site, water quality impacts or habitat losses associated with the entire fuel cycle (coal and oil extraction. refinement or cleaning, and ash disposal) can have significant impacts on aquatic communities over larger geographic areas (Hunsaker et al. 1990). Acid deposition from fossil plants (Sect. 3.3.1) can also affect aquatic biota in widespread areas.

3.3.4 Terrestrial Ecosystems

Impacts to terrestrial ecological resources from construction and operation of fossil plants are different in kind and magnitude than impacts from the various hydropower alternatives. Most construction of fossil plants occurs on land, and the area needed for facilities, storage piles. waste disposal. access, and utilities is much larger. Construction-related mitigative measures to control erosion, sedimen tation, and spills at hydroelectric facilities can be employed to minimize terrestrial impacts at fossil plants. Unless the fossil plant creates a large cooling lake, losses of terrestrial habitat may still be relatively small in a regional context, although larger than those for upgrading or retrofitting existing reservoirs for hydropower production.

Storage and disposal of large volumes of solid waste uses large land areas at coal-fired plants, sometimes including valuable habitats such as wetlands and floodplains. Inadequately controlled leachates from both coal and ash piles can degrade adjacent wetlands and soils in riparian zones and may have long-term toxic effects on terrestrial biota. In addition, potentially significant habitat losses are associated with the fuel cycle for coal-fired plants over larger geographic areas. Coal mining and transportation can seriously affect large areas of terrestrial habitat (Dvorak et al. 1978). Acid deposi tion and carbon dioxide releases from fossil plants may also cause long-term impacts to terrestrial ecosystems in large areas.

3.3.5 Recreation

The continued reliance on fossil fuels as the country's major source of electrical generating power could have significant impacts on recreational pursuits in some areas. Air quality impacts from coal

combustion (in combination with emissions from transportation) already affect the use of recreation resources by people with respiratory problems in some major U.S. cities during air inver- sion episodes. Acid deposition from coal combustion is believed to have affected fishing in lakes in New England and in some other areas of the country. Acid mine drainage from coal mines can affect the fishing, whitewater canoeing and kayaking, boating, swimming, hiking, and general aesthetic quality of streams in Appalachia and elsewhere. Surface mining of coal can disturb recreational opportunities such as hiking, hunting, and nature observation throughout the United States, although some reclaimed sites may enhance these same recreational resources.

Possible effects on recreation resources that may accompany increased concentrations of greenhouse gases in the atmosphere include changed regional precipitation quantities and regimes, more frequent and more severe air inversions, increased or reduced reservoir capac ities, more frequent and more severe major storms in coastal areas, sea level rise, altered wildlife habitat, and changed migration paths and times for wildlife. All of these will potentially affect almost any outdoor recreational pursuit.

Power generation using gas and oil results in some water quality impacts near refineries and drilling rigs and occusional oil spills onshore or offshore from tankers, rigs, or pipelines. All of these could affect recreational activities such as fishing, boating, swimming, and nature observation. Refineries are frequently viewed as noxious facilities (with both visual and olfactory impacts) incompatible with recreational resources. Pipelines can detract from aesthetic enjoyment of recreation where they occur. Increased use of gas and oil could mean drilling and other exploration and production activities in wildlife refuges and fragile offshore locations, with potential negative effects on recreational pursuits.

Natural gas desulfurization facilities, commonly located near the drilling rigs, could produce visual, auditory, and olfactory impacts in some relatively pristine environments in the western United States where the gas is found. Hiking, hunting, and nature observation could be affected.

3.3.6 Energy Security Benefits

Coal and domestic gas supplies provide a relatively secure energy resource. Coal is considered the most abundant nonrenewable energy resource in the United States. Fossil-fueled plants are highly reliable, although they may be affected by severe weather conditions such as droughts (which can make cooling less efficient and power production more expensive). Fossil-fueled thermal electric plants are not efficient for following daily demand cycles, but the use of gas turbine plants (which can respond quickly to changing loads but are less efficient) and pumped storage hydroelectric projects can mitigate this inefficiency. Fossil-fueled plants can have major environmental impacts, including air emissions of regional and global concern and consumptive water use, which can limit development of new plants at many sites.

Unlike coal and gas supplies, oil supplies in the United States are highly dependent on foreign sources. Power generation using oil is detrimental to energy security since it consumes a resource that is provided largely by foreign suppliers and has other important uses such as transportation and chemical production.

3.4 IMPACTS OF HYDROPOlrlER DEVELOPMENT AT NEW DAMS

The NES reference case predicts there will be increases in hydroelectric development at sites other than those affected by the DOE initiative. This scenario includes development both at existing dams and at sites requiring new dams or diversions. Impacts of development at existing dams would be the same as described in Sects. 3.1 and 3.2; impacts of hydroelectric development at new dams are discussed here.

New hydroelectric sites are expected to include mostly small dams, since few sites remain for new large-scale hydropower production. In a study of the potential development of small (less than 100-MY capacity) projects at new dams, FERC (1988a) predicted that, under favorable economic conditions and existing environmental constraints, approximately 180 new dams could be developed, with a capacity of about 1.5 CW. The national and regional environmental impacts of this development have been discussed in FERC (1988a).

3.4.1 Water Resources

The impacts of retrofitting dams to develop new hydropower (Sect. 3.2.1) are also encountered by projects at new dams. In addition, the impacts of constructing and operating dams, diversions, and reservoirs occur at new sites. In regions where many hydropower facilities exist, cumulative impacts to water resources, such as extensive water quality and aquatic habitat degradation, can occur.

Hydroelectric development at new sites usually involves substantial changes to local water flows and water quality. Simple diversion projects without storage capacity reduce water flows within the reach that is diverted but do not alter flow patterns downstream of the project. Larger projects that include storage reservoirs can change the seasonal flow patterns downstream of the plant-for example, by reducing flows during naturally high flow periods (by storing water) and augmenting flows during naturally low flow periods (by releasing stored water). Projects with storage can also induce daily flow cycles by releasing more water for generation during periods of daily peak demands. The impacts of reduced flows in a diverted reach can be mitigated by releasing more water (which cannot be used for generation) through the reach. The impacts of daily flow fluctuations can be mitigated by using a re-regulation structure to even out flows or by prohibiting such cycles.

New dams often alter water temperatures of the affected streams. Diversion projects reduce the flow in a stream reach, which allows greater solar heating and higher temperatures in the diverted reach. Projects with storage can have complex effects on temperature that

depend on the size and shape of the reservoir, local climate, and flow release patterns.

New reservoirs can substantially alter water chemistry in the reservoir and downstream of it. Impacts of reservoir operations on DO are discussed in Sect. 3.2.1. In addition, concentrations of nutrients (phosphorus and nitrogen) and algae can be altered within reservoirs. During the early years of a reservoir's operation, concentrations of nutrients and organic carbon are increased by the decay of the plants that were submerged.

3.4.2 Air Quality

New hydroelectric dams involve few air quality concerns. Fugitive dust and vehicle emissions occur during construction, but these emissions are usually short-term, local, and minor. No significant emissions typically result from operation of a hydroelectric plant.

3.4.3 Aquatic Ecosystems

Construction of new dams for hydropower development would cause impacts similar to those described in Sect. 3.2.3, except at a larger scale. The large amount of civil work associated with constructing the dam, powerhouse, penstock, roads, and other new facilities would result in greater risk of water quality degradation from soil erosion and spills. In addition, creation of an impoundment would eliminate free-flowing stream habitat behind the dam.

Hydroelectricity generation at a new dam may cause major changes in the timing and magnitude of stream flows below the reservoir, which in turn could significantly affect tailwater biota that were formerly adapted to a natural seasonal cycle of flows and temperature condi tions (Loar and Sale 1981, Sale 1985). The severity of these impacts depends on a number of factors, including the size (storage capacity) of the new reservoir and the length of the diverted reach. Turbine passage mortality (Sect. 3.2.3) could also affect fish populations in the stream.

A new hydroelectric dam will create a barrier to upstream move ment of fish that did not previously exist. This is a potential problem at any site but particularly where the stream supports runs of anadromous species (i.e., coastal and Great Lakes areas). Upstream fish passage facilities may be required to mitigate these effects (Hildebrand 1980a).

Compared with the other hydropower alternatives considered in this document, the chief additional impacts of development of new dams are loss of stream habitat (both above and below the dam) and the barrier to movements of fish represented by the new dam. These impacts are among the most difficult to mitigate and, from the standpoint of aquatic resources, may be the most serious impacts of new hydropower development.

3.4.4 Riparian and Terrestrial Ecosystems

Construction of new dams for hydropower development would cause impacts similar to, but more extensive than, those described in Sect. 3.2.4. The disturbance associated with constructing the dam, power house, penstock, roads, and other facilities would result in greater risk of habitat damage through soil erosion and spills. In addition, creation of a new impoundment could eliminate or alter terrestrial and riparian vegetation associated with free-flowing streams through inundation or flow changes.

Hydroelectric generation at a new dam may cause major changes in streamflows below the reservoir, which in turn could significantly impact tailwater wetlands and emergent vegetation. Projects that produce electricity by diverting water through penstocks for signifi cant distances may produce losses or undesirable changes to riparian zones along dewatered reaches (Kondolf et al. 1988). Such damage is particularly serious in semiarid or arid regions (including much of California and the southwestern United States) where streamsi.de vegetation is particularly important ecologically. In such regions the riparian zone may provide the only forest habitat.

3.4.5 Recreation

The creation of hydropower facilities at new dams involves a host of impacts to recreation resources but also offers new recreational opportunities. The impoundment of free-flowing streams necessarily means the conversion of aquatic habitat from flowing water to slack or slow-flowing water. It also can entail major reductions in flows in stream reaches.

Construction of dams, powerhouses, penstocks, intake structures, power lines, access roads, etc., can have severe negative impacts on fishing, swimming, hiking, and hunting. These effects should be short-lived in the East, but in the drier Yest, where vegetation takes longer to recover, the effects of hydropower development can be visible for years, affecting the aesthetics of many recreational pursuits. Development of high-head facilities will most likely cause more and longer-lasting construction impacts. than will the development of low-head facilities.

Many of the normal measures to protect against erosion and other disturbances common to licensed construction activities will be adequate to protect recreational resources from the worst construction impacts, but heavy equipment and major land-use change will cause severe effects on most recreational pursuits during the construction process. Following the measures outlined in Sect. 3.1.1.1 should ensure that long-term impacts from construction activities are minimized.

Blockage of fish migration can seriously affect the nature of the fishing resource and the types of fishing opportunities available. Partial dewatering can cause changes in riparian vegetation and the wildlife that it supports, inducing major changes to hunting, fishing. hiking. swimming, picnicking, and nature observation. Increased access through new roads can mean visitation by a wider variety of

users than that of the preconstruction site. Submergence of terres trial habitats by reservoirs has obvious long-term impacts on displaced recreational land uses (e.g., hunting, hiking, and nature observation could be replaced by fishing, boating, and swimming). Downstream of new hydropower facilities, long-term impacts could affect fishing, hiking, and boating.

Many impacts, including submerged lands, changed riparian vegetation, lost aquatic habitats, expanses of calm water, and partially dewatered streams, are irreversible as long as the facilities are in place.

3.4.6 Energy Security Benefits

The energy security benefits of hydroelectric development at new sites are similar to those at retrofitted dams (Sect. 3.2.6). However, the additional environmental impacts of developing new dams add uncertainty to the question of how much of this resource can be developed; environmental concerns would prevent the development of some new hydroelectric sites. Since few good sites remain for major new hydroelectric development, development at new sites can be expected to be less reliable (i.e., more vulnerable to short-term fluctuations in streamflows) and smaller than much of the existing hydropower resource.

4. CONCLlJSIONS

DOE's proposed initiative to upgrade existing power plants and to retrofit dams to generate new hydropower is expected to increase capacity by about 16 CW. This capacity could replace about 9 CW of fossil-fueled capacity or other electric power resources.

Hydropower plant upgrades can provide additional power with minimal environmental impacts. Upgrades that involve only efficiency increases are expected to have negligible impacts and to provide benefits such as reduced turbine mortality of fish and the opportunity to install aerating turbines. Upgrades that involve increasing the flow or head used by a plant (e.g., by adding turbines or raising the elevation of a reservoir) have greater potential to cause changes in the environment, such as changes in downstream flows and water quality and in the terrestrial environment near the reservoir. Mitigation techniques are available to minimize or eliminate most impacts of upgrade projects.

Retrofitting dams to generate new hydropower is attractive because most impacts of hydropower development have already occurred as a result of construction and operation of the dam. However, site specific impacts can still result, such as reductions in aeration at the dam, changes in reservoir and tailwater water quality resulting from changes in release elevation, turbine entrainment and mortality of fish, and slightly increased flood risks. Most of these impacts can be avoided or reduced by using common mitigation techniques. Site-specific evaluation of project impacts during the FERC licensing

process is designed to ensure that projects include adequate mitigation and that impacts are acceptable.

Hydropower developed under the proposed DOE initiative is most likely to replace fossil-fueled power generation. The use of fossil fuels for power generation has many potential significant environmental impacts. Coal- and oil-fired generation is an important contributor to local and regional air quality problems such as acid deposition. The extraction, transportation, and refining or cleaning of oil and coal involve many impacts such as oil spills, the impacts of coal mining, and solid waste disposal. Generation using natural gas causes fewer air emissions, but all fossil fuel combustion emits large quantities of carbon dioxide, contributing to the global greenhouse gas problem.

The development of hydropower at new dams could also be replaced by some of the power developed under the DOE initiative. Hydropower development at new dams involves some local, regional, and long-term impacts that would not result from development at existing dams, but generally does not cause impacts of global concern.

The hydropower that would be produced as a result of the DOE initiative would replace only a small part of the growth in U.S. fossil-fueled generation expected by 2030. The estimated 5.1 G~ of upgrade capacity and 10.6 ~ of retrofit c~paclty would replace approximately 1.2' of the increase in fossil-fueled capacity between 1990 and 2030 predicted under the NES reference case. However, there is a great need to reduce the impacts of fossil generation such as acid deposition, greenhouse gas emissions, and consumption of petroleum reserves. The proposed hydropower initiative could reduce sulfur emissions by replacing conventional coal-fired plants but would result in only very small reductions in emissions of nitrous oxides, carbon dioxide, and particulates. The development of hydropower at sites where impacts would be minor is an important and beneficial way to reduce fossil generation.

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Hyrdoelectric Power

http://www.ecospark.ca/wattwize/students/hydro December 07, 2014

Most electricity in Canada is derived from large-capacity hydroelectric plants with dams, which have a more serious environmental and social impact than do small ...

Dams produce water flow by elevating the water upstream from an electricity generation station. They create water reservoirs, the contents of which can be released depending on varying electricity demands. For more information on how hydroelectric power and dams work, have a look at this video .

Hydroelectric power is water power. Hydroelectricity is derived from the energy created by running or falling water. The pressure of flowing water turns underwater turbines, which are connected to a generator that produces electricity. Sometimes water flow and pressure are natural, but often they are created by dams constructed for that purpose.

There are two basic set-ups for hydro: the dam system and the run-of-river system. Dams are used for large capacity hydroelectric plants, while run-of-river systems have small plants with a very minor dam or none at all. The run-of-river system diverts some of the water in a river into a canal that sends the water through turbines at a small generation station. After that, it is channeled back to the river. The run-of-river system does not significantly alter the flow or water level of the river, unlike dams and reservoirs.

Hydroelectric power is a major electricity source in Ontario and the largest source in Canada overall. Most electricity in Canada is derived from large-capacity hydroelectric plants with dams, which have a more serious environmental and social impact than do small-capacity plants.

What are the benefits of hydroelectric power that make it so popular in Canada? And what environmental impacts should we consider when using electricity generated in this way?

Hydroelectric power and water. Basic information about hydroelectricity, USGS Water Science for Schools.

http://water.usgs.gov/edu/wuhy.html December 07, 2014

Hydropower is nonpolluting, but does have environmental impacts. ... and natural habitats in the dam area. Most hydroelectric power plants have a dam and a reservoir.

Hydroelectric power must be one of the oldest methods of producing power. No doubt, Jack the Caveman stuck some sturdy leaves on a pole and put it in a moving stream. The water would spin the pole that crushed grain to make their delicious, low-fat prehistoric bran muffins. People have used moving water to help them in their work throughout history, and modern people make great use of moving water to produce electricity. Although most energy in the United States is produced by fossil-fuel and nuclear power plants, hydroelectricity is still important to the Nation, as about 7 percent of total power is produced by hydroelectric plants. Nowadays, huge power generators are placed inside dams. Water flowing through the dams spin turbine blades (made out of metal instead of leaves) which are connected to generators. Power is produced and is sent to homes and businesses. Hydropower is the most important and widely-used renewable source of energy. China is the largest producer of hydroelectricity, followed by Canada, Brazil, and the United States (Source: Energy Information Administration). Approximately two-thirds of the economically feasible potential remains to be developed. Untapped hydro resources are still abundant in Latin America, Central Africa, India and China. Producing electricity using hydroelectric power has some advantages over other power-producing methods. Let's do a quick comparison: Fuel is not burned so there is minimal pollution Water to run the power plant is provided free by nature The technology is reliable and proven over time It's renewable - rainfall renews the water in the reservoir, so the fuel is almost always there Read an expanded list of advantages of hydroelectric power from the Top World Conference on Sustainable Development conference, Johannesburg, South Africa (2002) Disadvantages to power plants that use coal, oil, and gas fuel: They use up valuable and limited natural resources They can produce a lot of pollution Companies have to dig up the Earth or drill wells to get the coal, oil, and gas For nuclear power plants there are waste-disposal problems Hydroelectric power is not perfect, though, and does have some disadvantages: In some cases, inundation of land and wildlife habitat In some cases, loss or modification of fish habitat In some cases, changes in reservoir and stream water quality In some cases, displacement of local populations Hydropower is nonpolluting, but does have environmental impacts Hydropower does not pollute the water or the air. However, hydropower facilities can have large environmental impacts by changing the environment and affecting land use, homes, and natural habitats in the dam area. Most hydroelectric power plants have a dam and a reservoir. These structures may obstruct fish migration and affect their populations. Operating a hydroelectric power plant may also change the water temperature and the river's flow. These changes may harm native plants and animals in the river and on land. Reservoirs may cover people's homes, important natural areas, agricultural land, and archeological sites. So building dams can require relocating people. Methane, a strong greenhouse gas, may also form in some reservoirs and be emitted to the atmosphere. (EPA Energy Kids) Reservoir construction is "drying up" in the United States Gosh, hydroelectric power sounds great -- so why don't we use it to produce all of our power? Mainly because you need lots of water and a lot of land where you can build a dam and reservoir, which all takes a LOT of money, time, and construction. In fact, most of the good spots to locate hydro plants have already been taken. In the early part of the century hydroelectric plants supplied a bit less than one-half of the nation's power, but the number is down to about 10 percent today. The trend for the future will probably be to build small-scale hydro plants that can generate electricity for a single community. As this chart shows, the construction of surface reservoirs has slowed considerably in recent years. In the middle of the 20th Century, when urbanization was occuring at a rapid rate, many reservoirs were constructed to serve peoples' rising demand for water and power. Since about 1980, the rate of reservoir construction has slowed considerably. Hydroelectric energy is produced by the force of falling water. The capacity to produce this energy is dependent on both the available flow and the height from which it falls. Building up behind a high dam, water accumulates potential energy. This is transformed into mechanical energy when the water rushes down the sluice and strikes the rotary blades of turbine. The turbine's rotation spins electromagnets which generate current in stationary coils of wire. Finally, the current is put through a transformer where the voltage is increased for long distance transmission over power lines. (Source: Environment Canada) Hydroelectric-power production in the United States and the world As this chart shows, in the United States, most states make some use of hydroelectric power, although, as you can expect, states with low topographical relief, such as Florida and Kansas, produce very little hydroelectric power. But some states, such as Idaho, Washington, and Oregon use hydroelectricity as their main power source. in 1995, all of Idaho's power came from hydroelectric plants. The second chart shows hydroelectric power generation in 2006 for the leading hydroelectric-generating countries in the world. China has developed large hydroelectric facilities in the last decade and now lead the world in hydroelectricity usage. But, from north to south and from east to west, countries all over the world make use of hydroelectricity—the main ingredients are a large river and a drop in elevation (along with money, of course).

Environmental Impact of Hydroelectricity

http://turbinegenerator.org/hydro/environmental-impact-hydroelectricity December 07, 2014

Positive Environmental Impact of Hydroelectricity: 1. Hydroelectric power is considered a very clean source of renewable energy that emits very small, practically ...

1. Hydroelectric power is considered a very clean source of renewable energy that emits very small, practically negligible, amounts of greenhouse gases compared to fossil fuels.

2. They do not emit any carbon dioxide.

4. They do not require any sort of fire or combustion, so there is no risk of explosions or radioactive spills.

1. Hydro turbine generators, especially when is the form of a dam can cause serious damage to the surrounding ecosystems.

2. The water near the surface of a dam will become warmer, which will lower the oxygen content of the water and negatively impact certain species of plants and animals in the environment.

3. The height of the water level may frequently change when using a dam system which impacts the environment of plants and animals, especially animals that use the water near the shore line.

4. Dams make it difficult for fish to migrate up or downstream. Fish ladders are sometimes installed to make it easier for fish to travel past a dam, but it still can impede the movement of fish.

Micro-Hydro Electricity will not have the same negative environmental effects as large hydroelectric systems such as dams because micro systems require a much smaller, or often times, no reservoir of water to operate effectively. Yes, the micro hydroelectric systems will have a similar negative impact on the environment, but they will be significantly less than the larger dam systems that require a large reservoir of water.

Volcanoes of the Eastern Sierra Nevada

http://indiana.edu/~sierra/papers/2010/dietrick.html December 07, 2014

The Effects of Hydroelectric Power Production on ... With advances in waterpower technology reducing or eliminating the negative environmental effects of dams, ...

This paper describes the results of research conducted on hydroelectric power production. It considers the history and technicalities of hydropower, compares hydropower to other types of power, and examines its environmental impacts. In order to achieve this, a variety of sources have been referenced, looking at each side of hydropower: its basics, the business side, and various costs and benefits. Results showed hydropower to be a valuable source of power generation with a history of landscape destruction but the capacity to be the most environmentally friendly power source in the world. The benefits of hydroelectric power as a clean energy source are well worth the environmental costs it may inflict.

What is hydropower?

Hydropower is power created using fresh water, usually from rivers. Hydroelectric power is electricity created by using water to turn the blades of turbines. Water provides direct kinetic energy by twisting the blades, which are connected to power generators (Spilsbury and Spilsbury, 2008).

How It Works

Hydropower can be created through several different methods. Some hydropower plants use the run-of-river technique, which harnesses the natural flow of rivers (Spilsbury and Spilsbury, 2008). These are mostly smaller plants, called microhydro. However, most hydropower uses reservoirs of water stored in dams (see figure below). The water is then released through a sluice gate, and then turns a turbine (Spilsbury and Spilsbury, 2008).

Figure 1. Diagram of hydroelectric dam. Reproduced from Spilsbury and Spilsbury (2008).

Both dams and run-of-river systems use turbines (see figure below). Inside each turbine there is a shaft, which is attached to a generator. Water turns the rotor of the turbine. There are wire coils made of copper that move inside a circular strata of magnets when the rotor turns. This creates electrons when the wire coils pass the magnets, and the flow of these electrons is electricity. The generator is attached to transformers so that the electricity can be transmitted through cables over distances. All the utilities that are connected to these cables form the electric grid of the power plant (Spilsbury and Spilsbury, 2008).

Figure 2. Diagram of hydroelectric turbine. Reproduced from Spilsbury and Spilsbury (2008).

The History of Water Power

Using water for power is not a new idea. 4,000 years ago the Greeks used water to turn wheels to grind wheat into flour and the Chinese used water powered bellows (Spilsbury and Spilsbury, 2008). Water has been used in a variety of power-producing capacities throughout history, including pumps, waterwheels, clocks, and saws. In fact, water was used to run most machines until the invention of steam power in the early 19th century (Spilsbury and Spilsbury, 2008).

Water was first used to generate electricity in the 1880s, when generators were fixed to waterwheels for the first time (Spilsbury and Spilsbury, 2008). On September 30th of 1882, H.F. Rogers created electricity with the first commercial hydroelectric plant in the world, using a dam on Fox River in Appleton, Wisconsin (Davis, 2006). Hydroelectric power quickly established itself as an important power source, and by 1940, 40% of all electricity in the US was generated by waterpower. However, following WWII most new power systems were developed to use with fossil and nuclear fuels (Spilsbury and Spilsbury, 2008).

In the late 20th century, waterpower resurfaced as an important energy source when innovators began to experiment with harnessing the enormous power of the ocean waves and tides for hydroelectric power (Spilsbury and Spilsbury, 2008).

The History of Water Power Regulation

“This subject becomes political… And this subject is little known.”

-Jose Domingos Gonzalez Miguez, head of the climate sector of the Ministry of Science and Technology (MCT) of Brazil, Greenhouse Gas Emissions From Hydroelectric Dams

Most of the hydroelectric generation capacity in the US is controlled by one firm- the Bonneville Power Administration, or the BPA. This firm is, in actuality, a manifestation of the US government (Bushnell, 1998). Therefore most of the hydroelectric power in the US is government-owned.

Those few dams that are nonfederal, are regulated by the Federal Energy Regulatory Commission, or the FERC (Echeverria et al., 1989). Traditionally the FERC turned down most propositions for new dams. However, the Public Utility Regulatory Policies Act of 1978 drastically changed the way proposals were processed. The PURPA act accelerated the development of ‘clean’ energy and led the FERC to approve the construction of thousands of new dams (Echeverria et al., 1989).

There are still very few large-scale nonfederal hydroelectric projects, since large-scale dams are very expensive to construct (Spilsbury and Spilsbury, 2008). Therefore the electricity market, almost entirely controlled by the BPA, is highly deregulated (Bushnell, 1998) and there are often large gaps between what the public wants in terms of water power and what is actually occurring. Public support for environmental conservation is now higher than ever, but hydroelectric projects continue to be built in ways that cause environmental destruction (Rosenberg and Usher, 1985). Most of the problems that arise in regard to water power are problems relating to how they are regulated; they are problems “of jurisdiction and unfulfilled responsibilities (Rosenberg and Usher, 1985)” because, in many cases, these is insufficient lawmaking and regulatory practice to guide those endeavoring to use hydropower (Kahrl, 1982).

California’s Role

Most of the hydroelectric generation capacity in the US is located in the Pacific Northwest and California (Bushnell, 1998). In fact, hydropower plays such an important role in California’s history that Kahrl (1982) goes so far as to say that “the history of California in the twentieth century is the story of a state inventing itself with water.” He continues to posit that “the modern prosperity of the state has consequently been founded upon a massive rearrangement of the natural environment through public water development.” Hydropower, therefore, plays an important role in California’s modern economy.

Changes in Water Power

Most, if not all, of those against waterpower are primarily concerned with environmental harm caused by dams. Scientist Alexander Gorlov has developed a new turbine which would render these grievances immaterial by removing the need for dams altogether (Davis, 2006). The Gorlov Helical Turbine has the potential to “turn hydroelectric power into one of the most… environmentally benign renewable energy sources on the planet (Davis, 2006).” The Gorlov Helical Turbine would only use the energy of moving water, using hydrokinetic energy to create free-flow water power (Davis, 2006).

With advances in waterpower technology reducing or eliminating the negative environmental effects of dams, waterpower is now becoming a more viable option for the future of power production.

Current Water Power

One fifth of electricity worldwide is generated using water energy, mostly hydropower. The largest reservoirs and dams can be seen from space (Spilsbury and Spilsbury, 2008). However, waterpower is no longer a significant contributor to power in the United States. As seen in figure 3 below, the United States uses only 7% hydropower- but the actual amount of hydropower is comparable to that of other countries. The percentage is low because the United States uses a disproportionately large amount of energy in general (Spilsbury and Spilsbury, 2008).

.

Figure 3. Percentages of hydropower worldwide. Reproduced from Spilsbury and Spilsbury (2008).

600,000 miles of rivers in the US are currently being dammed (Echeverria et al., 1989). There are anywhere between 68,000 and 80,000 dams in total, which accounts for 17% of the 3.5 million miles of natural rivers in the US (Echeverria et a., 1989). Many have raised concerns that the amount of rivers being conserved is far too low- for each mile of river that is preserved, another 65 miles have been dammed (Echeverria et al., 1989).

Comparing Hydroelectric Power to Other Power Sources

Comparing Renewable and Nonrenewable Resources

Although power from ‘new’ energy is often more expensive than fossil fuels (Spilsbury and Spilsbury, 2008), there is a general public consensus that ‘clean’ energy (wind, water, geothermal) is more desirable than fossil fuels because renewables are “in endless supply” (Spilsbury and Spilsbury, 2008) and will not harm the environment. Though these claims are not entirely true, it certainly is true that nonrenewable resources are better for the environment than fossil fuels.

Emergy

Emergy is a term used to comprehensively measure the amount of energy needed to produce something. Emergy is the amount of available energy of one kind that is required to make something, and that is used up in the transformation process (Brown and Ulgiati, 2002). It measures the global processes needed to produce something. Therefore, the more work needed to produce something, the higher the emergy value of the product. This is called emergy valuation (Brown and Ulgiati, 2002).

Emergy valuation is beneficial because it measures both the thermodynamic and the environmental values of energy and material resources, thereby painting a truer picture of the effects production has on many different levels, and placing those effects within a common framework (Brown and Ulgiati, 2002).

Within the categories of renewable and nonrenewable resources, emergy index results are very similar. Using an emergy index of sustainability, it can be quantitatively proven that renewable energy source plants like wind, hydroelectric, and geothermal had higher sustainability compared to thermal plants, as would be expected (Brown and Ulgiati, 2002). These indices are shown below in Figure 4.

Environmental Loading

Environmental loading is a term used to refer to the “load” exerted on the environment when a process requires environmental services. It is also the concept that, once an environmental service is used by one process, it is not then available for use by another process (Brown and Ulgiati, 2002). Just as with emergy, it can also be quantitatively proven that renewable energy systems have lower environmental loading than nonrenewable energy systems (Brown and Ulgiati, 2002).

Figure 4. Emergy indices for different energy sources. Reproduced from Brown and Ulgiati (2002).

Comparing Different Renewables

As previously mentioned, the emergy and environmental loading results within the category of nonrenewable resources are very similar. However, the differences, small though they may be, show which of the renewables are the most sustainable.

As can be seen on the chart above, wind, geothermal, and hydro plants have the highest percent renewable inputs. Wind power has the highest renewability, followed by hydropower, then geothermal. Geothermal plants have high renewability but that renewability is coupled with high C02 release, much higher than wind or thermal and comparable to that of fossil fuel plants (Brown and Ulgiati, 2002). Additionally, geothermal plants may leave a larger and more long-lasting mark on the environment than wind or hydro power- at one plant in California, the hydrologic monitoring program on a plant found that geothermal development was causing changes in the hydraulic system as well as variations in precipitation and recharge (Class Binder, 2010). Plants should not be assessed just for their emissions, but also for their effects on the biosphere (Brown and Ulgiati, 2002).

Wind and hydropower plants also demanded less than half the amount of environmental support other plants required, demonstrating a lower pressure on the land. Wind and hydroelectric plants had the highest-over-all aggregated- that is to say, economic and ecological- sustainability, followed by geothermal electricity (Brown and Ulgiati, 333).

The Costs and Benefits of Water Power

Benefits

Once the high initial costs of construction are over, the actual operating costs of running a waterpower facility are very low- one quarter the price of operating a coal plant, and half the price of nuclear. In fact, hydropower is the cheapest way to generate power with today’s technology (Spilsbury and Spilsbury, 2008). In addition to its cheapness, water power is also very reliable, making it an excellent baseload power source- meaning that it can provide the energy needed all the time, not just during high demand periods such as intervals of very hot or very cold weather (Spilsbury and Spilsbury, 2008). Also, as mentioned above, hydropower is one of the most environmentally friendly forms of power production. However, it may be that hydropower gains its advocates not because of its good qualities, but simply because it is good in comparison to other power sources. In light of other energy crises, hydropower becomes a “benign bargain (Palmer, 2006).”

Costs

Hydropower has many advocates, but it also has many adversaries, who cite the “hidden costs of hydropower” and claim that the apparent benefits are merely a part of the “myth of hydropower (Palmer, 2006).”

The supposed costs of hydropower are varied and include negative effects on riparian zones, landscape destruction, and the release of greenhouse gases.

Riparian zones cover less than 1% of the landscape of the western US, but they provide valuable habitats for many species of breeding birds (Knopf et al., 1998). The importance of riparian zones as animal habitats is recognized by the government. The Bureau of Land Management has four basic policies in regard to riparian ecosystems: to avoid adverse impacts on riparian areas when possible, to avoid new construction in riparian areas where a practical alternative is available, to preserve and enhance riparian sites and regulate those uses which would cause irreparable damage, and to minimize actions causing definable adverse impacts (Knopf et a., 1998). However, these guidelines are very basic and riparian zones are under the jurisdiction of multiple governmental departments.

Specific written policies on riparian conservation have not been developed in the US Department of Agriculture’s Soil Conservation Service, despite numerous projects that have affected the conservation of riparian vegetation (Knopf et al., 1998).

The Bureau of Reclamation conducts projects designed to develop water resources in compliance with federal mandates, and the agency participates in riparian habitat and species management programs. However, BOR guidelines do not specifically address riparian or wildlife issues (Knopf et al., 1998).

The commonality throughout these departments is vague guidelines ensuring the protection and conservation of riparian zones, but a lack of specific attention and regulation.

Despite all the concern about effects that stream diversion for hydropower will have on riparian zones, in reality, the influence of diversion on riparian zones is not significant (Harris et al., 1987). The only impacts attributed to diversion as found by Harris et al. (1987) were increased shrub cover and decreased vegetated channel width, and diversion effects were not significant for any of the vegetation variables. Variability in results, as can be seen in Figure 5 below, impairs the possibility of generalization about vegetative responses- none of the results were consistent between different riparian zones studied, leading Harris et al. (1987) to conclude that riparian communities in the Sierra Nevada respond in an individualistic manner to hydroelectric diversions.

Figure 5. Effects of diversion on riparian streams. Reproduced from Harris et al. (1987).

Landscape Destruction

Hydroelectric power production can cause landscape destruction with redirected power- that is, power not used by the plant that is then unleashed on the surrounding landscape (Rosenberg and Usher, 1995).

Landscape destruction comes in many different forms- flooded reservoirs, river diversions, riverbank erosion, “dead zones” surrounding reservoirs due to drawdown, and far-reaching effects such as changes to ecosystems downstream of hydro plants, marked departure from past flows, long term reduction in summer and peak flows (which can cause wetlands to dry up), reduction of animal populations, reduced spawning success of fish, and 50-55% decrease in shorelines (Rosenberg and Usher, 1995). There could also be a reduction of soil fertility, and some scientists believe that big reservoirs can cause earthquakes as the weight of water pressing on rock weakens the earth’s crust (Spilsbury and Spilsbury, 2008). This is known as reservoir induced seismicity.

This destruction can occur quickly- the Owens Lake completely dried up in just 11 years when the Los Angeles Department of Water and Power expanded groundwater pumping (Hill, 1975).

The results of hydroelectric development are somewhat unique to specific projects; landscape destruction differs depending on the types of landforms involved (Rosenberg and Usher, 1995).

There is a lot of uncertainty surrounding the effects of hydropower development downstream of the project. These areas are often out of the jurisdiction of the agency responsible for the project, and there is a general lack of interest in pursuing post-audits of major projects due to their high costs and complexity (Rosenberg and Usher, 1995). As seen in Figure 6 below, much of the research going into the effects of hydropower development is guesswork at best.

Figure 6. Predicted effects of Hudson Bay hydroelectric project. Reproduced from Rosenberg and Usher (1995).

Greenhouse Gases

The release of greenhouse gases as a result of hydropower production is the newest “surprise” connected with reservoir creation (Rosenberg and Usher, 1995). The gases are released by microbial decomposition when upland forests and peatlands are flooded in the course of reservoir creation. Natural balances are upset by the flooding and the flux of greenhouse gases to the atmosphere increases. In fact, rate of emission after flooding may be similar to that of power plants run by fossil fuels (Rosenberg and Usher, 1995). Carbon dioxide emissions are highest during the first several years after filling a reservoir. Based on these first few years alone, any weighing of emissions impacts would favor fossil fuel alternatives over hydraulic generation (Fearnside, 2004).

Both the methane emitted from turbines and spillways and the carbon dioxide from above-water decay of standing trees contribute to emissions and pollution (Fearnside, 2004). Reservoirs can become virtual methane factories as the rise and fall of reservoirs flood and submerge land around the shore, causing vegetation to grow quickly then decompose when reservoirs rises again, which converts atmospheric carbon dioxide into methane (Fearnside, 2004).

Mercury also contaminates fish. Mercury has been found in fish many kilometers downstream of reservoirs in Canada, meaning these fish can carry the mercury to ecosystems otherwise out of reach of the dams themselves (Rosenberg and Usher, 1995). Reservoirs are now recognized as a leading cause of mercury contamination of fish (Rosenberg and Usher, 1995).

Rosenberg and Usher (1995) say that there is still a great deal of uncertainty surrounding hydroelectric development, and that some of the major impacts of hydroelectric development are still being identified.

The Issue of Values

The main issue surrounding hydropower may be that of values. The values of decision makers tend to differ from those of people concerned with environmental conservation. Although information about the adverse effects of waterpower is readily available, projects continue as before, without beneficial changes being implemented. For large-scale hydroelectric projects to make sense, water resources like rivers and lakes in their natural state would have to be regarded as having no monetary value (Rosenberg and Usher, 1995). Rosenberg and Usher (1995) assert that the attitude that these hydrological resources are wasted if they are allowed to exist in their natural state, and are not harnessed for industrial use, is commonplace.

This seems to be the case. The BPA places high value on being able to reduce its minimum flow requirements in June, the month when they are at their highest (Bushnell, 1998), despite the fact that these requirements are set in place in order to ensure the health of rivers and the fish and animals living in them.

The Electric Consumers Protection Act (ECPA) was created to change existing law that gave preference to power development, so that power development and the preservation of rivers would be giver equal consideration (Echeverria et al., 1989). However, if the rivers were valued for their natural benefits and uses, wouldn’t they be given more consideration than power development?

Conclusion

Though hydroelectric power has traditionally caused some environmental harm, it is not substantial enough to warrant this source of power unusable. Due to changing lifestyles and standards of living worldwide, energy needs are predicted to rise 50% in the next 20 years (Spilsbury and Spilsbury, 2008). As the United States and the world search for ways to increase the amount of power accessible without increasing strains on the environment, hydroelectric power could become a major part of the future of power generation.

Controversies in hydropower production provide a springboard for reevaluating the impacts of hydroelectric dams, and the role they play in climate change (Fearnside, 2004). The issues currently being experienced- i.e. greenhouse gases and landscape destruction- are not necessarily deal breakers for hydroelectric power, but perhaps an opportunity for scientists and innovators to discover new and improved methods for an old process.

If lakes were used only within their natural ranges, shoreline erosion and flooding- two of the most destructive elements of hydroelectric development- could be avoided (Rosenberg and Usher, 1995).

If public land management agencies could develop specific procedural guidelines for addressing management of riparian zones (Knopf et al., 1998) and other natural hydro resources, hydroelectric plants could work with the natural environment to utilize its power, instead of against it.

With the water resources available, there could be two to three times as much waterpower in the future as there is now (Spilsbury and Spilsbury, 2008). This added power can be harnessed from natural water sources or from pre-existing dams- only 3% of US dams are currently used for hydropower. These dams could be converted to include turbines and generators without much added cost (Spilsbury and Spilsbury, 2008).

Since dams are known to cause the most environmental harm of hydroelectric facilities, the biggest growth in the future will most likely be seen in wave, tidal, and microhydro installations (Spilsbury and Spilsbury, 2008). If the full power of hydropower was harnessed, use of fossil fuels could be cut drastically or eliminated. As Alexander Gorlov states in Alternative Energy Sources (2006), “The Gulf Stream (alone) contains enough energy for all of North America.” Hydropower could be the answer to questions about global warming, pollution, and sustainability- if it is used properly.

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Social and Environmental Impacts of Hydropower Projects

http://waterengnet.com/2011/social-and-environmental-impacts-of-hydropower/ December 07, 2014

Social and Environmental Impacts of Hydropower ... Hydroelectric power ... Changes in water quality are potential outcomes from locating a dam in a river. Effects are ...

The world population is growing at an accelerated rate. The question arise as how the people on this planet will continue to get the electricity to drive the economic engine. While most of the new generation energy supply will come from thermal resources, there is greater emphasis on using sustainable, renewable resources these days. Hydroelectric power is a renewable energy and has an important role to play in the future. It provides considerable benefits to an integrated electric system.

Similar to other infrastructure projects, hydro projects can have both positive and negative social and environmental impacts. The construction of a dam and power plant, along with the impounding of a reservoir has certain social and physical impacts. However, if anticipated and tackled early in the planning stage of a project with the required resources, the negative impacts can be addressed in a positive manner for local people, or in some cases avoided altogether. Whenever these impacts cannot be avoided or mitigated, compensation measures can be implemented.

Social aspects associated with development of hydro projects are mainly associated with transformation of land use in the project area, and displacement of people living in the reservoir area.

Relocating people from the reservoir area is the most challenging social aspect of hydropower, leading to significant concerns regarding local culture, religious beliefs, and effects associated with inundating burial sites. While there can never be a 100 percent satisfactory solution to involuntary resettlement, enormous progress has been made in the way the problem is handled. The countries in Asia and Latin America where resettlement is a major issue have developed comprehensive strategies for compensation and support for people who are impacted. The keys to success are clearly: timely and continuous communications between developers and those affected; adequate compensation, support and long term contact; and efforts to ensure that the disruption of relocation is balanced by some direct benefits from the project.

During the construction phase of a hydro scheme (often several years) there may be a large workforce, and access roads can lead to a sudden influx of outside labor and the development of new economic activities, with resulting tensions if populations in the area in question are unprepared. Issues of resettlement, sustainable livelihoods, cultural impacts and flood control must be addressed. Effective mitigation measures can be implemented if local authorities and project promoters acknowledge and address these issues. On the positive side, the additional economic activities create new employment opportunities.

During the operational stage, the hydro project may represent a significant source of revenues for local communities. The access roads, local availability of electricity and other activities associated with the reservoir are all possible sources of sustainable economic and social development. There must be good co-operation between proponents, authorities, political leaders and communities, and long-term benefits must be directed to affected communities.

Socially acceptable hydropower means that any proposal for a project must be discussed with stakeholders and adapted to their needs, and that successful negotiations must be concluded with affected local communities for a project to move ahead.

The IHA (International Hydropower Association) Working Group on Environmental Impact Assessment (EIA) calls for impact assessment to be an integral part of the multidisciplinary planning approach, and to include a strong element of public consultation. EIAs should cover both positive and negative impacts both upstream and downstream of a proposed project.

Sedimentation

Sedimentation occurs when weathered rock, organic and chemical materials transported in a river system are trapped in a reservoir. Over time these sediments build up and begin to occupy a significant volume of the original storage capacity. While large dams and reservoirs are often designed for an operating life of 100 years, there are cases where reservoirs have faced sedimentation problems within a much shorter time.

It is recommended that sediment yield of the river on which the project is located is assessed as accurately as possible at the conceptual stage of a project, so that appropriate measures can be taken. Erosion reduction techniques may have to be implemented in the upstream catchment area to reduce the sedimentation problem.

A number of measures can be taken such as periodic flushing or dredging from reservoirs. In the case of run-of-river projects, flow diversion structures can be provided with sediment excluding devices.

Hydropower projects have impacted fish and fisheries in a number of ways. These include changes in habitat quality and availability, changes in flow regime, and fish passage.

Many hydroelectric facilities rely on storage of water during high flow periods for use in generation of energy later in the year. This alteration of the natural river cycle can impact habitat availability and stability during periods of spawning and incubation. Determining appropriate flows for maintenance of habitat during all life phases is an important step in defining bounds on operations. However, these limitations can be readily identified and implemented.

There has been lots of research conducted on the specific risks to different sizes and species of fish. Measures commonly used include fish screens at turbine inlets, and many countries require this by law. Finer meshed screens can be placed at times of year when fish are actively migrating.

Various types of self-cleaning screen have been developed to cope with the build-up of debris. Behavioral methods have also been developed to defer fish from the intake, and guide them to the safety of a bypass channel.

Water Quality

Changes in water quality are potential outcomes from locating a dam in a river. Effects are often experienced both upstream and downstream of a dam. Some of the effects can be increased or decreased dissolved oxygen, increases in total dissolved gases, modified nutrient levels, thermal modification and heavy metal levels.

Longer term water quality problems generally reflect changing land use in the watershed. A recent study sponsored by the Environmental Protection Agency (EPA) in the USA identified agricultural practices to be the source of the majority of water pollutants, with industrial and municipal waste treatment and discharges also being major contributors. In the developing world the lack of waste treatment in the watershed will contribute significantly to the future availability of potable drinking water.

The world's remaining hydroelectric potential needs to be considered in the new energy mix, with planned projects taking into consideration social and environmental impacts, so that necessary mitigation and compensation measures can be implemented. Clearly, the population affected by a project should enjoy a better quality of life as a result of the project.

Any development involves change and some degree of compromise, and it is a question of assessing benefits and impacts at an early enough stage, and in adequate detail, with the full involvement of those people affected, so that the right balance can be achieved.

Environmental impacts of increased hydroelectric ...

http://hydropower.inel.gov/environmental/pdfs/ornltm-11673.pdf December 07, 2014

ORNL/TM- 116 7 3 Environmental Sciences Division ENVIRONMENTAL IMPACTS OF INCREASED HYDROELECTRIC DEVELOPMENT AT EXISTING DAMS S. F. Railsback

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Environmental Sciences Division

ENVIRONMENTAL IMPACTS OF INCREASED HYDROELECTRIC DEVELOPMENT
AT EXISTING DAMS

S. F. Railsback
G . F. Cada
C. H. Petrichl
M. J. Sale
J. A. Shaakir-Ali2
J. A. Watts
J. W. Webb

1. Energy Division
2. Computing and Telecommunications Division

Environmental Sciences Division
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Prepared by the
OAKRIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
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This report describes the environmental impacts of a proposed U.S. Department of Energy (DOE) initiative to promote the development of hydropower resources at existing dams. This development would include upgrading existing hydropower plants and retrofitting new projects at dams where no hydropower currently exists. It is estimated that by the year 2020 the following increases in the nation's hydropower capacity would result from the proposed initiative:

	C a m c i t y increase (GW).	
	jJD erades	Petrof itE
At nonfederal dams	2.2	5.8
A t federal dams	u	4.8
Total	5.1	10.6

The plant factors (the percentage of the capacity that would actually be generated, averaged over time) for hydropower upgrades and retrofits are assumed to be 14% and 50%, respectively. Assuming that fossil-fueled plants have a plant factor of 6 5 % , the power provided under the proposed hydropower initiative could replace approximately 9 GW of fossil-fueled capacity, or approximately 18 large (500-MW) coal-fired power plants.

Existing hydropower plants can be upgraded by (1) increasing the efficiency of the turbines and generators and (2) increasing the flow or head used by the plant. These two methods of upgrading pnants cause different environmental impacts.

The efficiency of a plant can be improved by replacing obsolete or worn turbine or generator parts with new equipment, fine-tunfng performance, reducing friction losses of energy, and automating operations. These efficiency improvements are expected to have only very minor and short-term environmental impacts. Replacement of turbine gates and runners (the surfaces against which water is impinged) can be environmentally beneficial because more efficient turbines generally kill fewer fish, and because new turbine parts can be designed to facflitate aeration at dams that release water with low dissolved oxygen (DO) concentrations.

Upgrading an existing plant to increase its flow or head can be accomplished by adding more turbines or replacing turbines with larger units, raising the reservoir level to increase head and storage capacity, or by reallocating the storage in a reservoir to increase the flow available for hydropower. The potential adverse effects of flow and head increases include (1) changes in downstream water quality (especially DO concentrations and temperatures) resulting from altered reservoir release patterns or from decreases in the amount of flow that is aerated when spilled from the dam, (2) changes in reservoir water quality from changes in the volume and the quality of water released, (3) reduced fish populations or growth because of water

quality changes, (4) increased entrainment and mortality of fish in turbines, (5) effects of altered reservoir levels on the terrestrial environment, and (6) altered availability of recreation. These impacts are expected to be minor in most cases, but the extent of impacts will depend on the kind of upgrade and the local environment. Most impacts would be local and could be adequately mitigated with available technology.

Retrofitting existing dams with new hydropower plants provides the benefits of new hydroelectric capacity without many of the environmental impacts of constructing new dams. New hydropower can be installed at existing storage and flood control dams, navigation dams, other kinds of impoundments, and water works such as canals and pipelines. The potential adverse environmental effects of retrofits include (1) changes in water quality (both in tailwaters and in reservoirs) resulting from changes in reservoir release volumes and qualities, (2) reductions in DO resulting from decreases in aerated spill flows, (3) mortality of fish that pass through turbines, (4) minor changes in recreational uses, and, (5) in some cases, small changes in flood elevations. As with the upgrading of existing plants, most of these impacts are local and can be adequately mitigated.

Increased hydropower capacity offers many energy security benefits. This resource is domestic and renewable. The environmental impacts of most hydropower development at existing dams are minor, so environmental concerns should not prohibit the development of most sites. However, the plant factors for projects developed at existing dams under this initiative may be lower on average than for existing operations, since the most reliable hydropower resources in the United States will have already been developed. Many new hydropower projects at existing dams may not be allowed to alter daily or seasonal flow release patterns and so may not be useful in following peaks in power demands.

The environmental impacts of fossil-fueled power generation, which would be reduced by the DOE initiative, are of greater regional and global significance than those of hydropower. These impacts include the negative effects of extraction and transportation of fossil fuels, emissions of acid-producing compounds, emissions of greenhouse gases, and disposal of large volumes of solid waste. The hydropower initiative is estimated to reduce the sulfur dioxide emissions from coal-fired generation by up to 1.3% by the year 2020. However, reductions would be less than 1% for nitrous oxides and less than 0.1% for particulates and carbon dioxide. (Hydropower would replace older fossil-fueled plants that emit more sulfur than do newer plants, which is why reductions in sulfur are predicted to be greater than reductions in other emissions. Newer plants do not generally emit less nitrous oxide or carbon dioxide than do old plants. Reductions in particulate emissions are low because almost all fossil-fueled plants currently have adequate particulate emission controls.)

Development of new hydropower capacity at new dams is a renewable energy resource that could also be partially replaced by the power resulting from the DOE initiative. Development of hydropower at new

dams has impacts similar to, but of greater magnitude than, development at existing dams.

Hydropower development at existing dams has, in general, fewer impacts than development of additional fossil-fueled resources or hydropower at new dams, although potential cumulative impacts of developing multiple hydropower projects have not been explicitly addressed. Environmental review of project impacts and mitigation needs can ensure that additional hydropower development at existing dams can provide a renewable, domestic energy resource with fewer impacts than alternative resources.

1. INTRODUCTION

This report has been prepared in support of the National Energy Strategy (NES) to examine the potential environmental effects of an initiative to enhance the development of hydropower at existing dams. This initiative is being considered by the U.S. Department of Energy (DOE) as a way to increase energy resources that are domestic, renewable, and environmentally acceptable. The initiative would promote both the upgrading (increasing the capacity and energy production) of existing hydropower projects and retrofitting hydropower (constructing new projects) at existing dams. The hydropower development that would result from this proposed initiative would be in addition to the growth in hydropower production that is expected to occur without it. This report compares the environmental effects of the proposed hydropower initiative with the effects of producing the same amount of power using the energy sources that the additional hydropower would likely replace.

The regions where additional development at existing dams is most likely to occur can be predicted from data on the location of suitable dams. However, the exact sites where additional development would occur with and without the initiative are urknown at this time. Therefore, this report discusses environmental effects qualitatively, noting regional differences in impacts Where they occur. Site-specific impacts of projects developed under the proposed initiative would be assessed before such projects would be (1) licensed for construction by a nonfederal entity or (2) constructed by a federal agency. This report covers only the development of additional conventional hydropower resources; it does not consider pumped storage projects .

The impacts of increased power production at existing dams are compared with impacts of two likely alternative electric power sources. Because the hydropower resulting from the proposed initiative is most likely to offset use of new or existing fossil-fueled generation and hydropower at new dams, the impacts of these other energy sources are compared with the impacts of the initiative.

2. DESCRIPTION OF PROPOSED INITIATIVE AND ALTERNATIVES

The hydropower initiative being considered by DOE would promote the upgrading of existing hydropower projects by increasing efficiency and by increasing capacity and energy production to the extent possible without unacceptable environmental impacts. The initiative would also promote the development of hydropower at existing dams where no power is currently generated. This section describes the proposed initiative and the kind of development that would occur under it. This section also briefly describes the power resources that are expected to be replaced should the hydropower initiative be implemented.

2.1 UPGRADING EXISTING HYDRO€”ER PIANTS

There are many ways to increase power production at existing hydropower projects. These can generally be classified as (1) methods to increase the efficiency of power generation [producing more power per unit of flow and head (elevation difference)] and (2) methods to add to the amount of water flow or head that can be used.

Methods of increasing efficiency include

1. replacing old turbine gates (the surfaces which control the flow and direction of water entering the turbine) and runners (the turbine blades) with newer, more efficient designs;
2. replacing turbine runners with new ones of the same design to eliminate cavitation or other imperfections;
3 . rewinding generators to make them more efficient;
4. fine-tuning turbine performance (e.g., gate and blade angle settings) to maximize efficiency;
5. eliminating leakage of water through gates or other structures,
6. improving trash rack cleaning to reduce friction losses of energy from them;
7. using coatings to reduce friction losses of energy in flow

passages ; and
8. installing automated diagnostic data collection and analysis systerns.

Methods being considered by DOE to increase usable flow and head include
1. adding more turbines to utilize flow that otherwise would be spilled,
2. replacing turbines and generators with new equipment that can use a wider range of flows,
3. raising the elevation of a dam to increase its storage capacity and head, and
4. making other changes in the allocation of reservoir storage and releases.

DOE predicts that, between the years 1990 and 2020, its initiative to upgrade existing projects would result in the development of approximately 2.2 GW of generating capacity at nonfederal projects (in addition to development that would occur without the proposed initiative) and approximately 2.6 GW at projects operated by federal agencies.

The Federal Energy Regulatory Commission (FERC) Hydropower Resources Assessment data base was used to determine the location of projects most likely to benefit from upgrades. Existing hydropower projects (federal and nonfederal) that were constructed prior to 1940 and those constructed between 1940 and 1970 were identified. Projects constructed prior to 1940 are considered most likely to benefit from upgrades, but projects built between 1940 and 1970 may also gain improved power generation through upgrading. The type of turbine used at a project also affects how beneficial an upgrade could be. Figure 1 shows the locations of existing hydropower projects that may be candidates for upgrade projects because they were constructed before 1940 or between 1940 and 1970. The figure also shows whether the projects use Francis or propeller turbines. (Figure 1 includes only

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the 186 projects for which adequate data were available; there are additional existing projects where either the age of the plant or the turbine type is missing in the data base. The 186 mapped projects include 95 built before 1940 with Francis turbines, 41 built between 1940 and 1970 with Francis turbines, 31 built before 1940 with propeller turbines, and 19 built between 1940 and 1970 with propeller turbines.)

2.2 RETROFITTING DAMS TO DEVELOP NEW HYDROPOWER

Testimony presented at public hearings for the NES indicated that only about 5% of 67,000 existing dams in the United States have hydropower capacity. Many of these dams are unsuitable for hydropower development because they are too small, too remote, or do not meet safety criteria. However, DOE (1990a) estimates that there are 2600 dams at which conventional hydropower could be developed. These dams include flood control and water supply reservoirs, navigation dams, abandoned or retired hydropower facilities, dams developed to provide industrial water power, and others. Some of these sites are currently being developed privately without DOE'S proposed initiative, but many others are not being developed because of a combination of high development costs, relatively low energy prices, and regulatory problems (DOE 1990b).

Retrofitting a dam to generate hydropower (Fig. 2, an example at a navigation dam) usually involves (1) construction of intakes, penstocks, and a powerhouse that either replaces part of the existing structure (at low-head dams) or is located downstream (at high-head dams); (2) diversion through the turbines of water that previously was spilled through gates or over a fixed-crest or spillway; (3) construction of power lines to tie the project into the existing power grid; and (4) implementation of mitigation measures to reduce the impacts of the project. Mitigation measures may include flow release requirements, construction of fishing facilities, use of screens to keep fish out of the turbines, and water quality monitoring.

DOE predicts that its proposed initiative will result in the development, through new projects to retrofit dams between the years 1990 and 2020, of 5.8 GW of new capacity at nonfederal dams (in addition to development that would occur without the proposed initiative) and 4.8 GW of new capacity at projects operated by federal agencies .

The locations of approximately 2400 existing dams with hydro-power development potential included in the FERC Hydropower Resource Assessment data base are shown in Fig. 3 . The proposed DOE initiative would result in the development of less than half of these sites (some sites are expected to remain undeveloped, and others will be developed even without the DOE initiative), but Figure 3 can be used to determine the geographic regions where dams could most likely be retrofitted to generate hydropower.

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Fig. 2. Proposed retrofit of hydropower at an existing navigation dam. Source: Application for license to the Federal Energy Regulatory Commission, Allegheny River Lock and Dam N o . 4 Project, FERC No. 7909, Allegheny County Hydropower Programs.

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Fig. 4. Energy sources for electric power generation under the National Energy Strategy reference case.

2.3 ALTERNATIVES TO HYDROPOWER DEVELOPHENT AT EXISTING DAW

For this report, it is assumed that energy not produced through additional hydropower development at existing dams would be provided by the mix of electric energy sources in the NES reference case. The NES reference case is DOE'S prediction of the future mix of energy sources in the United States without additional policy changes. This mix is illustrated in Fig. 4, which shows U.S. energy consumption for electric power generation, from the sources oil, gas, coal, nuclear, and renewables, in units of quads Btu) as it is predicted to change over time.

The development of additional hydroelectric generating capacity through the DOE hydropower initiative can be assumed to replace (1) new capacity that has greater costs (including capital costs and environmental impacts) than hydropower development at existing dams or (2) existing capacity that is expensive to operate, such as obsolete plants or plants using expensive fuel. The exact mix of capacity that would be replaced by hydropower under the proposed DOE initiative can be predicted only with detailed consideration of future energy costs, the types and locations of existing and future power plants, and site-specific environmental considerations. The predicted generating capacity provided by the initiative would nat have major effects on generation in any region of the United States but would probably make subtle changes in the power resources of several regions.

Figure 4 shows that most future power production under the NES reference case will be from fossil fuels, mainly coal, and that fossil fuels are also expected to provide the most growth in capacity. Therefore, it is assumed that the hydropower resulting from the DOE initiative would most likely replace additional power generation at fossil-fueled thermal electric plants. The generating capacity resulting from the DOE hydropower initiative is uncertain, but, for purposes of comparison with alternative power sources, it is assumed that the new hydroelectric capacity developed by the year 2030 under the initiative would replace 9 GW of thermal electric capacity.l This capacity is that of approximately 18 large coal-fired generating stations.

As discussed previously, the NES reference case includes substantial increases in hydroelectric power, including the development of new dams. Hydroelectric power is the largest component of renewable energy capacity under the NES reference case, which includes the growth in hydroelectric power generating capacity illustrated in

'This estimate is based on (1) a total of 5.1 GW of capacity, with a plant factor of 14%, for upgrades at existing hydropower projects; (2) a total of 10.6 GW of capacity, with a plant factor of 5 0 % , for new hydropower projects at retrofitted dams; and (3) a plant factor of 65% for fossil-fueled thermal electric generation. The plant factor for upgrades is taken from DOE (1990a). The plant factors for retrofits and for fossil-fueled plants are approximate national averages.

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Fig. 5. Hydroelectric development predicted under the National Energy Strategy reference case, with and without the DOE initiative promoting development at e x i s t i n g dams.

Fig. 5 (which illustrates the growth in hydropower capacity predicted to occur with and without the proposed DOE initiative). Because additional development of hydropower at existing dams resulting from the initiative may offset some of the hydropower expected at new dams in the NES reference case, additional hydropower at-new sites is discussed here as an alternative to the DOE initiative. (New hydro-electric power projects in Canada are currently an important and growing power resource, especially in the northeastern United States, where contracts for firm Canadian power supplies have recently been executed. Many Canadian hydroelectric projects are large and have had significant environmental impacts. However, the impacts of new Canadian hydropower development are not considered in this document.)

Under the NES reference case, nuclear power capacity is expected to decrease as existing plants reach their design lives and as their operating licenses expire. Therefore, additional nuclear power development is not discussed as an alternative power source.

3. ENVIRONMENTAL INPACTS OF THE PROPOSED INITIATIVE ANI) ALTERNATIVES

This section discusses the environmental impacts of the hydropower development that would result from the proposed initiative and the impacts of developing the power through other means. The discussion is most detailed for hydropower development and for fossil-fueled generation, the most likely alternative. Measures to mitigate the impacts of hydropower development at existing dams are also presented, Mitigation can be costly in some cases, but the costs of mitigation and their effects on the economic viability of projects are not evaluated here.

3.1 IMPACTS OF UPGRADING EXISTING WDROPOWER PUNTS

The environmental impacts of upgrading existing hydroelectric plants are generally minor compared with the impacts of other energy development. The impacts depend on the kind of upgrade made. Upgrades involving only replacement of turbines or generators, without changes in the volume or timing of reservoir releases, are expected to cause only minor and short-term impacts and could have some long-term environmental benefits. Upgrades that include increases in reservoir storage capacity or changes in the volume or timing of releases could have some long-term impacts.

3.1.1 Water Resources

3.1.1.1 Construction Impacts

Upgrades involving only replacement of turbines or generators, without alterations i n intakes, draft tubes, or other structures, can be completed with little or no effects on water resources. Such

upgrades require little outdoor work, so impacts such as erosion, disturbance of the riverbed, or fuel spill risks should be minimal. Reservoir levels and streamflows would not be changed by such upgrades.

Upgrades to install larger turbines or more turbines require more extensive construction and therefore have greater potential for impacting water resources. Such upgrades may require installation of cofferdams, dredging or excavation upstream or downstream of a dam or powerhouse, and the use of heavy machinery and outdoor storage areas. These kinds of activities can increase the local erosion of banks and streambeds during construction, resulting in increased sediment loads and potential deposition downstream. Sediments at a dam may be disturbed and redistributed by construction; if sediment contamination occurs locally then sediment redistribution may have adverse effects. The use of machinery near or in the waterway presents a risk of small fuel spills. These construction impacts are short-term, occurring only while the upgrade is being completed. It is unlikely that significant impacts on water quality (i.e., impacts that could have long-term effects on aquatic life) would occur during construction.

At upgrade projects involving extensive construction, or at simpler upgrades at projects with only one turbine, river flows in the tailwaters may be stopped for longer periods than would otherwise turbines and generators requires that there be no flow through the turbine, and at projects with storage capacity there may be no releases if the nature of the upgrade requires that all turbines be shut down. Shutting off releases to the tailwater could result in temporary dewatering and stagnation of the tailwater, contributing to high algal growth and low or highly fluctuating dissolved oxygen (DO) concentrations with consequent adverse effects on aquatic organisms.

Mitigation can be implemented to minimize or avoid most construction impacts. A t multiturbine projects, normal flows in the tailwaters can be maintained by operating other turbines when one is shut down for upgrading. At some single-turbine projects, tailwater flows could be maintained, if necessary, with nongenerating releases from gates or spillways, although prolonged nongenerating releases may offset much of the benefit of upgrading. Construction impacts such as erosion and fuel spill risks are typically addressed in the lkensing and permitting process for hydropower upgrades. Projects involving disturbance of the streambed or adjacent riparian zones or wetlands require permits from the U.S. Army Corps of Engineers and may also require water quality certification from the appropriate state water resources agency. These permits (which are issued under the Clean Water Act) and FERC license amendment orders for project upgrades are designed to mitigate construction impacts. Requirements of permits and FERC orders typically include development and approval of plans for (1) prevention of erasion, (2) prevention of fuel spills, and (3) deposition of dredged material. Compliance with permit and FERC licensing requirements should adequately mitigate construction impacts of major plant upgrades.

3.1.1.2 Decreased Aeration

Project upgrades can include installation of turbines capable of using higher flows at sites where some flow is otherwise spilled through gates or over spillways. Flows in excess of turbine capacity are spilled at such projects, because the existing turbines are too small to use all of the flow. The flows that are spilled may be aerated to some degree (i.e., the DO concentrations increased) during spillage. Increasing the capacity of the turbines would result in a higher percentage of the flow passing through the turbines, where little or no aeration occurs. At projects where DO concentrations are low (because of either upstream water quality impacts or impacts of the project itself), and where upgrading would result in less flow being aerated during spillage, there would be a net decrease in DO concentrations downstream. At sites where spillage occurs only during times of high flows (when DO concentrations do not tend to be low), impacts of using the spillage for power generation may not be significant. This impact tends to occur at low-head dams where the original project purpose was not hydropower and is less likely to be important at upgrades than for new hydro retrofits.

Decreases in downstream DO resulting from reduced spillage can be mitigated when necessary by requiring the projecz to spill flows through gates or over spillways, where aeration occurs. Such spill flows may be required during periods of low flows or high water temperatures, when DO concentrations tend to be low. Mechanical aeration processes (such as pumping air into the water as it passes through the turbine) have not yet been shown capable of economically replacing spill flows as a way of maintaining DO concentrations at low-head plants.

3.1.1.3 Improved Turbine Aeration

The replacement of turbines at projects that routinely suffer water quality problems offers the potential to reduce these problems. Many deep reservoirs stratify in summer, with a layer of cold water with low DO concentrations forming on the bottom. When this cold, deoxygenated water is released through the turbines, it provides inadequate DO in the tailwaters. Aerating the water as it passes through the turbine is one way to mitigate this problem.

Experiments with self-aerating turbines have been conducted by the Tennessee Valley Authority, the Army Corps of Engineers, and private utilities (Bohac et al. 1983, Wilhelms et al. 1987). These experiments indicate that, at some plants, turbines designed to entrain air into the flow as it passes through them could aerate the tailwaters adequately and cost-effectively (although adverse effects such as decreased efficiency and increased fish mortality can result). The upgrade of old turbines at such plants may provide an opportunity to install self-aerating turbines that could increase tailwater DO concentrations, providing a substantial environmental benefit.

3.1.1.4 Changes in Reservoir Storage and F l o w Releases

Upgrade methods for existing hydropower projects include increasing or reallocating reservoir storage and increasing the flow rates used by turbines. Increasing storage is accomplished by raising the elevation of the dam. Reallocating storage generally involves changing the times at which water is released throughout the year, with resulting changes in reservoir levels. These changes can affect reservoir and downstream water quality in many of the same ways that changing the release elevation does (see Sect. 3.2.1). These impacts can include changes in water temperature and DO Concentrations over time and space, which can be predicted only with site-specific modeling studies. Increased flow capacity of turbines allows the potential to increase daily flow fluctuations, the potential impacts of which are discussed in Sect. 3.2.1.2.

3.1.2 Air Quality

The air quality impacts of upgrading hydroelectric plants are expected to be local, short-term, and minor. Such impacts are likely to occur only as a result of fugitive dust emissions and emissions from machinery and vehicle use at upgrade projects requiring extensive construction. These impacts would occur only during construction and in almost all regions would be very minor compared with other emissions. There are no negative long-term air quality impacts of upgrading hydropower plants. Hydropower development can have positive effects on air quality by reducing fossil-fueled generation and its air emissions (Sect. 3.3.2).

3.1.3 Aquatic Ecosystems

The impacts to aquatic biota of upgrading existing hydropower plants result primarily from potential changes to water quality during construction and operation (see Sect. 3.1.1). Upgrades involving replacement of equipment inside buildings pose little threat for water quality degradation and subsequent biological impacts. However, substantial work outside of existing structures could lead to soil erosion and sedimentation, disturbance of contaminated sediments, and spills of construction oils and chemicals, all of which could have toxic effects on fish and other aquatic organisms (Miller et al. 1985). All sites could be affected by soil erosion and spills, but effects are readily controlled by proper construction practices. On the other hand, the possibility of encountering contaminated sediments would need to be evaluated at each site.

Changes in flow releases during construction could degrade tailwater quality (e.g., stagnation leading to increased temperatures and decreased DO concentrations). Fish and benthic invertebrates could be impacted not only by these water quality changes but also by the loss of habitat when the river below the dam is temporarily dewatered. Loss of instream habitat could range in severity from minor reduction of shallow riffle areas, which support many benthic

invertebrates and some fish species, to total l o s s of both riffle and pool areas (Hildebrand 1980b).

Decreased aeration, as a result of passing poorly oxygenated water through a turbine instead of spilling the water over a dam, could impact tailwater biota that require high levels of DO to survive and reproduce. Effects of low DO concentrations could range from decreased growth rates to mortality among sensitive species or life stages (USEPA 1986).

Replacement of older turbines with new designs could change the turbine-passage mortality experienced by fish. Older turbines (e.g., Francis or impulse turbines) often have small passages that may cause considerable injury or mortality (Turbak et al. 1981, Ruggles and Collins 1981). Further, operation of turbines under suboptimal conditions of flow and hydraulic head may lead to high levels of cavitation, which is particularly detrimental to fish (Cada 1 9 9 0) . Many of the newer turbine designs have large passages and, by adjusting wicket gates and turbine blades, the capability to operate efficiently under a variety of flow conditions (Fig. 6); these improvements could lead to lower turbine-passagemortality. However, at sites where the upgrade adds capacity, passing more water through additional or larger turbines could cause greater mortality among fish that were formerly spilled over the dam.

Most of the potential impacts to aquatic biota can be controlled or mitigated by the same techniques used to protect water quality. If care is taken to minimize soil erosion, spills, and changes in flow releases, construction impacts to aquatic biota within the reservoir and in the tailwaters should be minor. Spill flows or self-aerating turbines designed to ensure adequate reaeration of water would mitigate potential low W effects on tailwater biota. The use of multilevel intakes to remedy water quality problems may expose different reservoir fish to entrainment in the turbine intake flow. If surface waters of stratified impoundments support more fish than poorly oxygenated deep waters, increasing tailwater DO concentrations by increasing the surface withdrawal rates could exacerbate turbine-passage mortality. Considerable effort has gone into the development of fish screens for hydropower intakes (EPRI 1988); although the results have been mixed, some of these devices may be useful for reducing turbine-passagemortality at upgraded sites.

3.1.4 Riparian and Terrestrial Ecosystems

Impacts of upgrading existing power plants on terrestrial resources result mainly from construction-relateddisturbance to riparian habitats and wetlands. Such impacts are highly site- and project-specific but generally are likely to involve very small areas (e.g., for laydown, access, or larger facilities) and would usually be of little if any significance. In certain regions (e . g . , arid landscapes of the western United States, Kondolf et al. 1988) or habitats (e.g., old-growth riparian hardwoods), the issue of construction-related disturbance could be significant for particular projects.

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Fig. 6. Turbine passage and mortality of fish.
Source: American Electric Power, Inc.

Enhancements that involve raising dam elevations could result in significant loss of upstream terrestrial habitat through inundation (FERC 1988b). Valuable habitats that could be lost through such changes include bottomland hardwoods in the South, emergent wetlands throughout the United States, and riparian zones in semiarid or arid regions. Although such areas may be small (i.e., one to several acres) for individual projects, these habitats are increasingly valued, and the cumulative effect could be significant.

Temporary sedimentation and changes in flow regimes during construction are unlikely to have lasting effects on terrestrial resources. Similarly, replacing equipment inside buildings is unlikely to affect terrestrial resources.

Impacts to terrestrial resources can be mitigated by careful attention to siting of construction activities in relation to more important habitats and by strict adherence to erosion controls and other sound construction practices.

3.1.5 Recreation

Upgrades involving only replacement of turbiries or generators without alterations in intakes or other structures would likely have few effects on recreational opportunities or resources except for limited periods during construction. More extensive alterations to dams would cause increased interruptions to normal recreational pursuits on and around hydropower reservoirs and their tailwaters. With the potential for increased sediment loads due to erosion of banks and streambeds, the water quality impacts could affect fishing, swimming, water skiing, hiking, and boating. Isolated small fuel and lubricant spills associated with the operation of heavy machinery could temporarily affect recreational activities. Such impacts would most likely be short-lived and quickly cease after construction and soil stabilization.

If reservoir waters are drawn down during construction, exposed mudflats, reduced swimming and boating areas, changed fishing habitats, etc., all affect-for the short-term and locally-the recreational opportunities available.

Fishing around tailraces is often a preferred activity for some anglers; such fishing would be affected during construction because of both water quality impacts and modifications in the normally maintained flow regimes. Temporary cessation of flows through turbines and generators during upgrades may be required, resulting in no releases through the tailraces. Potential dewatering and stagnation as a result of such constrained flows could contribute to undesirable algal growths and low DO concentrations. Other aesthetic impacts such as exposed rocks, noxious odors, loud noises, fugitive dust, gaseous hydrocarbon emissions, and eroded banks and exposed mudflats would negatively affect the expected recreational experience. Fishing may be temporarily prohibited near a project during construction.

The mitigation discussed in Sect. 3.1.1 could protect most of the recreational resources to the extent feasible.

3.1.5.2 Long-Tern Impacts

Among the potential long-term effects on recreational opportunities is decreased aeration in waters released below the dams. As described in Sect. 3.1.1, new turbines could cause a decrease in available DO to fish and other aquatic species, potentially affecting the quality of the fishing experience and the aesthetics of fishing (such as through increased odors and algal growth).

At sites where turbines capable of using higher flows are installed (where some flow is otherwise spilled through gates or spillways), new flow regimes for impoundments could affect existing recreational activities such as whitewater canoeing or kayaking, swimming, and fishing. Changes in the magnitude or timing of flows downstream could affect aquatic habitats, riparian vegetation, breeding success of aquatic species, etc. All could have at least secondary effects on recreational opportunities, including safety, and the quality of the available recreational experience. Successful exploitation of available flows and head may require an increase in the height of dams and in the s i z e of storage impoundments. Impacts would be comparable to those described in Sect. 3.2.5. The conversion of some primarily flood control dams to increase hydropower capacity could require a less tightly maintained pool, resulting in a smaller reservoir at least seasonally and possibly over the whole year. Recreation impacts would then include inappropriate dock, marina, and boat ramp elevations; exposed expanses of mudflats and/or marshy vegetation; decreased wildlife support area; and decreased fishing, swimming, and boating areas. On the positive side, less severe fluctuations in pool elevations could mean a more pleasing shoreline, less-expensive dock structures in the long term, and potentially more or improved riparian vegetation and fish hab€tat upstream.

Mitigation for water quality (Sect. 3.1.1) would also eliminate many recreation impacts. Projects that would alter lake elevations could make funds available to modify structures to accommodate less severe fluctuations in reservoir elevations and to relocate structures to new shoreline locations where necessary. Fishing platforms could be installed to facilitate fishing access and safety along tailwater areas, improving the fishing experience.

3.1.6 Dam Safety and Flooding

Plant upgrades that do not include increasing reservoir storage generally pose no dam safety concerns (i.e., concerns about failure of a dam and the resulting flooding). When an upgrade includes raising the reservoir levels, there are additional structural loads on the dam, and the overall factor of safety for dam failure may be reduced. The design of such a project must consider dam safety concerns. The FERC license amendment process for such upgrades includes analysis of whether the dam would continue to be safe with the raised reservoir level.

There are generally no flooding concerns at most upgrade projects. However, one way to increase generation at an existing reservoir is to reduce flood storage to provide more water for generation (Sect. 2.1). Such a reduction in flood storage would increase risks of downstream flooding; the magnitude and impacts of the additional flooding depend on site-specific factors. Any construction work that would place temporary facilities (such as cofferdams, temporary dams used to dewater construction areas) or permanent structures (such as new powerhouses) in a floodway would increase upstream water levels during floods.

3.1.7 E n e r g y Security Benefits

The energy provided by upgrading existing hydroelectric power projects would be a relatively small portion of the additional U.S. power needs expected by 2030 (less than 1% of the increase in f o s s i l - fueled power generation expected between 1990 and 2030 under the NES reference case), but it would be a relatively inexpensive and beneficial form of energy. Energy from such upgrades would be totally domestic and renewable, so it would not be vulnerable to foreign control or fuel shortages. Because energy from most kinds of upgrades has minimal environmental impact, environmental concerns should not prohibit its development. Energy obtained from efficiency improvements at existing projects would have the same reliability as the existing hydroelectric power. Energy obtained from increased capacity (the ability to use additional flow) at existing plants would have less reliability than the existing power, since the additional capacity would be lost first in times of low flow or if additional flow releases are needed to improve water quality or aquatic habitat, In fact, DOE (1990a) estimates that the plant factor for upgrade capacity at existing projects is 14% (i.e., energy production over time would average 14% of capacity). The ability of some projects to generate this power during peak demands greatly increases the value of the power.

3.2 IKPACTS OF NEW HYDROPOWER AT WISTING DAHS

The installation of new hydroelectric projects at existing dams provides the benefits of additional renewable power resources without many of the adverse environmental impacts of hydropower development at new dams. The impacts that result from the impoundment of a stream have already occurred at existing dams; these impacts include alteration of aquatic habitat from flowing water to slack water in the impoundment, changes in the magnitude and timing of flows downstream of the d a m , changes in water quality that occur in the impoundment and affect the tailwaters, blockage of fish migration, and submergence of terrestrial habitat by the resenroir. However, retrofitting a dam to generate hydropower can involve some additional impacts.

3.2.1 Water Resources

3.2.1.1 Construction letpacts

At low-head dams, such as navigation dams, retrofitting usually involves replacing part of the existing dam with a powerhouse or adding a powerhouse to one end of the dam. At high-head plants, such as storage reservoirs, hydropower is usually added by installing penstocks through the existing dam and constructing a powerhouse and tailrace immediately downstream of the dam. Short-term, local impacts of construction on water resources are possible. Sediment loads to the tailwaters can result from erosion at the construction site and the accidental release of excavated materials into the stream. There is a risk of small fuel spills resulting from the use of construction equipment near and in the streambed. Contaminated sediments existing at a dam may be disturbed and distributed by construction. If construction of the power plant requires temporary cessation of flow releases, the tailwater reach could be dewatered or stagnated, as discussed in Sect. 3.1.1 for hydropower upgrades. Water quality impacts of retrofit hydropower projects are unlikely to persist after construction fs complete.

Mitigation to minimize or avoid constmction impacts at retrofit projects would be similar to that at upgrades (Sect. 3.1.1.1). Compliance with permit and license requirements should adequately mitigate construction impacts.

3.2.1.2 Changes in F l o w Release P a t t e r n s

Hydropower projects can generate more valuable power by releasing water during periods of peak daily power demands and storing it during off-peak periods. This peaking mode of operation is possible at retrofit projects built at dams with at least minimal storage capacity. The daily flow cycles that result can have adverse impacts downstream, such as stranding fish (including spawntng nests and juvenile fish), posing hazards to recreational users, and increasing bank erosion. These impacts can be mitigated by (1) not allowing daily flow cycles (a common requirement) or (2) building some kind of re-regulation structure (such as another small reservoir or a low-head weir) downstream to even out daily flow cycles. Since such fluctuating flows can have adverse impacts and can conflict with the original uses of an existing dam, they are often not allowed.

Changes in seasonal release patterns would be similar to those discussed in Sect. 3.1.1.4. However, at most dams a retrofit hydropower project would not be allowed to change seasonal flow release patterns because such a change. would reduce the ability of the dam to fulfill its original purposes.

3-2-1.3 Changes in Tailwater Quality Due to Changes in Release Elevation

A retrofit hydropower project can withdraw water from elevations different from the withdrawal elevations of the original impoundment.

In the case of a deep storage reservoir, water quality commonly varies with elevation, especially in summer. Thermal stratification results in an impoundment having cold water, often with low DO concentrations, in its lower elevations and warm water with relatively high DO concentrations in the higher elevations. In stratified impoundments where the existing release is from the top (over a spillway or through high-elevation gates), the installation of a hydropower plant withdrawing from low elevations would cause downstream water quality to change in summer from high to low temperatures and from high to low DO concentrations. Water released from low elevations also tends to have high concentrations of heavy metals, which can have toxic effects, and high concentrations of iron and magnesium, which are considered nuisance compounds. Even small changes in the withdrawal elevation can significantly change water quality over a summer season.

Cada et al. (1983) showed that problems with low DO concentrations in reservoir releases are much more common at large reservoirs than at small ones. Problems with low DO in releases at small hydropower projects were shown to be more common in the midwestern, southeastern, and southwestern regions of the United States. Large projects releasing low DO concentrations are most common in the midwestern, east-central, and southeastern states. Low DO problems are uncommon in winter.

In unusual circumstances even shallow impoundments, such as large rivers with low-head dams, can have stratified water quality (such as when thermal-electric power plants or upstream reservoirs contribute to temperature differences). The bulb-style turbines typically installed at low-head dams withdraw water from all levels of the upstream impoundment and eliminate stratification by mixing the water thoroughly; this mixing can actually improve water quality in situations where stratification occurs.

The release of deoxygenated water from the bottom of a reservoir can be mitigated in several ways. One way is to construct the hydropower project with a multilevel intake so that water can be withdrawn from the reservoir selectively from different elevations. Such selective withdrawal allows the project operator to release water with acceptable temperatures and DO concentrations (although water quality changes in the reservoir, discussed in Sect. 3.2.1.5, may result). Another way to mitigate the release of deoxygenated water is to aerate the water as it is released through turbines. Numerous other methods have been used to increase DO in turbine releases (Bohac et al, 1983). These methods include venting air into the turbine, with or without air pumps; pumping air or oxygen into either the tailwaters or the reservoir just upstream of the intake; forcing water from the surface layer of the resenroir down and into the turbine intakes; and, where tailwaters are adequately steep (to avoid backpressure on the turbine), installing of a weir downstream that provides aeration and evens out flow fluctuations. Such a weir is currently being designed by the Tennessee Valley Authority. The installation of a multilevel intake, aerating turbines, or other DO enhancement technologies in a retrofit hydropower project can mitigate tailwater quality problems. In cases where existing DO concentrations were high, some decrease in DO would be expected with the addition of hydropower. However, in

cases where existing DO concentrations were low, better quality releases may be possible with hydropower and DO mitigation than without hydropower.

3.2.1.4 Decreases in Aeration

Installation of hydropower at some existing dams can replace well-aerated spill flows with unaerated flows through turbines. This impact is important at many low-head dams, especially navigation dams on large rivers (e.g., 19 dams considered by F'EEtC 1988b, Sale et al. 1989, Thene et al. 1989). At low-head dams without hydropower, flows are spilled over spillways or through gates that may (or may not) provide important aeration (Railsback et al. 1990). Such spill flows may be aerated up to or above the saturation concentration of DO. This aeration can be very important for water quality since impounded rivers receive relatively little other aeration because they are deep and slow. Flows through low-head hydropower turbines receive negligible aeration. Therefore, when hydropower is installed at a dam that aerates well, the flows through the turbines do not receive the aeration they would receive without hydropower, and a net decrease in downstream DO concentrations results. The magnitude of DO reductions varies between sites and over time and may be sufficient to significantly affect fisheries. Where hydropower is installed at adjacent dams on the same river, cumulative decreases in DO could occur, resulting in DO concentrations low enough to affect fisheries (e.g., FERC 1988b).

A l o s s of aeration can also occur when hydropower is installed at some high-head multipurpose storage reservoirs. Some dams release cold, deoxygenated water from the bottom of a reservoir through gates and energy dissipators that greatly increase DO concentrations. This water, if released through hydropower turbines, would not be aerated, and DO concentrations downstream would be significantly reduced. Reductions in summer DO concentrations to levels harmful to fish could result without mitigation.

Loss of aeration resulting from installation of hydropower can be mitigated at both low-head and high-head plants. At low-head plants, DO concentrations can be maintained during critical periods (e.g., during summer low-flow periods) by requiring some or all of the flow to be spilled for aeration instead of being used for hydropower generation, with a resulting loss of power production. There may be ways to mechanically aerate flows cost-effectively at low-head projects, but none have been demonstrated. (Mechanical aeration is less cost-effective as a mitigation measure at low-head plants than at high-head plants because (1) much more water must be aerated per unit of power generated; (2) low-head turbines are typically designed so that water pressures are never less than atmospheric pressure, so self-aeration by venting air into the turbine at low-pressure zones is infeasible; and (3) very little research on aeration of low-head turbines has been conducted.)

Mitigation for the discharge of low-DO water from high-head plants is discussed in Sect. 3.2.1.3.

3.2.1.5 Changes in Reservoir Water Quality Due to Changes in Xelease Elevation

The effects on downstream water quality of installing hydropower that withdraws from different elevations of a stratified impoundment are discussed in Sect. 3.2.1.3. Changes in the elevation of withdrawal from a reservoir can also affect water quality in the impoundment upstream of the dam. For example, replacing a gate release with a turbine intake at even a small difference in elevation could reduce the amount of cold water on the bottom of a reservoir and increase the amount of warmer water in the reservoir in summer. Such changes can affect water temperatures, DO concentrations, algal production, and other water quality parameters at different times and locations in the reservoir. These effects are complex, variable, and site-specific, and reservoir simulation models are used to predict them. In some situations, the alteration of the withdrawal elevation could be beneficial for reservoir water quality (e.g., if deoxygenated water were flushed from the bottom of a reservoir), and in other situations the effects could be negative (e.g., if the reservoir volume with unsuitably high temperatures were increased).

In situations where water quality impacts on the impoundment of a proposed retrofit hydropower project were predictsd to be negative, a multilevel intake for the project might be able to mitigate the impacts. However, maintaining water quality both in a reservoir and in its tailwaters may in some cases be conflicting objectives, and there may not be selective withdrawal schemes that satisfactorily prevent all water quality impacts. In some cases, water quality problems within an impoundment can be mitigated by reducing upstream sources of pollutants (e.g., wastewater discharges, non-point-source runoff) contributing to the problems.

3.2.1.6 Nitrogen Supersaturation

Nitrogen supersaturation and the gas bubble disease it causes in fish are commonly associated with hydropower projects. Gas bubble disease occurs in fish exposed to water supersaturated with dissolved nitrogen. The disease results in formation of gas bubbles within the fishes' bodies and can cause mortality at nitrogen concentrations as little as 105% of saturation (Norwegian Hydrodynamics Laboratories 1984). Nitrogen supersaturation can occur when air is entrained into poorly designed penstocks, when water saturated with nitrogen deep in a reservoir (where pressure increases the saturation concentration) is released to tailwaters, and when reservoir releases are very highly aerated (Wolke et al. 1975). Nitrogen supersaturation is not commonly found at dams suitable for addition of hydropower, and, although gas bubble disease may occasionally occur because of site-specific conditions, it is not expected to be a significant adverse impact of hydropower development at retrofitted dams.

3.2.2 Air Quality

As with upgrading hydropower projects (Sect. 3.1,2), the air quality impacts of retrofitting dams with hydroelectric plants are expected to be local, short-term, and minor. Impacts such as fugitive dust emissions and emissions from machinery and vehicle use would occur only during construction and in almost all regions would be very minor compared with other emissions.

3.2.3 Aquatic Ecosystems

Construction impacts to aquatic resources from retrofit hydropower development would be similar in nature to those associated with upgrading existing hydroelectric plants (Sect. 3.1.3). However, because construction is likely to be more extensive under this alternative, the potential for impacts to aquatic resources, especially from water quality degradation, is greater. Also, the mitigative measures needed to control these potential impacts would be similar to those described in Sect. 3.1.1.

Operation of a retrofitted dam could impact aquatic organisms through habitat and water quality degradation. Although the reservoir already exists and the biological communittas have adapted to the lake environment, commencement of hydropower production may alter the magnitude and timing of releases. This in turn could result in rapid and more extreme water level fluctuations in both the reservoir and tailwaters, which degrade important shallow-water habitat fox aquatic biota (Hildebrand 1980b).

The release of cool, poorly oxygenated, deep water from stratified reservoirs will degrade the water quality of the tailwaters and adversely impact tailwater communities that are adapted to releases of warmer, well-oxygenated surface waters. As with the potential decreased aeration problem described for the upgrade alternative (Sect. 3.1.3), effects can range from decreased growth rates to mortality. The mitigative measures suggested in Sect. 3.2.1 to enhance

DO concentrations of new hydropower releases should also serve to protect tailwater biota. The use of multilevel intakes to correct low DO problems would need to take into account not only the DO sequirements but also the temperature requirements of aquatic organisms below the reservoir. A n additional complicating factor associated with the use of multilevel intakes is that withdrawal of water from different levels of the reservoir may expose different reservoir fish to entrainment in the turbine intake flow. If surface waters support more fish than deoxygenated deep waters, correcting water quality problems by increasing the surface withdrawal rates could exacerbate turbine-passage mortality.

Water quality changes within the reservoir resulting from new hydropower releases could have either beneficial or adverse effects on aquatic organisms. Releases of poorly oxygenated deep w a t e r could increase the amount of well-oxygenated habitat available to both fish and bottom-dwelling invertebrates in a stratified reservoir. On the other hand, releases of surface water, for example to correct tailwater quality problems, may reduce the amount of adequately oxygenated

habitat for reservoir biota. Because different release schemes will alter impoundment temperatures as well as DO concentrations, the thermal requirements of reservoir organisms must also be considered. As with water quality considerations (Sect. 3.2.1), such effects are complex, variable, and must be evaluated on a site-specificbasis.

Turbine-passage mortality would be a new impact of installing hydroelectric facilities at existing dams. The seriousness of this issue depends on a number of factors, including the species of fish affected; sport fish are generally of greater concern than rough fish. Behavior of the fish has an important influence on turbine passage mortality. Bottom-dwelling species may not encounter surface-level intakes. Anadromous fish such as salmon, American shad, and striped bass must migrate downstream and therefore must pass over the dam either in spill flows or through the turbines; on the other hand, many inland fish species in reservoirs do not move great distances and may not be exposed to turbine intake flows. Finally, the size of the fish entrained in the intake flow is important in that large fish are more likely than small fish to be injured by turbine passage (Cada 1990). Different turbine types cause different mortality rates: in general, the farther apart the blades are, the lower the mortality, although other factors are also important.

3.2.4 Riparian and Terrestrial Ecosystems

The impacts to terrestrial resources from retrofits are similar to those from upgrading existing hydroelectric plants (Sect. 3.1.4). However, because more extensive construction is likely under this alternative (e.g., several to many acres for powerhouse, penstock, access, parking, and transmission lines), the potential for disturbance to riparian habitats and wetlands is greater. The installation of new power lines, in addition to disturbing habitat, may pose collision hazards for birds and bats and electrocution hazards for large raptors. The latter can be mitigated by proper tower design. Other mitigative measures needed to control these potential impacts would be similar to those described in Sect. 3.1.4.

Hydropower production at retrofitted dams may alter flow releases, thereby affecting shallow-waterhabitat including emergent vegetation in wetlands near tailwaters. Altered flow regimes may also alter reservoir levels enough to affect upstream wetlands and riparian zones. The seriousness of such effects depends on the extent and value of wetlands present; effects would normally be small for individual projects but could be cumulatively significant.

Projects that produce electricity by diverting water through penstocks for significant distances may produce losses or undesirable changes to riparian zones along dewatered reaches. Such damage is particularly serious in semiarid or arid regions where streamside vegetation is particularly important ecologically (Kondolf et al. 1988).

3.2.5 Recreation

3-2.5.1 Construction Impacts

The retrofitting of dams to generate new hydropower will entail many of the same construction effects as described in Sect. 3.1.5.1. Where new penstocks and powerhouses are required downstream of the existing dams (high-head situations), significantly more riparian disturbances are likely. This could affect fishing, hiking, swimming, boating, nature observation, and access to any of these. If construction of the power plant requires temporary cessation of flow releases, the tailwater reach could be at least partially dewatered, and the remaining waters could become stagnant, as discussed in Sect. 3.1.5.1. Fishing in dam tailwaters could be prohibited during construction.

If greater impoundments are needed to accommodate the flaw requirements of the new generation capability, a variety of impacts can be expected. Construction could bring erosion and sedimentation impacts to water quality, affecting fishing, swimming, and boating. Recreational activities could be directly affected by construction noises, aesthetic impacts of heavy machinery in a recreational environment, and temporary cessation of activities because of safety concerns.

The mitigation strategies outlined in Sect. 3.2.1 would be appropriate to partially protect water quality-dependent recreation resources. Noma1 flows should be maintained in tailwaters via use of flows from gates or spillways.

3.2.5.2 Long-Term Impacts

Retrofitted dams could create local impacts due to the presence of mechanized fish screens ln place of simple spillways and gates. These could affect swimmers, scuba divers, boaters, nature watchers, and anglers who normally use the waters near the dam area for their recreational pursuits.

Sect. 3.2.1 describes the potential reservoir water quality impacts due to changes in release elevation. These possible changes could affect swimming, fishing, and wildlife observation at different times of the year and in different locations around the reservoir.

Long-term effects of expanding reservoir sizes to accommodate new hydropower generation regimes could result in both negative and positive impacts for recreational resources. Increased impoundment size could mean greater expanses of calm water for sailing, rowing, fishing, and swimming. On the negative side, access to the water could be changed due to higher water levels. For example, docks, boat ramps and marinas might have to be relocated or redesigned to accommodate the higher or more frequently changing water levels. Riparian vegetation and riparian aquatic habitat of some sports fisheries could be lost to expanded impoundments. Wildlife, possibly seasonal wfldlife, could be affected by changes in the water regime in impoundments. This could affect hunting, fishing, and nature watching.

Anglers accustomed to using tailwaters might have to adjust to the changed water release regimes that would accompany conversion to

hydropower development. There could be safety risks to boaters and fisherman who use the areas immediately downstream of the newly converted dams. The smaller impoundments of the New England area might experience some changes in recreational use or potential with modest augmentation of reservoir size. Similarly, the loss of free-flowing upstream waters and their associated recreational resources could mean some loss of recreational and aesthetic resources. On the larger reservoirs used for navigation and flood control in other areas, the increased surface areas would also likely be only modestly increased.

As described in Sect. 3.2.1, the installation of new hydropower facilities at existing impoundments can result in the withdrawal of water from different depths than was the case prior to conversion. The net result can be significant changes in water temperatures and in DO concentrations-potentially negative effects on fishing and swimming.

Mitigation can be provided for many impacts to recreation. Horns or warning whistles could notify recreational users just below retrofitted dams of the dangers of sudden water releases and the associated potential for rapid changes in water levels. Warning signs could also be posted on both riverbanks. Funds could be made available to compensate riparian owners who might have to lose lakeshore property, move docks or boat ramps, or otherwise change or redesign their use of the reservoir area. Fishing platforms could be installed to facilitate fishing access and safety along tailwaters areas.

3.2.6 Dam Safety and Flooding

3.2.6.1 Dam Safety

Some dam safety concerns are associated with retrofitting dams with hydropower. Removal of some parts of existing dams is usually required for installation of powerhouses and penstocks. This demolition must be conducted properly to avoid weakening the structure or foundation of the d a m . The new structures and cofferdams must be properly designed and constructed to avoid failure.

When a hydropower dam operated by a federal agency (e.g., the Army Corps of Engineers or the Bureau of Reclamation) is retrofitted, the agency reviews the plans prepared by the hydropower developer and oversees all demolition and construction work. The agency retains responsibility for dam safety during construction and operation of the hydropower project. The agency review process and oversight responsibility are designed to prevent hydropower development from significantly increasing r i s k s of dam failure.

When a hydropower project is proposed at a dam not operated by a federal agency, FERC evaluates d a m safety as part of the licensing process. If the dam does not meet FERC's safety criteria, the project will not be licensed unless the hydropower proponent agrees to bring the dam i n t o compliance with the safety criteria. If the project is licensed, the licensee assumes responsibility for the safety of the dam. The FERC requirement for a hydropower developer to assume responsibility for safety of an existing d a m may discourage development at

some dams but is designed to prevent hydropower development from significantly increasing the risk of dam failure. In cases where existing dams would be upgraded to meet FEXC's safety criteria, an increase in dam safety would result from hydropower development.

3.2.6.2 Flooding

The construction of hydropower projects at low-head dams may, depending on design, increase the magnitude and frequency of flooding upstream (Schmitt and Varga 1988). For example, hydraulic modeling studies for powerhouses built at two existing navigation dams on the Allegheny River predicted that water levels during extreme fl.oods would increase by up to 2 ft. as a result of the hydraulic resistance of the powerhouse. (Floodwaters would flow over the powerhouse less smoothly than over the existing dam.) During construction of projects, any obstruction (especially cofferdams) in the path of flood flows would Increase the upstream flood elevations.

The potential increases in upstream flooding caused by retrofit hydropower projects can be studied with hydraulic models. Projects can be designed to minimize effects on flood elevations. At projects Where some increases in flood elevation are unavoidable, hydropower developers can avoid the financial impacts of increased flood elevations by purchasing flood easements.

3.2.7 Energy Security Benefits

The energy provided by retrofit hydropower projects would be a relatively small portion of the additional U.S. power needs expected by 2030 (less than 1% of the increase In fossil-fueled power generation expected between 1990 and 2030 under the NES reference case), but it would be relatively inexpensive and beneficial energy. This hydroelectric resource would be totally domestic and renewable, so it would not be subject to foreign control or fuel shortages. Development at many existing dams could have minimal environmental impacts, so environmental concerns should not prohibit it. (However, real and perceived environmental impacts could lead to strong apposition to development at some existing dams.)

Energy obtained from many retrofitted dams, such as storage projects and navigation dams, would be as reliable as that from most existing hydroelectric projects. However, new power capacity at some kinds of dams, such as m a l l projects, may provide less-reliable power because flows too low to generate occur frequently. Few retrofitted dams are expected to be allowed to use peaking operation or to otherwise change storage patterns, so the projects would tend not to be useful for following daily or seasonal cycles of demand.

3.3 TXPACIX OF CENFaATION USING FOSSIL msLs

Generation using fossil fuels (coal, gas, and o i l) accounts for most U . S . capacity and is likely to provide most of the power that would otherwise be generated by hydropower under the proposed DOE

initiative, The power provided under the initiative could replace the capacity of approximately 18 large (500-MU) fossil power plants. The environmental impacts of fossil-fueled generation have been described in other studies, including Dvorak et al. (1978) and DOE (1989).

3.3.1 Water Resources

Fossil-fueled generation causes a number of impacts to water resources. Fossil plants are generally constructed adjacent to large bodies of water, which provide cooling water and, sometimes, barge transportation of fuel. The construction of plants disturbs large land areas, which can increase erosion and, consequently, stream sediment loads.

Many water resources impacts of coal-fired generation result from coal mining and transportation. Coal mines in humid regions (such as the eastern United States) have historically caused severe degradation of water resources as a result of stream channel alteration (from direct effects of mining, hydrologic changes to watersheds, and increased sediment loads) and acid mine drainage. These impacts can be controlled to some extent but cannot be totally avoided. In arid regions, impacts of mining to water resources are generally less than in humid regions, although some impacts such as changes in groundwater can occur. Transportation of fossil fuels by barge on existing waterways generally has minor impacts on water resources, but some other modes of fuel transportation, such as coal slurry pipelines, can have major effects on local water resources. Coal is often washed at the mine or power plant to improve its burning and emissions qualities; this process consumes and degrades the quality of large amounts of water.

The production and transportation of gas and oil for electric power production also have impacts on water resources. These include impacts of offshore oil development and oil spills during transportation and refining.

The operation of fossil-fueled power plants causes a number of impacts to water resources. These plants require cooling water to condense steam prior to its reuse in the boilers. Cooling water can be used either once and discharged to surface waters or recycled using a cooling tower to release the heat to the atmosphere. Once-through cooling can cause significant temperature increases and evaporation in the receiving body of water. Cooling towers consume water by evaporating it and require the release of blowdown water, which has higher-than-natural concentrations of dissolved solids. On average, cooling is estimated to consume 1500 liters of water per megawatt-hour of power generation (DOE 1989). There are other smaller wastewater streams from fossil-fired power plants, such as boiler blowdown and scrubber effluents. Runoff from coal, fly ash, and scrubber sludge storage areas are other wastewater sources which, if not controlled, can release toxic compounds into surface water or groundwater. Water consumption for coal cleaning, scrubbers, and other uses besides cooling is estimated to average 2300 liters per megawatt-hour (DOE 1989).

Air emissions from fossil-fueled power generation have important regional impacts on water quality. Coal-fired power generation contributes large fractions of sulfur and nitrous oxide emissions, which cause acid deposition. The effects of acid deposition (both as precipitation and dry deposition) on water resources is being studied by the National Acid Precipitation Assessment Program (e.g., Malanchuk and Turner 1987, NAPAP 1990). The effects of acid deposition vary regionally with deposition rates and also depend on local geology. The regions most at risk from acid deposition from U . S . power plants appear to be t h e northeastern United States and some of southeastern Canada.

Global water resources could be affected increasing carbon dioxide emissions (Waggoner 1990). The effects of increased greenhouse gas concentrations in the atmosphere are poorly understood, but regional changes in the amounts and timing of precipitation, air temperatures, winds, and vegetation types, all of which could result from global warming, would have major effects on water availability and water quality in many parts of the world.

3.3.2 A i r Quality

Unlike hydroelectric generation, power generation using fossil fuels is a major source of air emissions. Emissions include fugitive dust releases from coal piles and mines, emissions from vehicles used to mine and transport fossil fuels, volatile hydrocarbon emissions from the storage and handling of petroleum and gas, and combustion emissions.

The air quality impact of fossil-fueled generation that is of greatest concern is the emission of the combustion products sulfur dioxide, nitrous oxides, particulates, and carbon dioxide. Fossil-fired electric power generation produces approximately 70% of U.S. sulfur emissions and 40% of nitrous oxide emissions but only about 10% of particulate emissions (Placet et al. 1986). These emissions are mostly from coal and oil combustion; natural gas-fired plants have significantly lower air emissions.

Sulfur dioxide and nitrous oxides are of concern mainly because they contribute to acidic precipitation and dry deposition, although they may also affect human health. Particulates have adverse: effects on human health, weather, and visibility.

Carbon dioxide emissions are also of concern because of their contribution to potential greenhouse warming of the earth. Carbon dioxide emissions have risen steadily since at least the 1950s. It appears that approximately half of the carbon dioxide emitted remains in the atmosphere, where it may contribute to global warming, and the rest is dissolved in the oceans, taken up by vegetation, or otherwise sequestered (DOE 1989). Coal-fired generation in the United States contributes about 8% of the current global carbon dioxide emissions from energy consumption (including transportation). Fossil-fueled power generation in the United States is one of the largest single sources of carbon dioxide emissions but is still a relatively small part of the global emissions and activities that contribute to climate change concerns.

Many technologies (referred to as clean coal technologies) are potentially capable of reducing emissions of sulfur and nitrogen compounds from fossil-fueled plants (DOE 1989). These technologies are expected to be used even more in the future, especially following passage of the 1990 revisions of the Clean Air Act. However, no technologies exist to significantly reduce carbon dioxide emissions of fossil-fueled generation.

The effects on air emissions of replacing 9 GW of coal-fired capacity with hydropower were analyzed. Hydropower would result in greater reductions in air emissions if it were developed quickly, replacing existing conventional coal-fired capacity before most coal-fired plants are converted to or replaced by clean coal technologies (WE 1989). The scenario simulated is the replacement, over the period 1995-2010, of 2 . 2 5 GW of coal generation every 5 years. Predictions of air emissions from all electric utilities for 1990 to 2020 without the hydropower initiative are those estimated by DOE for the NES reference case; these predictions are based on actual emissions in 1987. It was assumed that coal-fired plants without clean coal technologies would be replaced by the additional hydropower. Table 1 gives the air emissions predicted under the NES reference case, and Table 2 gives the emissions predicted with the hydropower initiative.

With the hydropower initiative, emissions of particulate matter are predicted to change negligibly from the baseline case. This finding is attributed to the high removal rate of TSP at existing coal plants. The impacts of the hydropower initiative on sulfur dioxide, nitrous oxides, and carbon dioxide emissions are shown in Fig. 7. The predicted reduction in sulfur is 2.2% by the year 2010. Hydropower developed after about 2010 may replace power generated at relatively new plants (built during or after the 1980s) that use clean coal technologies and emit less sulfur. Therefore, hydropower developed after 2010 would be less beneficial in reducing emissions than would hydropower developed before 2010. The hydropower initiative would result in decreases of 2.1% in nitrous oxide emissions and 1.0% in carbon dioxide emissions from electric utilities by 2010.

3.3.3 Aquatic Ecosystems

Many of the impacts to aquatic ecological resources from construction and operation of fossil-fueled power plants are much different in kind and magnitude than impacts from the various hydropower alternatives. Most of the construction of fossil plants occurs on land, and the same mitigative measures discussed in Sects. 3.1.1 and 3.2.1 to control erosion, sedimentation, and construction spills at hydroelectric facilities can be employed to minimize aquatic impacts at fossil plants. Unless the fossil plant creates a cooling lake, losses of aquatic habitat are generally relatively small, comparable to those resulting from by upgrading or retrofitting existing reservoirs, and much less than the amount of riverine habitat lost to a new hydroelectric impoundment.

Operation of the condenser cooling system of a fossil plant can impact aquatic organisms through entrainment, impingement, and

Table 1. Predicted emissions from electric utilities under the National Energy Strategy reference case, and 1987 base values

1987	14630	6651	479
1990	14911	6737	49 5
1995	16426	7524	562
2000	17787	8370	653
2005	18231	8885	752

2010	18730	9496	863
2015	18811	10149	994
2020	17242	10086	1117
2025	15410	9986	1241
2030	13841	9359	1364

T a b l e 2. P r e d i c t e d e m i s s i o n s from e l e c t r i c u t i l i t i e s w i t h the DOE hydropower i n i t i a t i v e , and 1987 b a s e v a l u e s

	so2 (103 t o n s / y e a r)	NO, (103 t o n s / y e a r	c02 (106 tons
1987	14630	6651	479
1990	14911	6737	49 5
1995	16324	747 3	5 60
2000	17582	8268	648
2005	17924	8732	745
2010	18324	9292	8 54
2015	18405	9945	985
2020	16836	9882	1108
2025	15004	9782	1232
2030	13435	9655	1355

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With hydropower initiative

Fig. 7. Air emissions from electric utilities with and without hydropower from the DOE initiative.

chemical and thermal discharges (Langford 1983). The amounts of water used to cool the power plant condenser can be large; a 1000-MW power plant with once-through cooling discharges about 48 cubic meters of water per second (761,000 gallons per minute) at a temperature elevated 10°C (18°F) (Coutant 1981). Large numbers of aquatic organisms may suffer mortality as a result of being drawn through the cooling system (entrainment) or being trapped against the fine-mesh debris screens in the intake (impingement). Periodic discharge of chlorine or other chemicals and continuous discharge of heat can affect aquatic life in the receiving water.

Coal-fired power plants produce large amounts of solid waste (e-g., combustion ash and scrubber sludges). Leachates from both coal and ash piles can degrade water quality and have toxic effects on aquatic biota if not controlled. In addition to effects at the power generation site, water quality impacts or habitat losses associated with the entire fuel cycle (coal and oil extraction, refinement or cleaning, and ash disposal) can have significant impacts on aquatic communities over larger geographic areas (Hunsaker et al. 1990). Acid deposition from fossil plants (Sect. 3.3.1) can also affect aquatic biota in widespread areas.

3.3.4 Terrestrial Ecosystems

Impacts to terrestrial ecological resources from construction and operation of fossil plants are different in kind and magnitude than impacts from the various hydropower alternatives. Most construction of fossil plants occurs on land, and the area needed for facilities, storage pilea, waste disposal, access, and utilities is much larger. Construction-related mitigative measures to control erosion, sedimentation, and spills at hydroelectric facilities can be employed to minimize terrestrial impacts at fossil plants. Unless the fossil plant creates a large cooling lake, losses of terrestrial habitat may still be relatively small in a regional context, although larger than those for upgrading or retrofitting existing reservoirs for hydropower production.

Storage and disposal of large volumes of solid waste uses large land areas at coal-fired plants, sometimes including valuable habitats such as wetlands and floodplains. Inadequately controlled leachates from both coal and ash piles can degrade adjacent wetlands and soils in riparian zones and may have long-term toxic effects on terrestrial biota. In addition, potentially significant habitat losses are associated with the fuel cycle for coal-fired plants over larger geographic areas. Coal mining and transportation can seriously affect large areas of terrestrial habitat (Dvorak et al. 1978). Acid deposition and carbon dioxide releases from fossil plants may also cause long-term impacts to terrestrial ecosystems in large areas.

3.3.5 Recreation

The continued reliance on fossil fuels as the country's major source of electrical generating power could have significant impacts on recreational pursuits in some areas. Air quality impacts from coal

combustion (in combination with emissions from transportation) already affect the use of recreation resources by people with respiratory problems in some major U . S . cities during air inver- sion episodes. Acid deposition from coal combustion is believed to have affected fishing in lakes in New England and in some other areas of the country. Acid mine drainage from coal mines can affect the fishing, whitewater canoeing and kayaking, boating, swimming, hiking, and general aesthetic quality of streams in Appalachia and elsewhere. Surface mining of coal can disturb recreational opportunities such as hiking, hunting, and nature Observation throughout the United States, although some reclaimed sites may enhance these same recreational resources.

Possible effects on recreation resources that may accompany increased concentrations of greenhouse gases in the atmosphere include changed regional precipitation quantities and regimes, more frequent and more severe air inversions, increased or reduced reservoir capacities, more frequent and more severe major storms in coastal areas, sea level rise, altered wildlife habitat, and changed migration paths and times for wildlife. All of these will potentially affect almost any outdoor recreational pursuit.

Power generation using gas and oil results in some water quality impacts near refineries and drilling rigs and occcsional oil spills onshore or offshore from tankers, rigs, or pipelines. All of these could affect recreational activities such as fishing, boating, swimming, and nature observation. Refineries are frequently viewed as noxious facilities (with both visual and olfactory impacts) incompatible with recreational resources. Pipelines can detract from aesthetic enjoyment of recreation where they occur. Increased use of gas and oil could mean drilling and other exploration and production activities in wildlife refuges and fragile offshore locations, with potential negative effects on recreational pursuits.

Natural gas desulfurization facilities, commonly located near the drilling rigs, could produce visual, auditory, and olfactory impacts in some relatively pristine environments in the western United States where the gas is found. Hiking, hunting, and nature observation could be affected.

3.3.6 Energy Security Benefits

Coal and domestic gas supplies provide a relatively secure energy resource. Coal is considered the most abundant nonrenewable energy resource in the United States. Fossil-fueled plants are highly reliable, although they may be affected by severe weather conditions such as droughts (which can make cooling less efficient and power production more expensive). Fossil-fueled thermal electric plants are not efficient for following daily demand cycles, but the use of gas turbine plants (which can respond quickly to changing loads but are less efficient) and pumped storage hydroelectric projects can mitigate this inefficiency. Fossil-fueled plants can have major environmental impacts, including air emissions of regional and global concern and consumptive water use, which can limit development of new plants at many sites.

Unlike coal and gas supplies, oil supplies in the United States are highly dependent on foreign sources. Power generation using oil i s detrimental to energy security since it consumes a resource that is provided largely by foreign suppliers and has other important uses such as transportation and chemical production.

The NES reference case predicts there will be increases in hydroelectric development at sites other than those affected by the W E initiative. This scenario includes development both at existing dams and at sites requiring new dams or diversions. Impacts of development at existing dams would be the same as described in Sects. 3.1 and 3.2; impacts of hydroelectric development at new dams are discussed here.

New hydroelectric sites are expected to include mostly small dams, since few sites remain for new large-scale hydropower production. In a study o f the potential development of small (less than 100-MW capacity) projects at new dams, FERC (1988a) predicted that, under favorable economic conditions and existing emironmental constraints, approximately 180 new dams could be developed, with a capacity of about 1.5 GW. The national and regional environmental impacts o f this development have bean discussed in FERC (198th).

3.4.1 Water Resources

The impacts of retrofitting dams to develop new hydropower (Sect. 3.2.1) are also encountered by projects at new dams. In addfition, the impacts of constructing and operating dams, diversions, and reservoirs occur at new sites. In regions where m n y hydropower facilitfes exist, cumulative impacts to water resources, such as extensive water quality and aquatic habitat degradation, can occur.

Hydroelectric development at new sites usually involves substantial changes to local water flows and water quality. Simple diversion projects without storage capacity reduce water flows within the reach that is diverted but do not alter f l o w patterns downstream o f the project. Larger projects that include storage resewoirs can change the seasonal flow patterns downstream of the plant-for example, by reducing flows during naturally high flow periods (by storing water) and augmenting flows during naturally low flow periods (by releasing stored water). Projects with storage can also induce daily flow cycles by releasing more water for generation during periods of daily peak demands. The impacts of reduced flows in a diverted reach can be mitigated by releasing more water (which cannot be used for generation) through the reach. The impacts of daily flow fluctuations can be mitigated by using a re-regulation structure to even out flows or by prohibiting such cycles.

New dams often alter water temperatures of the affected streams. Diversion projects reduce the flow in a stream reach, which allows greater solar heating and higher temperatures in the diverted reach. Projects with storage can have complex effects on temperature that

depend on the size and shape of the reservoir, local climate, and flow release patterns.

New reservoirs can substantially alter water chemistry in the reservoir and downstream of it. Impacts of reservoir operations on DO are discussed in Sect. 3.2.1. In addition, concentrations of nutrients (phosphorus and nitrogen) and algae can be altered within reservoirs. During the early years of a reservoir's operation, concentrations of nutrients and organic carbon are increased by the decay of the plants that were submerged.

3.4.2 Air Quality

New hydroelectric dams involve few air quality concerns. Fugitive dust and vehicle emissions occur during construction, but these emissions are usually short-term, local, and minor. No significant emissions typically result from operation of a hydroelectric plant.

3.4.3 A q u a t i c Ecosystems

Construction of new dams for hydropower development would cause impacts similar to those described in Sect. 3.2.3, except at a larger scale. The large amount of civil work associated with constructing the dam, powerhouse, penstock, roads, and other new facilities would result in greater risk of water quality degradation from soil erosion and spills. In addition, creation of an impoundment would eliminate free-flowing stream habitat behind the dam.

Hydroelectricity generation at a new d a m may cause major changes in the timing and magnitude of stream flows below the reservoir, which in turn could significantly affect tailwater biota that were formerly adapted to a natural seasonal cycle of flows and temperature conditions (Loar and Sale 1981, Sale 1985). The severity of these impacts depends on a number of factors, including the size (storage capacity) of the new reservoir and the length of the diverted reach. Turbine-passage mortality (Sect. 3.2.3) could also affect fish populations in the stream.

A new hydroelectric dam will create a barrier to upstream rnovement of fish that did not previously exist. This is a potential problem at any site but particularly where the stream supports runs of anadromous species (i.e., coastal and Great Lakes areas). Upstream fish passage facilities may be required to mitigate these effects (Hildebrand 1980a).

Compared with the other hydropower alternatives considered in this document, the chief additional impacts of development of new dams are l o s s of stream habitat (both above and below the dam) and the barrier to movements of fish represented by the new dam. These impacts are among the most difficult to mitigate and, from the standpoint of aquatic resources, may be the most serious impacts of new hydropower development.

3.4.4 Riparian and Terrestrial Ecosystems

Construction of new dams for hydropower development would cause impacts similar to, but more extensive than, those described in Sect. 3.2.4. The disturbance associated with constructing the dam, powerhouse, penstock, roads, and other facilities would result in greater risk of habitat damage through soil erosion and spills. In addition, creation of a new impoundment could eliminate or alter terrestrial and riparian vegetation associated with free-flowing streams through inundation or flow changes.

Hydroelectric generation at a new dam may cause major changes in streamflows below the reservoir, which in turn could significantly impact tailwater wetlands and emergent vegetation. Projects that produce electricity by diverting water through penstocks for significant distances may produce losses or undesirable changes to riparian zones along dewatered reaches (Kondolf et al. 1988). Such damage is particularly serious in semiarid or arid regions (including much of California and the southwestern United States) where streamside vegetation is particularly important ecologically. In such regions the riparian zone may provide the only forest habitat.

3.4.5 Becreation

The creation of hydropower facilities at new dams involves a host of impacts to recreation resources but also offers new recreational opportunities. The impoundment of free-flowing streams necessarily means the conversion of aquatic habitat from flowing water to slack or slow-flowing water. It also can entail major reductions in flows in stream reaches.

Construction of dams, powerhouses, penstocks, intake structures, power lines, access roads, etc., can have severe negative impacts on fishing, swimming, hiking, and hunting. These effects should be short-lived in the East, but in the drier West, where vegetation takes longer to recover, the effects of hydropower development can be visible for years, affecting the aesthetics of many recreational pursuits. Development of high-head facilities will most likely cause more and longer-lasting construction impacts than will the development of low-head facilities.

Many of the normal measures to protect against erosion and other disturbances common to licensed construction activities will be adequate to protect recreational resources from the worst construction impacts, but heavy equipment and major land-use change will cause severe effects on most recreational pursuits during the construction process. Following the measures outlined in Sect. 3.1.1.1 should ensure that long-term impacts from construction activities are minimized.

Blockage of fish migration can seriously affect the nature of the fishing resource and the types of fishing opportunities available. Partial dewatering can cause changes in riparian vegetation and the wildlife that it supports, inducing major changes to hunting, fishing, hiking, swimming, picnicking, and nature observation. Increased access through new roads can mean visitation by a wider variety of

users than that of the preconstruction site. Submergence of terrestrial habitats by reservoirs has obvious long-term impacts on displaced recreational land uses (e.g., hunting, hiking, and nature observation could be replaced by fishing, boating, and swimming). Downstream of new hydropower facilities, long-term impacts could affect fishing, hiking, and boating.

Many impacts, including submerged lands, changed riparian vegetation, lost aquatic habitats, expanses of calm water, and partially dewatered streams, are irreversible as long as the facilities are in place.

3.4.6 Energy Security Benefits

The energy security benefits of hydroelectric development at new sites are similar to those at retrofitted dams (Sect. 3.2.6). However, the additional environmental impacts of developing new dams add uncertainty to the question of how much of this resource can be developed; environmental concerns would prevent the development of some new hydroelectric sites. Since few good sites remain for major new hydroelectric development, development at new sites can be expected to be less reliable (i.e., more vulnerable to short-term fluctuations in streamflows) and smaller than much of the existing hydropower resource.

4. CONCLUSIONS

DOE'S proposed initiative to upgrade existing power plants and to retrofit dams to generate new hydropower is expected to increase capacity by about 16 GW. This capacity could replace about 9 GW of fossil-fueled capacity or other electric power resources.

Hydropower plant upgrades can provide additional power with minimal environmental impacts. Upgrades that involve only efficiency increases are expected to have negligible impacts and to provide benefits such as reduced turbine mortality of fish and the opportunity to install aerating turbines. Upgrades that involve increasing the flow or head used by a plant (e.g., by adding turbines or raising the elevation of a reservoir) have greater potential to cause changes in the environment, such as changes in downstream flows and water quality and in the terrestrial environment near the reservoir. Mitigation techniques are available to minimize or eliminate most impacts of upgrade projects.

Retrofitting dams to generate new hydropower is attractive because most impacts of hydropower development have already occurred as a result of construction and operation of the dam. However, site-specific impacts can still result, such as reductions in aeration at the dam, changes in reservoir and tailwater water quality resulting from changes in release elevation, turbine entrainment and mortality of fish, and slightly increased flood risks. Most of these impacts can be avoided or reduced by using common mitigation techniques. Site-specific evaluation of project impacts during the FERC licensing

process is designed to ensure that projects include adequate mitigation and that impacts are acceptable.

Hydropower developed under the proposed DOE initiative is most likely to replace fossil-fueled power generation. The use of fossil fuels for power generation has many potential significant environmental impacts. Coal- and oil-fired generation is an important contributor to local and regional air quality problems such as acid deposition. The extraction, transportation, and refining or cleaning of oil and coal involve many impacts such as oil spills, the impacts of coal mining, and solid waste disposal. Generation using natural gas causes fewer air emissions, but all fossil fuel combustion emits large quantities of carbon dioxide, contributing to the global greenhouse gas problem.

The development of hydropower at new darns could also be replaced by some of the power developed under the DOE initiative. Hydropower development at new dams involves some local, regional, and long-term impacts that would not result from development at existing dams, but generally does not cause impacts of global concern.

The hydropower that would be produced as a result of the DOE initiative would replace only a small part of the growth in U.S. fossil-fueled generation expected by 2030. The estimated 5.1 GW of upgrade capacity and 10.6 GW of retrofit capacity would replace approximately 1.2% of the increase in fossil-fueled capacity between 1990 and 2030 predicted under t h e NES reference case. However, there is a great need to reduce the impacts of fossil generation such a5 acid deposition, greenhouse gas emissions, and consumption of petroleum reserves. The proposed hydropower initiative could reduce sulfur emissions by replacing conventional coal-fired plants but would result in only very small reductions in emissions of nitrous oxides, carbon dioxide, and particulates. The development of hydropower at sites where impacts would be minor is an important and beneficial way to reduce fossil generation.

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Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects

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Large dams vary considerably in their adverse environmental and related social impacts. From an environmental standpoint, there are relatively good dams and bad dams.

Large dams vary considerably in their adverse environmental and related social impacts. From an environmental standpoint, there are relatively good dams and bad dams. While some large dams are relatively benign, others have caused major environmental damage. The severity of environmental impacts from a hydroelectric project is largely determined by the dam site. While dams at good sites can be very defensible from an environmental standpoint, those proposed at bad sites will inherently be highly problematic, even if all feasible mitigation measures are properly implemented.

This paper provides a simple, yet robust, methodology for comparing proposed hydroelectric project sites in terms of their expected negative environmental impacts, and relating these to power generation benefits. The paper also summarizes the environmental mitigation options for large dams. If properly implemented, these mitigation measures can effectively prevent, minimize, or compensate for many (though not all) of a hydroelectric project's negative impacts. Nonetheless, the most effective environmental mitigation measure is good site selection, to ensure that the proposed dam will cause relatively little damage in the first place. The paper presents quantitative indicators (using data that are relatively easy to obtain) for rating and ranking proposed new hydroelectric projects in terms of their likely adverse environmental impacts. Projects with a small reservoir surface area (relative to power generation) tend to be most desirable from both an environmental and social standpoint, in part because they minimize natural habitat losses as well as resettlement needs. In general, the most environmentally benign hydroelectric dam sites are on upper tributaries, while the most problematic ones are on the large main stems of rivers. Power expansion planning should ensure that environmental criteria, of the type outlined in this paper, are given appropriate weight in hydroelectric project site selection. Many of the more problematic dam sites are best left undeveloped, because the environmental or related social impacts are likely to be unacceptably high. In those cases, other power generation technologies are likely to be more environmentally desirable. Conversely, hydroelectric dams at good sites (with relatively low adverse impacts) and with effective implementation of proper mitigation measures are likely to be more attractive from an environmental standpoint than the most likely power generation alternatives.

A SUMMARY OF THE SOCIAL AND ENVIRONMENTAL IMPACTS OF THE ...

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A SUMMARY OF THE SOCIAL AND ENVIRONMENTAL IMPACTS OF THE PROPOSED ARENG VALLEY HYDROELECTRIC DAM, SOUTHWEST CAMBODIA SUMMARY The upper Areng Valley consists of a ...

A SUMMARY OF THE SOCIAL AND ENVIRONMENTAL IMPACTS OF THE PROPOSED ARENG VALLEY HYDROELECTRIC DAM, SOUTHWEST CAMBODIA

SUMMARY

The upper Areng Valley consists of a matrix of evergreen forest, grasslands, swamps and lakes, rivers and associated riparian forest, interspersed with small indigenous communities. These local families, many of which have lived in the Areng Valley for centuries, live in harmony with nature. Land cleared by the Khmer Rouge for rice cultivation has since been returned to their natural marshland habitat that abounds with wildlife. These villagers are the original protectors of the valley's habitats and wildlife. Their sacred forests abound with some of the largest trees in southwest Cambodia and teem with animals, and the traditional conservation beliefs of the villagers are the main reason why the world's largest population of one of the world's most endangered crocodiles, the Siamese Crocodile, has managed to survive where almost all other populations have been driven to extinction.

The upper Areng Valley is threatened by plans to build a hydroelectric dam that will inundate nine villages, 1500-2000 ha of indigenous lands including sacred forests covering over 500 ha, and at least 39 faunal species that are globally threatened or nationally protected. Unlike other dams proposed for the region, this dam will flood a broad, flat valley that is densely populated and includes the richest agricultural land in southwest Cambodia as well as some of Cambodia's rarest and most threatened wildlife. The environmental and social damage relative to the amount of power generated is therefore disproportionately high.

The effects of this dam on the downstream biome will also be extremely severe. Changes to the flow regime of the Areng River will stop the annual freshwater flush of the brackish and saline water that enters the river system during the dry season. This has the potential to drastically reduce rice yields in approximately 1500 ha of paddy in the coastal zone. This will directly affect the livelihoods of at least 1800 people. Reduced wet season flooding will also reduce the fish production, which depends on spawning in the seasonally inundated swamp forests in the lower Areng Valley. These forests also support populations of many globally threatened and nationally protected species which will be locally extirpated if the dam is built. Within the mid-reaches of the Areng River, alterations to flow regime will have devastating effects on a unique fish fauna due to disrupted breeding cycles and alterations to the turbidity, salinity and oxygen content of the river.

This report summarises the social and biological impacts of the proposed Areng River hydroelectric dam.

1. SOCIAL IMPACTS

1.1 The Upper Areng Valley Inundation Zone

The Areng inundation zone is presently home to over 1500 people, many of whom consider the area their ancestral home. These indigenous people, the Khmer Daeum (or 'old Khmer'), are thought to be the original descendents of the Khmer race and have existed in the area for at least 600 years. The communities living in the Areng Valley depend on the natural resources of the area for their survival, including productive rice paddies, forest gardens (chamkars), fish from the Areng River and the harvesting of non-timber forest products from the nearby evergreen forest.

These communities are very close-knit, with links that run through the landscape which are bound to village life by local Buddhist and animist beliefs. This is emphasised by the role and importance of 'spirit forests' and local forest deities, such as Neck Ta, who is thought to inhabit the forest and waterways of the valley. Any forced migration instigated by the creation of a dam and lake will break this connection and have deep social repercussions for a people who feel spiritually linked to the forest and the valley.

It should be noted that the inhabitants of the upper Areng Valley suffered severely during the Khmer Rouge period and in the years immediately after the fall of this regime. In 1979 most of the villagers in the valley, for example, were forced out of the area by the Vietnamese army and were moved to Chi pat, while others fled to Thailand. In subsequent post-conflict years the villagers have slowly returned to the valley; however, any activities that result in their forced migration, again, will result in the re-traumatisation of a people who have already suffered tremendously over Cambodia's recent past.

1.2 The Downstream Biomes

The downstream village of Trapeang Rung has an approximate population of 500 families, comprising over 2500 people. These people depend on the inundation of over 600 ha of rice paddies, much of which will not be inundated due to changes in flow regimes by the hydroelectric dam. Most of this village also relies on the riverine fishery for their protein needs, with excess being sold in nearby markets to neighbouring towns. Alterations to the flow regime of the river means that this livelihood activity would be jeopardised as a result of the impacts on water levels and associated impacts on spawning grounds and fish feeding areas.

2. BIOLOGICAL IMPACTS

2.1 The Upper Areng Valley Inundation Zone

The upper Areng Valley contains over 20,000ha of pristine habitats including grasslands, deciduous forest, evergreen forest, rivers and streams, and standing wetlands (lakes and marshes). The Areng River is the largest of only a handful of Cambodian rivers that are not connected to the Mekong River and its tributaries. For this reason the Areng River has been found to harbour a unique fish fauna that does not occur anywhere else in Cambodia, including globally threatened and endemic species. Most of these species only occur in the upper reaches of the Areng River, so their habitat will be almost entirely lost if the Areng Valley dam is built.

As shown by Table 1, the upper Areng Valley contains an extremely diverse fauna - almost 300 known species including at least 31 mammals, birds, reptiles, fish and amphibians that are globally threatened with extinction (IUCN, 2007). An additional eight species are classified as nationally threatened with extinction (MAFF Wildlife Prakas, 2007). Appendix 1 lists these species and their global and national conservation status.

Table 1: Numbers of globally threatened and nationally protected species in the upper Areng Valley

	Total number of species recorded in the upper Areng Valley*	Globally threatened species (IUCN, 2007)	Nationally protected species (MAFF, 2007)
Mammals	57	14	4
Birds	93	7	1
Reptiles	55	8	3**
Amphibians	29	1	0**
Fish	43	1	0**
Total	277	31	8

* Emmett, D.A. & Olsson, A. (Editors) (2005). Biological Surveys in the Central Cardamom Mountains. Conservation International (CI) Cambodia Program and Forestry Administration (FA), Phnom Penh

** The National Fisheries Red List for threatened Cambodian fish, turtles and amphibians has not yet been passed as law

The upper Areng Valley is therefore one of the most important areas for biological conservation in Cambodia and indeed the Indo-Burma Hotspot. Crucial habitats for conservation of the species listed in Table 1 and Appendix 1 will be lost if the valley is inundated, and the species populations themselves will be locally extirpated. This will have serious impacts on the national and global status of these species. For example, the upper Areng Valley contains approximately 30% of the global hatchling recruitment of the critically endangered Siamese Crocodile (see below), so the loss of this population would represent a global crisis for this species.

2.1.1 Priority Taxa

Taxa of exceptionally high conservation importance that are threatened by the hydroelectric dam are described in detail below.

Siamese Crocodile: The Siamese Crocodile (Crocodylus siamensis) is one of the rarest crocodile species in the world, and is listed as critically endangered by the IUCN. Global populations number considerably fewer than 200 individuals, with only 6 breeding sites known. The upper Areng River represents the most significant and secure Siamese Crocodile site in the world. This population has been the centre of international conservation efforts since 2002, and the focus of documentaries by the BBC and National Geographic, as it is the only location in the world where these crocodiles can be readily seen and studied. This is the largest breeding population known, yet only contains an estimated 40-50 individuals composed of adults, juveniles and young crocodiles. If the Areng River is dammed, this fragile population will be seriously reduced or wiped out. The inundation will destroy vital lakeside nesting areas, shallow feeding zones, sandy basking areas along the river, and essential lakeside burrows used for shelter.

Asian Elephant: The Asian Elephant (Elephas maximus) is classified by IUCN and the Cambodian National Red List as endangered. The upper Areng Valley is an important site for elephants as it is within the home range of several herds. Elephants are often sighted in the valley. The inundation will flood an important part of the species' range and disrupt the annual migratory route of this endangered species.

White-winged Duck: The White-winged Duck (Cairina scutulata) is classified as endangered by IUCN and the Cambodian National Red List. The species is in rapid global decline due to deforestation, wetland drainage and hunting. An assessment in 2002 indicated that fewer than 800 remain in the wild (IUCN, 2007). However, breeding pairs are frequently observed in the upper Areng Valley, including a recent sighting of two pairs and a single bird at one wetland site. Estimates suggest the upper Areng Valley may provide vital habitat for as many as 30-40 White-winged Ducks. All suitable habitat for this species (small densely forested wetlands) will be lost if the dam is built.

Tortoises and Freshwater Turtles: Six species of turtle and tortoise are known to occur in standing wetlands and forested areas along the upper Areng Valley. The Elongated Tortoise (Indotestudo elongata) and Yellow-headed Temple Turtle (Heosemys annandalii) are classified by IUCN as endangered, and the Asiatic Softshell Turtle (Amyda cartilaginea), Black Marsh Turtle (Siebenrockiella crassicollis), Asian Box Turtle (Cuora amboinensis) and Giant Asian Pond Turtle Heosemys grandis) are classified as vulnerable. Five of these species rely on shallow weed-filled wetland habitats; the sixth, the Elongated Tortoise, is restricted to lowland grassland and open forest in the valley. All of these habitats will be lost if the valley is inundated, and the resultant reservoir with its wide draw-down zone will provide an entirely unsuitable habitat for freshwater turtles. These six globally threatened species are all predicted to become locally extinct if the dam is built.

Asian Arowana: The Asian Arowana (Scleropages formosus) is listed as endangered by IUCN due to loss of habitat and over-collection for the pet trade. In Cambodia, these fish are only known to occur in the slightly acidic streams that drain into the Gulf of Thailand. The species is possibly extinct in Thailand and Vietnam (IUCN, 2007) and remaining populations in Indonesia and Malaysia are highly fragmented and under extremely high threat. The largest known population in Cambodia occurs in the upper Areng Valley. This population is globally important for the conservation of this rare species and has been the focus of a successful community-based government conservation program. The entire population of this fish will be destroyed if the dam is built because it cannot survive in the resultant reservoir as its life-cycle is adapted to clear fast-flowing rivers. A smaller population of Asian Arowana that is located in the Areng River downstream of the proposed dam site will almost certainly driven to extinction because their breeding behaviour is closely linked to annual flow regimes which will be significantly and permanently disrupted by the dam.

2.2 The Downstream Biomes

Aquatic biodiversity in the mid-reaches and lower sections of the Areng River will also be severely threatened by the proposed hydroelectric dam due to changes in the flow regime. Seasonal flooding will be greatly reduced because the water will be used to refill the reservoir, and the annual cycle of changing water-levels will be permanently altered in order to generate electricity year round. Studies of the effects of hydroelectric dams on downstream biomes in Thailand and Laos clearly show that this has dramatic negative impacts on the river and its biodiversity. The reduction in wet season flooding will have a devastating effect on the entire river system, as annual floods are crucial to maintain the salinity and nutrient balance in the lower reaches and to flush the river and prevent stagnation in the mid-reaches. Fish migration and breeding, which depend directly on the extent of the seasonally flooded forests, will also be severely disrupted. This will lead to the local extinction of many species whose life cycles are tied to annual changes in the river.

The sharp reduction in seasonal flooding that will result from the hydroelectric dam will dramatically impact the seasonally inundated swamp forest ecosystem in the lower Areng Valley. These ecosystems were once extensive in the deltas and lower floodplains of many rivers in the region, but are now restricted to isolated fragments (Tordoff et al, 2006). These ecosystems are important for a number of globally threatened species, notably large waterbirds, otters and freshwater turtles. The lower Areng Valley contains over 1,000 ha of seasonally inundated swamp forest. These forests are crucial for fisheries management in Koh Kong Province because, when inundated, they form the breeding and feeding grounds for vast numbers of fish, as well as other aquatic fauna which are essential for the freshwater ecosystem such as crustaceans. Studies have shown that these flooded forests are crucial breeding and feeding grounds for globally threatened and nationally protected species including the Smooth-coated Otter, Lesser Adjutant, the endangered Yellow-headed Temple Turtle, and five other turtle species that are classified by IUCN as vulnerable with global extinction (Som et al, 2005; Tordoff et al, 2006). The seasonally inundated swamp forests are also feeding grounds for the only known Cambodian population of the critically endangered Mangrove Terrapin (Batagur baska), one of the world's rarest turtles. This species has been the focus of a comprehensive conservation program since 2002. The reduction in annual floodwaters due to the proposed hydroelectric dam will prevent flooding of these seasonally inundated swamp forests which will lead to the loss of this rare ecosystem, a dramatic reduction in the productivity of the downstream fishery, and the loss of crucial breeding and feeding grounds for some of Cambodia's most endangered species.

2.3 The Construction Period

The construction period will lead to a massive influx of workers into the Areng Valley for the duration of the dam's construction, which is likely to last several years. This will lead to vastly increased levels of illegal fishing and hunting, especially within the Central Cardamoms Protected Forest (CCPF). In addition, legal tree removal within the inundation zone is likely to lead to additional, illegal logging in areas surrounding the inundation zone. There will also be high levels of hunting within and around the inundation zone during this period, which is a very serious concern as over half of the inundation zone lies within the CCPF, a sanctuary for rare and threatened species.

This massive and prolonged pressure on the wildlife and forests surrounding the dam construction area by workers at the site will have severe impacts on the biological diversity of the area, particularly on the rare wildlife which lives in the CCPF.

2.4 The Post-Construction Period
When the dam is complete and the reservoir is fully inundated, it will provide easy access to the core protection zone of the CCPF. Hunters will be able to travel quickly across the reservoir by boat to areas that were previously inaccessible. The large reservoir, with its long periphery, will be very difficult to patrol.

This will lead to vastly increased levels of illegal logging and hunting within the CCPF which will put many rare species (e.g., clouded leopards, bears, gaur) at increased risk. Access roads for the dam will also provide easy routes for hunters and illegal loggers to use. This dramatic increase in access to the CCPF is certain to have serious consequences for its wildlife and forests.
Figure 1: A map of the area which will be inundated if the proposed hydroelectric dam is built
Appendix 1: Globally or nationally threatened wildlife recorded in the upper Areng Valley inundation zone

Species	Common name	IUCN or National Status*
Mammals		
Elephas maximus	Asian Elephant	IUCN: Endangered National Red List: Endangered
Neophelis nebulosa	Clouded Leopard	IUCN: Vulnerable National Red List: Endangered
Pardofelis marmorata	Marbled Cat	IUCN: Vulnerable National Red List: Rare
Catopuma temminckii	Asian Golden Cat	IUCN: Vulnerable National Red List: Rare
Hylobates pileatus	Pileated Gibbon	IUCN: Vulnerable National Red List: Rare
Ursus tibetanus	Asiatic Black Bear	IUCN: Vulnerable National Red List: Endangered
Bos frontalis	Gaur	IUCN: Vulnerable National Red List: Rare
Neamorhedus sumatraensis	Southern Serow	IUCN: Vulnerable National Red List: Rare
Lutrogale perspicillata	Smooth-coated Otter	IUCN: Vulnerable
Cuon alpinus	Dhole	IUCN: Endangered National Red List: Rare
Macaca nemestrina	Pig-tailed Macaque	IUCN: Vulnerable
Arctictis binturong	Binturong	IUCN: Vulnerable
Viverra megaspila	Large-spotted civet	IUCN: Vulnerable
Hystrix brachyura	East Asian Porcupine	IUCN: Vulnerable
Manis javanica	Sunda Pangolin	National Red List: Rare
Ursus malayanus	Sun Bear	National Red List: Rare
Arctonyx collaris	Hog Badger	National Red List: Rare
Nycticebus coucang	Slow Loris	National Red List: Rare
Birds		
Arborophila cambodiana	Chestnut-headed Partridge	IUCN: Vulnerable National Red List: Rare
Cairina scutulata	White-winged Duck	IUCN: Endangered National Red List: Endangered
Oriolus mellianus	Silver Oriole	IUCN: Vulnerable National Red List: Rare
Pavo muticus	Green Peafowl	IUCN: Vulnerable National Red List: Rare
Leptoptilos javanicus	Lesser Adjutant	IUCN: Vulnerable National Red List: Rare
Heliopais personata	Masked Finfoot	IUCN: Vulnerable National Red List: Rare
Mycteria cinerea	Milky Stork	IUCN: Vulnerable National Red List: Rare
Buceros bicornis	Great Hornbill	National Red List: Rare
Reptiles		
Crocodylus siamensis	Siamese Crocodile	IUCN: Critically endangered
Indotestudo elongata	Elongated Tortoise	IUCN: Endangered
Manouria impressa	Impressed Tortoise	IUCN: Vulnerable
Amyda cartilaginea	Asiatic softshell turtle	IUCN: Vulnerable
Cuora amboinensis	Asian box turtle	IUCN: Vulnerable
Siebenrockiella crassicollis	Black Marsh Turtle	IUCN: Vulnerable
Heosemys grandis	Giant Asian Pond Turtle	IUCN: Vulnerable
Heosemys annandalii	Yellow-headed Temple Turtle	IUCN: Endangered
Ophiophagus hannah	King Cobra	National Red List: Rare
Naja kouthia	Monocled Cobra	National Red List: Rare
Lycodon cardamomensis	Cardamom Wolf Snake	National Red List: Rare
Amphibians		
Paa fasciculispina	Giant Spiny-breasted Frog	IUCN: Vulnerable
Fish		
Scleropages formosus	Asian Arowana	IUCN: Endangered

* MAFF Wildlife Pracas, 2007

The Impact Of Hydroelectric Power Development Environmental Sciences Essay

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The Impact Of Hydroelectric Power Development Environmental Sciences Essay. Over the years, there has been increasing interest in electricity generation using hydropower.

Over the years, there has been increasing interest in electricity generation using hydropower. However, it is only recently that the impacts of hydroelectric power plants on the environment have been recognized; until now, it was assumed that hydroelectric power generation was a clean and environmentally friendly electricity production method, compared to other methods. After extensive research, it has been found that hydroelectric power production has some impacts that include production of greenhouse gases from the decaying vegetation that have been submerged in the dams, and flooding of big land areas, rendering them unfit for agriculture and other human activities, among others. Perhaps the biggest impact from hydroelectric power production is the effect it has on water quality. Dam construction, for the purposes of power production, can change the quantity and quality of water of a river. The decaying vegetation contains bacteria that may also transform the mercury found in basic reservoir rocks into a water soluble form, which builds up in the fish bodies and consequently posing a health risk. This paper will explore the impact of upgrading of existing hydroelectric power plants on water quality by, first, describing typical proposed initiatives and alternatives when upgrading existing hydropower plants, and then exploring the environmental impacts of such proposed initiatives and alternatives.

For any project that aims at upgrading an existing hydropower plant, the main objective should be to increase efficiency and increase energy production and output to the maximum with no undesirable environmental impacts.

Several methods exist that can be used to increase the production of power at existing hydropower plants. Usually, these methods can be grouped into two: methods that increase the power production efficiency and methods that increase the usable water or head volume.

To improve efficiency, old turbine runners and gates can be replaced with newer, more efficient designs; coatings can be used to minimize loss of energy through friction in flow channels; the performance of the turbine can be tweaked; turbine runners can be replaced with newer ones having a similar design to reduce cavities and other defects; generator efficiency can be increased by rewinding them; water leakage can be reduced in gates and other structures; trash track cleaning can be bettered to minimize friction losses; and automated systems for collection and analysis of diagnostic data can be set up.

To increase the usable water or head volume, the dam elevation can be increased to increase the head and storage capacity; more turbines can be added to use the water that is being spilled; installing newer turbines and generators that have wider flow ranges; and other modifications can be effected during distribution of storage and releases of the reservoir.

The main activities during retrofitting a dam for hydropower generation include: constructing penstocks, intakes, and a powerhouse that may, in high-head dams, be located downstream, or, in dams with low head, replace sections of the existing structure; employment of mitigation actions to minimize the project's impacts; erection of power lines to connect the project into the existing power grid; and rerouting through the water turbines. Monitoring of quality of water, screening to prevent fish from entering the turbine, building of fishing facilities, and flow release conditions can make up the mitigation actions.

When upgrading a hydropower plant to improve its generating capacity, it is presumed it replaces the existing capacity since it is costly to operate because of high costs, for example obsolete plants or those that use costly fuel, and the new capacity that is more expensive than hydropower generation at existing dams. To determine the correct capacity mix that the proposed hydropower upgrade will replace, there is need for a complete regard for future energy expenses, the nature and location of existing and future hydropower plants, and environmental factors particular to a site.

As has been established, any hydropower development, and other methods of generating power, causes several environmental impacts. The next sections explore the impacts of hydropower upgrades and also for power generation using fossil fuels, which is the most probable alternative.

Usually depending on the type of upgrade being done, the environmental impacts of hydroelectric plant upgrades are not as severe when measured up against other energy development impacts. In fact, upgrades that only require the generators or turbines to be replaced, leaving the reservoir's volume and release timings unchanged, have few immediate impacts and may even have several lasting environmental benefits. The upgrades that see the volume and release timings change on the other hand may some lasting impacts.

Minor upgrades do not require much work and thus have little or no impacts on the water resources, like erosion, oil spills, and riverbed disruption, among others. However, major upgrades would need more broad construction and thus the impact on water resources is increased. Activities in such upgrades such as excavation or heavy machinery use during construction increase the local streambeds' and banks' erosion, causing more sediment loads and possible deposition downstream. The redistribution of sediments by construction may have harmful effects when the contamination of the sediment is local. While lasting impacts on the water quality are unlikely, construction during upgrades may lead to short-term impacts like small oil spills. Due to the stoppage of water flow in major upgrades, short-term dewatering and stagnation of the tailwater may occur, resulting in high growth of algae and varying concentrations of dissolved oxygen (DO) which eventually adversely impacts aquatic life.

Turbines able to use higher flows may be installed during project upgrades where spillage of flow occurs via spillways or gates because the existing turbines' size cannot use all the flow. During spillage, the spilled flow may somewhat have increased DO concentrations, or become aerated. When the turbines' capacity is increased, there will be an increase in the flow percentage in the turbine, where aeration is minimal or absent. Total concentrations of DO would decrease in projects where the DO concentration is low and an upgrade would cause less flow aeration during spillage. In projects where spillage happens during high flow periods only, spillage may be used for power generation because it does not have significant impact

To reduce problems of water quality is some projects, turbine replacement may be the solution. In the hot season, stratification occurs in most deep reservoirs. At the bottom is a layer of low DO concentrated cold water, which when released through the turbines means the tailwater will have insufficient DO concentration. To ease this problem, the water can be aerated prior to passing it through the turbine. Research has shown that in a few plants where the turbines have been constructed to entrain air into the flow when it passes through them, aeration of the tailwaters is sufficient and economical; aquatic life and efficiency may however be affected. In such projects, upgrading of old turbines may enable the installation of self-aerating turbines that consequently may increase the DO concentrations of the tailwater, eventually benefiting the environment.

As seen, to upgrade existing hydropower plants, methods like increasing the turbines' flow rates or increasing or altering reservoir storage, done by increasing the dam's elevation and changing the water release periods during the year respectively, can be used, which may impact the downstream and reservoir water quality such as changing the concentrations of DO and temperature of water.

The impacts of hydropower plants upgrades on the air quality are usually temporary and minimal, and normally occur only because of dust emissions and other emissions that have escaped from the equipment used in upgrade projects that need major construction. In fact, hydropower upgrades may positively affect the air quality by minimizing generation using fossil fuel.

It has been established that the changes that may occur during construction and operation activities during existing hydropower plant upgrades impact aquatic life. While minor upgrades do not significantly impact the water quality, major upgrades may result in soil erosion and sedimentation, chemical and construction oil spillage, and disruption of contaminated sediments, which may affect aquatic life. Increased temperatures and decreased concentrations of DO, poor tailwater quality, could result because of variations in flow releases during construction. Moreover, because of passing lowly DO concentrated water through a turbine, rather than spilling the water over a dam, there could be decreased aeration which also affects aquatic life.

Disruption to riparian wetlands and habitats due to construction activities is the main cause of the impacts of existing hydropower plants upgrade on terrestrial ecosystems. However, these impacts, which depend on the site or project, are usually insignifanct and only a few projects may cause significant impacts. Upstream terrestrial habitat may significantly be lost through inundation because of developments that comprise enhancing elevations of the dam. Short-term sedimentation and variations in flow schedules during construction, in addition to equipment replacement inside buildings, is not likely to have long-term impacts on terrestrial ecosystems.

Recreational facilities will not be significantly impacted by minor hydropower plant upgrades except during a small construction period. Major upgrades on the other hand may impact recreational activities. With the possibility of the sediment loads increasing as a result of streambed and bank erosion, the affected water quality may impact recreational activities such as water skiing, fishing, boating, and swimming, among others; such activities may also be affected by rare minor spillage of oil and lubricants. During upgrade construction, there may be dewatering and stagnation because of controlled flow, which results in unwanted growth of algae and low concentrations of DO, consequently affecting activities like fishing. Open rocks, nasty smells, loud clamors, dust, harmful gas emissions, and eroded banks, among others may also impact the aesthetics and thus the recreational activities.

Decreased aeration in downstream dam water is among the lasting impacts of hydropower plant upgrade on recreational activities. New turbines decrease the DO concentration, affecting aquatic life and eventually fishing activities. Recreational activities may also be impacted in projects where high flow-capable turbines are used because there will be different flow schedules for impoundments. Modifications in the downstream flow scale or scheduling may impact the aquatic life, thus impacting recreational activities.

Concerns for dam safety are usually as a result of major, not minor ones, hydropower plant upgrades which involves elevating the reservoir levels that results on more structural loads on the dam, consequently compromising the general dam's safety factor. In most upgrade developments, flooding fears are uncommon. Still, among the methods of increasing generation at existing reservoirs is to minimize flood storage so as to make more water available for generation. There would, as a result of this decrease in flood storage, be an increased concern for downstream flooding; different sites have different impacts and magnitude of the extra flooding.

Although it will not significantly to the U.S.'s total power grid, the upgrade of existing hydropower plants would provide cheap and valuable energy form that is local and renewable, thus is not susceptible to foreign regulation or fuel scarcities. The value of energy resulting from such upgrades is felt more during peak demands, even though it may sometimes prove unreliable, especially during low flows or when more flow releases are required to improve water quality and aquatic life.

When an existing dam is developed by installing new hydropower plants, many advantages are realized, minus the several bad environmental effects experienced during hydropower development at new dams. This is because at existing dams, the impacts caused by stream seizure such as submergence of terrestrial habitat, obstruction of fish migration, change in volume and timing of downstream flow, among others, have already been felt; more impacts may still be felt during retrofitting.

There may be some temporary impacts on water resources that result from the construction activities during retrofitting. Erosion at the site of construction and the inadvertent discharge of unearthed materials into the stream may cause the tailwaters to have sediment loads. Moreover, the construction activities may cause spillage of oil and disturbance and distribution of contaminated sediments present at a dam. These temporary impacts usually end after construction is complete.

Due to changes in release schedules of water in hydropower plants, the downstream may have harmful effects like disrupting aquatic life, recreational activities, and increasing erosion of the bank. As such, flow changes are usually prohibited because they may lower the dam's capacity to meet its initial targets.

Water in a retrofit hydropower plants can be extracted from elevations separate from the initial impoundment's withdrawal elevation. During summer, the quality of water in deep storage reservoir usually fluctuates with elevation. An impoundment, with cold water usually having low concentrations of DO in its lower elevations and warm water having high concentrations of DO in the higher elevations, is caused by thermal stratification. In such stratified impoundments where the existing release is through a spillway or high elevation gates at the top, there would be variations in downstream quality during hot weather from high to low concentrations of DO and high to low temperatures when there is installation of a hydropower plant withdrawing from low elevations. There is usually a high heavy metal concentration like magnesium and iron, irritant compounds, in yatter discharged from low elevation. Rarely, shallow impoundments may also have stratified water quality.

Variations in the withdrawal elevation from a reservoir, in addition to the impacts discussed earlier, may also impact quality of water in the impoundment upstream of the dam. A gate release replacement with a turbine intake at even the slightest elevation change for instance may lower the volume of cold water on the reservoir's bottom and raise the warm water volume in the reservoir in hot weather. These variations may impact temperature of water, production of algae, concentration of DO, and other issues of water quality at varying times and sites in the reservoir. Reservoir simulation models are employed in the prediction of the compound, unpredictable, and site-exclusive impacts. Changing the withdrawal elevation may sometimes be useful for the water quality in the reservoir, and sometimes harmful.

Hydropower upgrade projects cause nitrogen super saturation and subsequently the fishes' gas bubble infection which causes the formation of gas bubble in a body of the fish which may kill. Three conditions may result in the formation of nitrogen super saturation: when releases from the reservoir are very aerated, when air is entrained into badly constructed penstocks, and when nitrogen saturated water from inside the reservoir is discharged to tailwaters. Nitrogen super saturation does not generally have large impacts in hydropower development at retrofitted dams.

As has been established, impacts of air quality of retrofitting dams are similar to hydropower plant upgrade's local, temporary and minimal impacts. Occurring only during construction, effects may include escaping dust emissions and equipment use emissions and are generally minimal compared with other emissions.

The aquatic resources during construction from dam retrofitting are impacted the same way as during upgrade of existing hydropower plants. There is however greater chance for the impact on aquatic resources, by degrading the water and habitat quality, to be more, particularly from water degradation, because of the major construction in this alternative. Despite the already existing reservoir and the organisms' adaptation to the water environment, beginning of hydroelectricity production may change the releases' volume and timing. Consequently, there may be instant and more severe water level variations in the tailwaters and reservoir, which destroy vital shallow-water habitat for aquatic life. Moreover, when lowly concentrated DO, cold, deep water is discharged from stratified reservoirs will degrade the quality of water of the tailwaters and negatively affect the ecosystem adapted to deep warm, highly concentrated DO water releases.

Retrofitting hydropower dams has a few dam safety worries. Because construction may require removing of some of the existing dam's parts, there is a possibility of the dam's groundwork or structure weakening if improperly done.

Design-specific, the construction of hydropower plants at dams with low-head may upsurge the flooding upstream's rate and scale. If there is the slightest obstruction in the flows' path due to construction, the upstream flood elevations would increase.

Although it will not significantly to the U.S.'s total power grid, energy from retrofitting dams would provide cheap and valuable energy form that is local and renewable, thus is not susceptible to foreign regulation or fuel scarcities. The value of energy resulting from such an alternative is felt more during peak demands, even though it may sometimes prove unreliable, especially during low flows or when more flow releases are required to improve water quality and aquatic life.

Most of U.S. power production capacity is due to the use of fossil fuels (coal, gas and oil). The power that would have been produced by hydropower is then got from the use of these fossil fuels.

The generation of fossil-fuels can lead to a number of effects to water resources. In most cases fossil fuels plants are usually constructed next to large water bodies to provide water for cooling or to barge as means of transport for the fuels. The construction of these plants also interferes with the land areas leading to erosion and as a result leading to residue loads in the water bodies.

Coal mining and transportation are the main effects of coal- power generation to numerous water bodies. In the humid regions coal mines have for a long period triggered serious pollution of water bodies due to changing of the river channels (because of direct mining effects, hydrologic changes to watershed, and increased residue loads) and drainage of acids from mines. Although these impacts can be controlled, to a certain extent they cannot be entirely avoided. In arid areas, these effects are less compared to those in humid areas. However, impacts such as alteration of groundwater can occur. Even though, the transportation of fossil fuels by barge on water resources can causes minor impacts, other means of transportation such as coal slurry pipelines, can result into severe impacts on local water bodies. The washing of coal at the power plant or mine to improve its burning or emissions qualities; large amounts of water are consumed as well as pollution as a result of these processes.

Water resources can also be degraded due to production and transportation of gas and oil used in the production of electric power. These effects can be due to offshore oil production and oil spills in the course of refining and transportation. The production of fossil-fuel power plants is the root to several pollution effects to water bodies. Cooling water is required by these plants in the condensation of steam after it has been recycled in the boilers. The cooling water can be used once and channeled to surface water or it can be recycled through the cooling tower releasing the heat out to the atmosphere. Significant temperature increase and evaporation in the receiving water body can also be caused by cooling processes. Water is similarly consumed by the cooling towers through evaporation and the discharge of blow down water, which contains higher concentrations of dissolved solids.

The major source of air emissions is due to the use of fossil fuels in power generation as compared to the use hydroelectric generation. Some of these emissions include; dust discharged from coal piles and mines, vehicles used in mining and transportation of these fossil fuels, the storage and usage of petroleum and gas also release hydrocarbon emissions and emissions from combustion.

Air quality as an impact of fossil- fuel production is of the greatest concern as it leads to the emission of combustion products such as sulfur dioxide, nitrous oxide, particles and carbon dioxide. Approximately 70% sulfur emissions, 40% of nitrous oxide emissions and 10% of particulate emissions of U.S. are produced during fossil- fueled power production. With most emissions coming from oil and coal combustion, natural gas- fuel plants have significantly lowered air emissions.

The main concerns are sulfur dioxide and nitrous oxides; they not only affect human health but also contribute to acidic rain and dry deposition. Particulates can likewise have severe effects on human health, weather and visibility. Carbon dioxide emissions are also potential contributors to global warming. Ever since the 1950s, a steady rise in the emissions of carbon dioxide has been experienced. Whereas approximately half of the emitted carbon dioxide released remains in the atmosphere contributing to global warming, the remaining half is either dissolved into oceans or taken up by plants or sequestered.

Several of the impacts due to the construction and operation of fossil-fueled power plants to aquatic ecological resources are very different both in kind and magnitude to the impacts brought about by several hydropower substitutes. Unless a cooling lake is created by the fossil fuel plant, the loss of aquatic habitat will be relativity small, compared to those due to upgrading or retrofitting of already existing reservoirs. This will be much less compared to the amount of riverine habitats that would be lost due to a new hydroelectric impoundment.

Entrainment, impingement and chemical and thermal discharges are some of the effects brought about by the operation of a cooling system condenser of a fossil plant to aquatic organisms. Large amounts of solid wastes such as combustion ash and scrubber sludge are also produced by coal-fired power plants. If not controlled, leachates form coal and ash piles can degrade the water quality as well as having poisonous effects on the aquatic organisms. Moreover, aquatic communities over a large geographical area can experience significant water quality effects and habitat loss associated to the whole fuel cycle (coal and oil mining, refinement or cleaning, and ash deposition). Aquatic organisms in widespread areas can similarly be affected by acid deposition from fossil fuel plants.

The country’s continuous dependence on fossil fuels as the main source of production for electrical power has appeared to have significant effects on recreational hobbies in various areas. During the air inversion episodes in some of the major cities in the U.S., air quality effects due to the combustion of coal are already affecting people with respiratory complications who the use some of these recreational resources. In New England and other parts of the U.S., acidic depositions from coal combustion is said to have affected fishing in various lakes. Drainage of acids from coal mines has not only affect fishing but whitewater canoeing and kayaking, boating, swimming, hiking and the overall aesthetic qualities of streams in Appalachia and in other places. Through the surface mining of coal recreational opportunities such as hunting, hiking and nature observation can be disturbed throughout the U.S. However, through reclamation, these sites may enhance some of these recreational resources.

Increased concentrations of greenhouse gases in the atmosphere can also bring with it impacts to recreational resources such as change in the precipitation quantities and regimes of a region, more serious or more recurrent air inversions, raising or lowering of reservoirs capacities, numerous or more severe major storms in the coastal areas, rise in the sea level, changing of wildlife habitats, and alteration of wildlife migration paths and times. Any outdoor recreational hobby will be significantly be affected by all these.

The drilling rigs near the refineries for gas and oil used in power generation can likewise result in water quality impacts from rigs, tankers or pipelines which may lead to occasional oil spills both onshore and offshore. Recreational activities such as fishing, boating, swimming, and nature observation can also be affected as result of these impacts. Refinery facilities (with both visual and olfactory effects) are often seen to be noxious places making them incompatible with recreational resources. Aesthetic enjoyment of such recreational resources can be reduced where there are pipelines. Drilling, production and other research activities due to increased used of gas and oil can have potential negative effects on these recreation resources especially in wildlife refuges and fragile offshore locations.

In Western United States, in some of the relatively pristine environment where natural gas desulfurization facilities are located near the drilling rigs; visual, auditory and olfactory impacts could be produced where this gas is found. Activities such as hiking, hunting and nature observation could also be affected.

Supplies form Coal and domestic gases are considered to be secure energy resource providers. In the United States, coal is known to be the richest nonrenewable energy resources. Although, fossil-fueled plants are considered to be highly reliable, they can be also be affected by severe weather conditions such as droughts (that result into inefficient cooling making it expensive for power production). Following the daily cycle demands, fossil-fuel power plants are not all that efficient. In the quest to mitigate this inefficiency, pumped storage hydroelectric power projects and gas turbine plants though less efficient are often used because the turbines respond quickly to changing demands. Environmental impacts which involves air emissions both regional and globally and the high consumption of water are some of the factors that limit the development of new fossil-fueled plants at various sites.

Electricity from Hydro

http://powerscorecard.org/tech_detail.cfm?resource_id=4 December 07, 2014

Electricity and the environment ... What are the environmental impacts? It is the dams and powerhouse ... Potential environmental impacts. Hydroelectric facilities ...

Harnessing the force of falling water may be the world's oldest source of mechanical power. Hydropower currently supplies 10 percent of the nation's electricity and 80 percent of the electricity now produced from renewable resources. Normally, rain water and melting snow flows by gravity, producing streams, rivers, and lakes. Hydropower facilities intercept the water on its downward path, converting its mechanical energy into electricity. Because the cycle of water evaporating from the heat of the sun and falling back to earth is continuously renewed by the sun's energy, hydropower is often considered a renewable energy resource. However, the construction and operation of hydropower dams impact natural river systems and fish and wildlife. Whether specific hydropower projects create unacceptable environmental damage requires a case-by-case review. There are several types of hydropower facilities:

"Storage" projects impound water behind a dam, forming a reservoir. Water is released through turbine-generators to produce electricity. The water storage and release cycles can be relatively short, for instance, storing water at night for daytime power generation. Or, the cycles can be long, storing spring runoff for generation in the summer when air conditioner use increases power demand. Some projects operate on multi-year cycles carrying over water in a wet year to offset the effects of dry years.

"Run-of-river" projects typically use relatively low dams where the amount of water running through the powerhouse is determined by the water flowing in the river. Because these plants generally do not hold back water behind storage dams, they tend to affect upstream water levels and downstream stream flow less than storage projects. Electricity generation from these plants will vary with changes in the amount of water flowing in the river.

"Pumped-storage" projects use off-peak electricity to pump water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity. There are only about 40 pumped-storage facilities in the U.S., but some are very large. (Note: the Power Scorecard rates electricity from pumped storage on the basis of the electricity used to pump the water and the impacts of the storage operations.)

What are the environmental impacts? It is the dams and powerhouse operations essential to hydropower plants that cause the primary environmental impacts. The changes in river conditions and the land and vegetation bordering the water bodies caused by dams and powerhouse turbines may impact fish populations and other wildlife significantly. Even small dams can cause big impacts on to the health of regional fish populations. The impacts of large dams are wide-ranging. The impacts of any dam depend upon many important factors, including the location of the dam, the facility design, the sensitivity of the local environment to effects of the hydropower facility, and steps taken to modify the design and/or operation of each facility to reduce potential impacts. Many impacts (see list below) can be significantly reduced by changing operations of the dam. For example, installing fish passage systems can reduce impacts on migratory fish; and converting a dam from peaking to "run-of-river" operation can ensure the natural flow of the river remains undisturbed and can adapt the hydropower facility to the unique conditions of each river system. Because every river and every dam are different, the type and severity of impacts caused by each dam differs. Because these potential impacts are severe, it is important to distinguish the plants that have successfully reduced or eliminated specific impacts from those that have not. Since 1987 the licensing and review process conducted by the Federal government has more thoroughly addressed environmental impacts. Before 1987 the environmental impacts of facilities were considered inconsistently and sometimes not at all. The Power Scorecard recognizes this change in the quality of environmental review by giving a better environmental rating to projects reviewed since January 1987. Recently the Low Impact Hydropower Institute has created a Low Impact Hydropower Certification program to identify and reward efforts by dam owners to minimize the impacts of their hydropower dams. The program certifies hydropower facilities with impacts that are low compared to other hydropower facilities based on eight environmental criteria:

The Power Scorecard recognizes plants that have obtained this "low impact certification" by giving them a better environmental rating. The following paragraphs outline some of the kinds of environmental impacts hydropower plants can create and measures that can be used to mitigate such impacts. The scope and severity of such impacts vary from facility to facility, and depend on site conditions and the extent to which possible mitigation measures are actually used. By diverting water out of the river for power, dams remove water needed for healthy in-stream ecosystems. Stretches below dams may be completely de-watered. By withholding and then releasing water to generate power for peak demand periods, dams may cause downstream stretches to alternate between no water and powerful surges that erode soil and vegetation, and flood or strand wildlife. These irregular releases destroy natural seasonal flow variations that trigger natural growth and reproduction cycles in many species. Peaking power operations can also cause can cause dramatic changes in reservoir water levels - up to 40 feet - that can degrade shorelines and disturb fisheries, waterfowl, and bottom?dwelling organisms. Dams also slow down the flow of the river. Many fish species, such as salmon, depend on steady flows to flush them downriver early in their life and guide them upstream years later to spawn. Slow reservoir pools disorient migrating fish and significantly increase the duration of their migration. These impacts can, at times, be mitigated by technological and operational enhancements to the hydro project - e.g., minimum flow turbines, re-regulating weirs, and pulsed operation at peak efficiency. Impoundments can be managed to create new upstream and downstream habitat for fish species and to provide minimum discharges and improved habitat during seasonal or annual drought conditions. Hydropower may alter river and riverside habitat.

Construction of a dam can flood riverside lands, destroying riparian and upland habitats. Construction of a dam can also convert river habitat into a lake-like reservoir, threatening native populations of fish and other wildlife. Warm, slow moving reservoirs favor predators of naturally occurring species. Dramatic changes in reservoir water levels, described above, can degrade shorelines and disturb fisheries, waterfowl, and bottom-dwelling organisms. Dams alter water quality.

Impoundments can cause changes and variation in temperature or the amount of dissolved gases in the river. Surface temperatures in the reservoir may rise when the flow of the water is slowed. If water is released from the top of the dam, this warmer water may increase river water temperature down stream. Cooler downstream temperatures may result when cool water is released from the bottom of a reservoir. Such altered conditions can affect the habitat, growth rate, or even the survival of fish and other species. For hydropower projects with intakes located deep in the reservoir, water with low dissolved oxygen (DO) levels released to the river downstream may harm aquatic habitat in the river and contribute to other water quality problems. Applying mitigating technologies can improve dissolved oxygen levels. Water sometimes passes over a spillway, rather than through the turbines. As water plunges into the pool at the base of the dam, too much air can be trapped in the water, creating "gas supersaturation," a condition that in some fish species fosters something called lethal gas bubble disease. This can be mitigated by installing structures to keep fish away from such areas. A dam or a powerhouse can be a significant obstacle to fish migration.

Ladders or lifts can be installed to pass certain fish species upstream, though multiple dams on a river reduces the success rate of these fish passage devices. Fish migrating downstream can become disoriented, bruised, stressed, or mortally injured from contact with turbines or other parts of the facility. Bypass systems can improve survival rates for migrating juveniles. When fish are trucked or barged around the dams, they may experience increased stress and disease and decreased homing instincts. Survival rates for fish passing through large turbines vary but may approach 90-95 percent. In the case of multiple dams along a river these effects can significantly harm migrating populations of important, sensitive juvenile fish populations. Impoundments also slow down the flow velocities of rivers. Slow reservoir pools may disorient migrating fish, increase the duration of their migration, which in turn may increase their mortality rate. The steep decline in salmon populations in the Pacific Northwest and California is perhaps the best known negative environmental impact associated with hydroelectric facilities. Although several factors have affected this decline - including commercial fish harvests, habitat degradation, and artificial fish hatcheries - hydropower dams have contributed significantly. The causes for these declines and the best strategies for restoring these important fisheries are currently the subject of a major public policy debate. Hydropower projects can impede the natural flow of sediments.

Flowing water transports sediment. When the flow velocities are reduced in an impoundment, sediment drops out and collects on river and reservoir bottoms, where it can affect habitat for fish spawning. The loss of sediment downstream can degrade in stream habitat and cause the loss of beach at the mouth of the river. The deposited sediment also may contain chemical or industrial residues from upstream sources. Dams may block and concentrate contaminated sediment in the impoundment. Dredging is used in some cases, though it is costly and may raise questions regarding disposal of the dredged material. Various flushing and piping techniques are available for moving non-contaminated sediment downstream. See also Water Use, Water Quality and Land Impacts Issue Papers for more information on hydropower impacts.

American Rivers http://www.amrivers.org/index.php?module=HyperContent&func=displayview&shortname=riverconservation

Union of Concerned Scientists: "How Hydroelectricity Energy Works" http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=82

Low Impact Hydropower Institute http://www.lowimpacthydro.org

Hydropower Reform Coalition http://www.hydroreform.org

Idaho National Engineering and Environmental Lab (INEEL)Hydropower Program http://hydropower.inel.gov/

National Hydropower Association http://www.hydro.org/

U.S. Dept. of Energy - Energy Efficiency and Renewable Energy Network/Hydro Links Page http://www.eren.doe.gov/RE/hydropower.htm

Foundation for Water and Energy Education (FWEE) http://www.fwee.org/hpar.html

Association of State Dam Safety Officials http://www.damsafety.org/

Bureau of Reclamation Hydropower Program http://www.usbr.gov/power/

Hydro Research Foundation http://www.hydrofoundation.org/

Northwest Power and Conservation Council - "Guide to Major Hydropower Dams of the Columbia River Basin" http://www.nwcouncil.org/library/2004/2004-1/default.htm

The United States Society on Dams http://www2.privatei.com/~uscold/

Wisconsin Valley Improvement Company http://www.wvic.com/hydro-works.htm

World Commission on Dams http://www.dams.org

Site C dam granted environmental assessment approval

http://www.cbc.ca/news/canada/british-columbia/site-c-dam-granted-environmental-assessment-approval-1.2798543 December 07, 2014

Development of construction protocols to mitigate environmental impact ... The project would provide a third dam and hydroelectric generating station on the ...

The federal and B.C. governments have issued an environmental assessment certificate to B.C. Hydro for the Site C Clean Energy Project, located seven kilometres southwest of Fort St. John.

In a statement issued Tuesday, the B.C. forest and environment ministers said they had decided that Site C, a proposed $8-billion hyrdoelectric dam on the Peace River in Northern B.C. is in the public interest and that the benefits provided outweigh the risks of significant adverse environmental, social and heritage impacts.

Later in the afternoon, the federal government issued its own environmental approval in a separate statement.

In May, a federal-provincial Joint Review Panel made 50 recommendations on the proposed project but recommended the project proceed, saying it would "provide a large and long-term increment of firm energy and capacity at a price that would benefit future generations."

However the JRP questioned the project's timetable and left the final decision on its future in the hands of the B.C. and federal governments.

The provincial government says it must still decide whether to proceed with the project based on "an investment decision."

B.C. Hydro says Site C would be a source of clean, renewable and cost-effective electricity in B.C. for more than 100 years.

“This is a significant milestone for the Site C project. After a rigorous environmental assessment process, the project has received environmental approval,” said Susan Yurkovich, BC Hydro’s executive vice-president responsible for the Site C project.

The project would provide a third dam and hydroelectric generating station on the Peace River in northeastern B.C. producing 1100 megawatts of capacity and generating 5100 gigawatt hours of electricity each year — enough to power the equivalent of about 450,000 homes per year.

Tracking the Impacts of a Hydroelectric Dam Along the Tigris River

http://www.greenprophet.com/2013/04/tracking-the-impacts-of-a-hydroelectric-dam-along-the-tigris-river/ December 07, 2014

One thought on “ Tracking the Impacts of a Hydroelectric Dam Along the Tigris River ” P Jacob April 28, 2013 at 8:43 PM. Congratulations Julia on securing the ...

Upstream hydroelectric dams have already inhibited the recovery of Iraq’s legendary Mesopotamian Marshes. A massive dam currently under construction in Turkey may wipe them out completely.

For the next two months, I’ll be taking a break from my usual Green Prophet posts to report on a transnational environmental issue: the Ilısu Dam currently under construction in Turkey, and the ways it will transform life along the Tigris River. My trip is funded by a National Geographic Young Explorer Grant and the Center for Investigative Reporting.

Turkey’s hydroelectric dams are notorious for stirring resentment around its region. The impacts of some of these projects are confined to Turkey — but they still have the potential to inflict terrible damage on Turkey’s own ecosystems and inhabitants.

With a 2-GW power generating capacity, the Ilısu Dam is the biggest hydroelectric dam currently under construction in Turkey, but it is by no means the only one — 18 have so far been built under the scope of the Southeastern Anatolia Project (GAP), a massive development program approved by the Turkish government in 1982. Several more dams besides Ilısu are expected to be completed as part of GAP in the next five years.

In 2011, the UN issued a report condemning Turkey’s Tigris and Euphrates River hydroelectric dams for violating the human rights of downstream countries, including Iraq. That’s why I’ve begun my expedition in Basra, near the confluence of the Euphrates and Tigris Rivers, where

My regular dispatches from the expedition will appear on the National Geographic Newswatch website. Here’s an excerpt from the first post, filed today from Basra, Iraq:

Few places illustrate the vitality of water more starkly than Southern Iraq. The region that gave rise to human civilization as we know it, the heartland of ancient Mesopotamia, the original referent of the Garden of Eden – Iraq’s lower third has been many things, but today it is the site of a wrenching ecological and human struggle. Driving north from Basra along the Shatt al-Arab, the waterway that forms at the confluence of the Tigris and Euphrates Rivers, desert engulfs you. The only patches of color on the landscape are posters for Iraq’s April 20 provincial elections. As the road branches and you turn northwest, following the route of the Euphrates away from the Tigris, the river takes some time to appear. The Euphrates no longer extends all the way to the Shatt al-Arab, according to Jassim Al-Asadi, director of the Southern Iraq branch of the environmental NGO Nature Iraq. It has been diverted back into the Awhar, or Mesopotamian Marshes: a vast wetlands nestled into the crook of the Tigris and Euphrates confluence. For millennia, Marsh Arabs lived in these marshes in reed huts, hunting and keeping water buffalo for sustenance. But in the 1990s, the marshes were drained by former Iraqi President Saddam Hussein, displacing hundreds of thousands of Marsh Arabs. After the fall of Hussein, the marshes began to come back, aided by the efforts of Nature Iraq. But in 2007, a massive drought hit the area, and the levels of the Tigris and Euphrates have been falling ever since, the water loss exacerbated by more than 40 new upstream dams that have come online in the past three decades. In the central marshland district of Chibayish, where Al-Asadi was born, he says the population dropped from 60,000 to 6,000 in just three decades.

Read more about hydroelectric dams in Turkey:

Impacts from decommissioning of hydroelectric dams: a life ...

http://www.hydroreform.org/sites/default/files/Pacca-%20Impacts%20of%20decommissioning%20of%20hydroelectric%20dams.pdf December 07, 2014

Impacts from decommissioning of hydroelectric dams: a life cycle perspective Sergio Pacca Received: 25 May 2004 /Accepted: 14 March 2007 /

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Impacts from decommissioning of hydroelectric dams: a life cycle perspective

Sergio Pacca

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Abstract Greenhouse gas (GHG) emissions from hydroelectric dams are often portrayed as nonexistent by the hydropower industry and have been largely ignored in global comparisons of different sources of electricity. However, the life cycle assessment (LCA) of any hydroelectric plant shows that GHG emissions occur at different phases of the power plant's life. This work examines the role of decommissioning hydroelectric dams in greenhouse gas emissions. Accumulated sediments in reservoirs contain noticeable levels of carbon, which may be released to the atmosphere upon decommissioning of the dam. The rate of sediment accumulation and the sediment volume for six of the ten largest United States hydroelectric power plants is surveyed. The amount of sediments and the respective carbon content at the moment of dam decommissioning (100 years after construction) was estimated. The released carbon is partitioned into CO_2 and CH_4 emissions and converted to CO_2 equivalent emissions using the global warming potential (GWP) method. The global warming effect (GWE) due to dam decommissioning is normalized to the total electricity produced over the lifetime of each power plant. The estimated GWE of the power plants range from 128–380 g of CO_2eq./kWh when 11% of the total available sediment organic carbon (SOC) is mineralized and between 35 and 104 g of CO_2eq./kWh when 3% of the total SOC is mineralized. Though these values are below emission factors for coal power plants (890 g of CO_2eq./kWh), the amount of greenhouse gases emitted by the sediments upon dam decommissioning is a notable amount that should not be ignored and must be taken into account when considering construction and relicensing of hydroelectric dams.

1 Introduction

Greenhouse gas (GHG) emissions from reservoirs have become a topic of investigation for researchers interested in the assessment of the impacts of hydroelectricity on the global climate (Rudd et al. 1993; Gagnon and Chamberland 1993; Rosa and Schaeffer 1994;

S. Pacca (*)
Escola de Arte Ciências e Humanidades, Universidade de São Paulo, Sao Paulo, Brazil
e-mail: spacca@usp.br

Fearnside 1995; Duchemin et al. 1995; Galy-Lacaux et al. 1999; Delmas et al. 2001; Fearnside 2004; Rosa et al. 2004). Other studies have revealed the life-cycle carbon emissions of hydroelectric plants normalized by their energy output (Chamberland and Levesque 1996; Gagnon and van de Vate 1997; Tahara et al. 1997; Dones and Frischknecht 1998; Gagnon et al. 2002; Uchiyama 2002). Such studies use a life-cycle assessment (LCA) approach to find out the carbon emissions of hydroelectric plants and compare those emissions with other electricity generation technologies. Nevertheless, most of these studies are incomplete because they do not assess the decommissioning of the dam.

A LCA is a method to evaluate the environmental impacts of a product or service from "cradle to grave." In the case of power plants, such impacts manifest themselves during various phases of the plants' life time. The importance of these impacts from each given phase in the overall emissions of the power plant varies and is a function of the technology, location, and design of the power plant. Most studies claiming to use a LCA method have only considered the construction phase of hydroelectric plants; while, other non life-cycle studies have looked at emissions from biomass decay in reservoirs (Rosa et al. 2003; Fearnside 2004; Rosa et al. 2004; Abril et al. 2006; Santos et al. 2006). A study combining dam construction, equipment manufacturing, emissions from flooded biomass, and displacement of active ecosystems is also available (Pacca and Horvath 2002). While Bioscience (2002) published a special issue about dam decommissioning, there still exists a general lack of information about the impacts from decommissioning and its global environmental implications (Hart and Poff 2002). To correctly calculate the greenhouse gas emissions from hydroelectric plants, these impacts must be known so that they can be factored into the LCA.

Other electricity generation technologies have been subject to investigations on their end-of-life repercussions. Nuclear power, for instance, demands an impact assessment beyond the operational life of the power plant because of long lasting radiation in the fuel rods and contaminated materials produced during the demolition of old reactors (Wald 2003; OECD 2003). So, decision makers must foresee impacts, such as the disposal of radioactive materials, when they decide to build and run a nuclear power plant. Similar to the concern with nuclear power plants, impacts due to dam decommissioning should also be assessed previous to construction. One remaining question is how to assess such impacts in the future and how to allocate them to the electricity produced over the power plant's life. During their operation, reservoirs accumulate sediments and the environmental implications of that material during the decommissioning and demolition of the dam is not yet clear.

Over 300 dams have been removed in the United States as they become old enough to require Federal Energy Regulatory Agency relicensing and as costs of repairs and maintenance outweigh the benefits of their operation (Hotchkiss et al. 2001). Usually, the potential negative impacts from the release of trapped sediments are not addressed in assessments. While these negative impacts have not been researched, they may include downstream fish kills, filling-in of riffle-pool habitats, blockage of upstream navigational channels, increased downstream deposition, and destabilization of stream banks. Several case studies have been done to address sedimentation issues, and they observed that sediments released after decommissioning harm the environment (Simons and Simons 1991; Stoker and Willians 1991; Pansic et al. 1995; Klumpp et al. 2003). After dam demolishment, the options are to allow sediments to travel downstream, to dredge or otherwise control sediments, or to leave sediments in place. However, any option affects the biochemical properties of the sediments.

Economically, the costs of managing sediments may lead to the earlier retirement of dams. Sediment management already accounts for 48% of the total dam decommissioning

costs (Annandale and Morris 1998), and if the costs of environmental impacts from sediments are added, the significance of sediment management can be even higher.

The volume of all storage reservoirs in the world is 4900 km^3, and the annual rate of sedimentation in reservoirs worldwide is roughly 50 km^3 (Sloff 1991). A recent study concluded that 47% of the major world rivers have their sediment flux reduced due to impoundments (Syvitski et al. 2005). The annual rate of sedimentation in U.S. reservoirs is about 1.2 km^3 (Glymph 1973). Accordingly, most reservoirs in the world could be filled with sediments within the next 100 years. Actually, reservoirs are designed based on a 100 year sediment storage capacity (Poff and Hart 2002) and a hydroelectric plant’s lifetime is in the range of 50–100 years or more (Oud 2002). Sedimentation problems in reservoirs should be considered during the planning phase and its potential impacts should be contemplated when comparing between hydroelectric plants and other electricity sources.

Because of the considerable volume of sediments trapped in reservoirs and their noticeable carbon content, I hypothesize that dam decommissioning is a source of GHG emissions. The rate of sediment accumulation and the volume of sediment for six of the ten largest US hydroelectric power plants is assessed. The results express the global warming effect (GWE) of the carbon in the sediments since it is most likely that still-water saturated sediments will be exposed to the atmosphere and release the stored carbon. The addition of this global warming potential to a hydroelectric plant’s total GHG emissions, when compared to the lifetime energy output of the hydroelectric plant, may demonstrate that hydroelectricity is a less effective way to combat global warming than previously assumed.

2 Source and fate of sediments

There are two basic sources for sediments in a reservoir:

1. Sediments produced outside the reservoir (allochthonous) load into the reservoir through river flow.
2. Sediments produced out of dead plankton born in the reservoir (autochthonous).

Artificial impoundments affect the dynamics for both sediment sources. As soon as the river is dammed, sediment accumulation begins in the reservoir. Water flow velocity decreases within the reservoir, which allows increased particle deposition and lowers the turbidity of the water, in turn, increasing light penetration (Klumpp et al. 2003). Thus, the primary productivity in reservoirs tends to be high, which contributes to the fixation of CO_2. Both the increased particle deposition rate and production rate lead to sediment build-up above the dam that persists throughout the dam’s life.

Carbon contained in a reservoir’s sediments may originate from carbon previously available in the watershed and transported through runoff to the river bed and loaded in reservoirs or may be captured from the atmosphere by autotrophs, such as blue algae and macrophytes. If the latter prevails, carbon fixed from the atmosphere would be released when sediments are exposed to the atmosphere, leading to a net zero effect on the global atmospheric carbon concentration. However, because carbon is absorbed in the form of CO_2, and because of anoxic digestion, it may be released in the form of CH_4, which would potentially result in a negative net impact because of the higher radiative efficiency of CH_4 compared to CO_2. If no dam exists, the carbon contained in sediment is transported in runoff flows through the environment. While environmental impacts of erosion have long been recognized, lesser attention has been devoted to the consequences on the global carbon cycle (Lal 2003).

Models to calculate the theoretical volume of sediments deposited in reservoirs are available (Morris and Fan 1997). However, in this paper, information on actual reservoir sedimentation rates is used.

Each reservoir’s sediment volume after 100 years is calculated using coefficients from a regression of the actual sedimentation rate time series. Figure 1 shows the results of the regressions for the reservoirs managed by the US Army Corps of Engineers (USACE). Because the forecast based on the regression expresses a tendency that combines the effect of all data points, I use this method to project the future volume of sediments trapped in the reservoirs.

Figure 2 shows a plot of the 100 year sediment volume versus the installed power capacity of the reservoirs analyzed. Although sediment yield has been correlated to the size of the drainage basin (US Bureau of Reclamation 1987), the installed power of hydroelectric plants seems to have a direct relationship with the amount of sediments trapped behind the dams. The installed power is a function of the flow volume and the head of the power plant.

3 Characterization of sediments in lakes and reservoirs

Because runoff is the major source of sediments, the carbon content in reservoir sediments is comparable to the carbon content in soils of the donor watershed. Sediments transported by rivers contain 2–3% of particulate organic carbon (POC) (Lal 2003). After precipitation to the bottom of reservoirs, soil’s POC may be the main source of organic carbon in oligotrophic lakes (Kalff 2002). A sediment survey in Puget Sound in Washington State has shown a range of organic carbon (OC) content between 0.4 and 3.7% based on dry weight (Pamatmat and Jones 1973).

Fig. 1 Projected sediment content after 100 years of operation

Fig. 2 Sediment volume after 100 years versus installed capacity

1.2E+10 m 3

Hoover

1.0E+10 m 3

)
3
100 yr. Sediment Volume (m

3

8.0E+09 m

6.0E+09 m 3

4.0E+09 m 3 Garrison

Glen

Canyon

Fort Peck Oahe

2.0E+09 m 3

Fort Randall

0.0E+00 m 3

0 500 1,000 1,500

2,000 2,500

Installed capacity (MW)

The specific weight of dried sediment samples collected in Lake Mead (Hoover dam) in September 1948 and October 1964 were 1,041 and 961 kg/m3, respectively (Dendy and Champion 1975), and the average of five sampling campaigns in the Fort Peck reservoir was 929 kg/m3 (Dendy and Champion 1970). Therefore, a carbon content of 2% by dry sediment weight and a sediment density of 1,000 kg/m3 seems plausible for sediments at the bottom of reservoirs.

Based on the projected sediment volume, the sediment density, and the carbon content, it is possible to calculate the total sediment organic carbon (SOC) in the reservoirs. Figure 3 shows the estimated stored SOC in reservoirs versus their respective surface area. Aberg et al. (2004) concluded that the carbon balances in lakes and reservoirs are comparable. Therefore, I compared the estimated SOC values with known values for lakes in Alberta, Canada

3.50E+08

Athabasca

3.00E+08

2.50E+08

Claire

Estimated SOC (Mg)

Hoover

2.00E+08 Lesser Slave

lakes

1.50E+08

reservoirs

1.00E+08

Bistcho Glen Canyon

Cold Garrison

5.00E+07 Utikuma Oahe

Fort Randall

La Biche

Fort Peck

0.00E+00

0.00E+00 5.00E+04 1.00E+05 1.50E+05 2.00E+05

2.50E+05

Surface area (ha)

Fig. 3 Estimated stored SOC versus lake or reservoir surface area

(Campbell et al. 2000). Figure 3 shows that in most of the cases, SOC volume is proportional to surface area; however, this is not the case for the Hoover and the Oahe dam.

The shape of sediment deposits on the bottom of reservoirs can be characterized by the area increment method, which assumes that the elevation area curve due to sedimentation follows the original depth profile of the reservoir (USACE 1995). The area increment method applied to Fort Peck dam indicates that the surface area of the 100 year sediment deposit is 2.2×108 m2 (USACE 1995). The same reasoning is applied to Lake Mead (Hoover dam). By combining information from the capacity area ratio of the dam (US Bureau of Reclamation 1987) with the 100 year projected sediment volume, the surface area of the sediment deposit in Lake Mead equals 2.5×108 m2.

The drainage of water through the sediments can be characterized by Darcy's law. According to this law, the drainage velocity in a reservoir is proportional to the head of water above the sediments. As the water table subsides, the drainage velocity decreases and evaporation becomes the main driver of water disappearance. On average, it takes 1 year to evaporate 1 m of water in the main stem reservoirs along the Missouri River (USACE 1979).1

4 Mineralization of carbon in sediments

Carbon mineralization rate is the rate of carbon release from sediments in the form of CO_2 and CH_4 (Liikanen et al. 2002). Sediments at the bottom of reservoirs are substrates for colonies of decomposers, and decomposition processes in sediments produce CO_2, CH_4, and N_2O (Liikanen et al. 2002). Mineralization is caused by microorganisms, and CH_4 production results from fermentation.

The presence of microorganisms is fundamental for mineralization. In freshwater ecosystems, decomposers are two to three orders of magnitude more abundant in sediments than in the water (den Heyer and Kalff 1998). Undisturbed sediments may be a notable source of CH_4 because steady conditions support the development of methanogenic cultures in contrast to agitated environments that have been shown to produce less CH_4 (Dannenberg et al. 1997). Mora-Naranjo et al. (2004) developed a model of methane emissions in landfills that shows that at 85% of water content, the production of methane reaches a maximum level in 12 days. Another model of methane emissions from rice paddies shows that the emissions reach a peak after 26 days (Van Bodegom et al. 2001).

When a reservoir is drained, a slab of eutrophic water rests on top of the sediments. As a eutrophic reservoir becomes anoxic, its sediments switch from being a nutrient sink to a source (Harris 1999). Draining reservoirs leads to alternating exposure to oxic and anoxic conditions that stimulate the overall mineralization of organic matter (OM). The bioavailability of OM is always greatest under oxic conditions, and the maximum mineralization of OM occurs under oxic conditions (Bastviken et al. 2004).

The rate of carbon mineralization is directly proportional to temperature increases (Bartlett and Harriss 1993; Mora-Naranjo et al. 2004). So, as reservoirs are drained, and the amount of solar radiation transferred and absorbed increases as a result of the shallower water table, the substrate temperature also increases and more mineralization occurs.

1 For example, assuming that the hydraulic conductivity for sediments is 10–6 m/s (Nazaroff and Alvarez-Cohen 2001), it takes 2.5 years to drain a 1 m deep slab of water over the sediments in Fort Peck reservoir. In comparison the evaporation rate of the Missouri stem reservoirs averages 1 m per year (USACE 1979).

The water table dynamics also affect carbon mineralization rates. In a landfill, water transports methanogenic microorganisms and is essential for their survival. Because compaction prevents water and gas circulation within the landfill, it is common to find municipal solid waste in its original form years after it was buried (Meraz et al. 2004). Additionally, the height of the water table beneath the landfill surface controls the oxidation of methane, and in the absence of water, methane is oxidized into CO_2.

Thus, the extent of carbon mineralization in a substrate is a function of moisture content. Hackley et al. (1999) did however find that an earthen pier built on a shallow wetland contained up to 70% of CH_4 concentrations within the headspace of several piezometers screened at depths ranging from 8 to 17 m. This demonstrates that if the appropriate conditions are available, methane can be produced at considerable depths. Despite this, different studies assessing methane production in landfills assume that mineralization occurs only within a 1 m deep substrate slab (Jones and Nedwell 1992; Kightley et al. 1995; Perera et al. 2002).

Assuming that carbon within a 1 m deep slab of sediments in a reservoir being drained is subject to mineralization and that the surface area of the 100 year sediment deposit in the Fort Peck and the Hoover dam is 2.5×10^8 and 2.2×10^8 m^2, 11 and 3% of the total 100 year SOC volume is mineralized, respectively.[2] This is a conservative assumption because the mineralization could reach depths beyond the 1 m deep zone.

For each mole of CO_2 produced, fermentation produces one mole of CH_4 (Kalff 2002). Thus, stoichiometry imposes a 50% ratio limit in the maximum amount of carbon mineralized as CH_4 by fermentation, which yields a unitary molar ratio between CO_2 and CH_4. However, depending on the aeration of the substrate, part of the methane produced is converted into CO_2. When the water table of a wetland is between 20 and 10 cm above the surface of the sediments, the CO_2:CH_4 ratio is 10 (Potter 1997). I use this molar ratio in the assessment of the greenhouse gas emissions. The reason to use this value is because the drainage of the last 1 m slab of water covering the reservoir's sediments is one order of magnitude higher than the average time required for bacteria to maximize methane production in shallow aquatic environments. Thus, in comparison with time scales characteristics of microbiological activity, the drainage of the reservoir takes a considerable amount of time. Therefore, most of the carbon in the sediments is mineralized under anoxic conditions. If a 1 m high slab of water above the sediments is considered, a significant amount of organic carbon is mineralized before all water drains out and sediments are exposed to air. Even after the water table reaches the sediments surface, anoxic mineralization occurs because sediments below this level are still underwater.

5 Conversion of methane emissions in carbon dioxide equivalents

The global warming effect of greenhouse gas emissions from sediments during the decommissioning of reservoirs is a function of the amount of sediments mineralized and released as CO_2 and CH_4. To calculate the potential impact of GHG emissions from sediments after decommissioning, I convert CH_4 emissions to CO_2 equivalent using the Global Warming Potential (GWP) method. This allows for the comparison of potential impacts from CH_4 and CO_2 emissions on the global climate system due to dam decommissioning. The GWP is a ratio between the radiative efficiency of methane times the integral of the function representing disappearance of methane in the atmosphere over a

2 The total volume of each reservoir, which was used to derive the percentages, is shown on Table 1.

given time interval and the radiative efficiency of CO_2 times the integral of the function representing the evolution of the airborne fraction of CO_2 in the atmosphere (Houghton et al. 2001).

The temporal component in the calculation is fundamental for assessing the potential effects of CH_4 compared to the effects of CO_2. For example, the IPCC publishes the GWP for 20, 100, and 500 years, which correspond to 62, 23, and 7 g of CO_2 per g of CH_4, respectively (Houghton et al. 2001). Thus, a shorter time period reflects a greater impact of methane emissions on the global climate forcing.

In a previous analysis of GHG emissions from hydroelectric plants, Fearnside (1997) considered that reservoirs produce a large pulse of emissions in the first years after filling due to the decay of flooded biomass. In this case, the use of a 100-year GWP factor to convert CH_4 emissions into CO_2 equivalent emissions coincides with an analysis of the environmental repercussions of the hydroelectric plant 100 years after construction. In reality, a GWP calculated based on a 100-year time period corresponds to discounting the impact of each GHG relative to the impact of CO_2 over 100 years after its emission (Fearnside 2002).

Usually, analysts assume a 100 year life time for hydroelectric plants in their assessments (Gagnon et al. 2002; Oud 2002). In this study, the period of analysis reflects 200 years, which corresponds to the 100 year electricity generation period of the power plant plus 100 years to compare the potential of the methane released during decommissioning to the potential global warming effect of CO_2. That is, methane emissions released during the end-of-life of the hydroelectric plant will be compared over a 100 year period to CO_2 equivalent emissions, which represent the potential impact on global climate. Because the emissions of GHG from sediments occur after electricity generation comes to an end, a GWP based on a shorter period could be applied. The adoption of a GWP based on a shorter time period would incorporate the effects of the emissions from the sediments closer to the 100 years of power generation. However, to be consistent with the majority of analyses using GWPs, the assessment in this work uses a 100-year GWP, which equals 23.

6 Summary of methods and results

Data on sediment accumulation was collected by contacting personnel from the Army Corps of Engineers. The “Summary of Reservoir Surveys and Storage Changes – Missouri River Main Stem” reports the total storage loss in 1,000 acre feet for the Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point dams (USACE 2004). Changes in storage capacity for Hoover dam were copied from the report on “Sediment Deposition in U.S. Reservoirs” (Dendy and Champion 1975). The measured sediment volume in Lake Powell (Glen Canyon Dam) was copied from the “1986 Lake Powell Survey” (Ferrari 1988).

Based on the reservoirs studied, the amount of carbon seems to be exponentially proportional to the installed capacity of the power plant (Fig. 2). The total sediment volume at the end of the plant’s life, which is set at 100 years, is estimated using a regression applied to the time series with the actual sedimentation rate for each reservoir. Table 1 shows the 100 year sediment volume, the storage capacity of the reservoirs, the percentage of the volume of each reservoir that will be filled with sediments after 100 years of operation, the average annual gross electricity generation of each power plant, the 100 year sediment mass, and the total mass of carbon available in the sediments. The SOC is

Table 1 Summary of results

Reservoir	Sediment volume (m3)	Annual max . storage (m3)	Percent filled after 100 years (%)	Average annual gross energy (MWh)	100 year energy (MWh)	100 year sediment mass (Mg)	100 year carbon mass (Mg)	Potential CO2 emissions (Mg)	Potential CH4 emissions (Mg)
Hoover	1.04E+10	3.52.E+10	30	4.1E+06	4.1E+08	1.0E+10	2.2E+08	7.3E+08	3.0E+07
Glen Canyon	3.49E+09	3.23.E+10	11	3.5E+06	3.5E+08	3.5E+09	7.4E+07	2.5E+08	9.9E+06
Garrison	3.11E+09	3.00.E+10	10	2.4E+06	2.4E+08	3.1E+09	6.6E+07	2.2E+08	8.8E+06
Oahe	2.42E+09	2.78.E+10	9	2.8E+06	2.8E+08	2.4E+09	5.2E+07	1.7E+08	6.9E+06
Fort Peck	1.98E+09	2.34.E+10	8	1.1E+06	1.1E+08	2.0E+09	4.2E+07	1.4E+08	5.6E+06
Fort Randall	1.92E+09	6.E+09	31	1.8E+06	1.8E+08	1.9E+09	4.1E+07	1.4E+08	5.5E+06

estimated by multiplying the total volume of sediments by the sediment density (1,000 kg/m3) and by the carbon density in the sediments (2%).

Carbon mineralization produces both CO_2 and CH_4; however, not all SOC is assumed to be remineralized. The percentage of carbon mineralized is based on the estimations made for the Fort Peck and Hoover dams, which are then applied to the other reservoirs. According to the two case studies, 3 and 11% of the total available SOC is mineralized.

The CO_2:CH_4 molar ratio used in the analysis is 10, and a GWP of 23 is used to convert CH_4 into CO_2 equivalents. Results in metric tons of CO_2 equivalent are normalized by the predicted electricity output of the power plant for 100 years. The average annual gross energy output of the hydroelectric plants managed by the U.S. Army Corps of Engineers was obtained from the Monthly Project Statistics (USACE 2004) and the net energy output for the 2003 fiscal year is used for the Hoover and Glen Canyon power plant (US Bureau of Reclamation 2004a, b). The final global warming effect (GWE) is expressed in grams of CO_2 equivalent per kWh.

7 Discussion

The present assessment allows for the comparison of the GWE due to the decommissioning of dams with other life-cycle phases or with other studies of hydroelectric plants. The estimated emissions due to the construction of the Glen Canyon Dam are 800,000 metric tons of CO_2 equivalent (Pacca and Horvath 2002). Emissions during the operation of the dam, which are associated with the decay of the biomass in the reservoir, account for 3,500,000 metric tons of CO_2 equivalent. Finally, emissions from decommissioning of the reservoir dam account for 33,000,000 metric tons of CO_2 equivalent (Fig. 4). Therefore, emissions from the decommissioning account for more than nine times the emissions from biomass decay in the reservoir, and render a tremendous contribution to the overall life cycle emissions of hydroelectric plants. In the case of the Glen Canyon hydroelectric plant, emissions from decommissioning are one order of magnitude higher than the emissions from the biomass decay in the reservoir, which are one order of magnitude higher than the emissions from the construction of the dam.

This analysis looks at carbon emissions at the time of dam decommissioning, which assumes that all SOC will be emitted when the sediments are exposed to air. The emissions should occur over a very short period of time since I am only looking at the immediate effects during the hydroelectric power plant’s end-of-life.

Figure 5 shows a comparison of average emission factors from fossil fueled power plants based on a literature review on LCA (Pacca 2003) and the emission factors found in this study observing the maximum and the minimum molar ratios between CO_2 and CH_4. Emission factors due to dam decommissioning are on the same order of magnitude as emissions from fossil fueled power plants, if 11% of SOC is mineralized.

Various factors contribute to the mineralization of SOC during decommissioning. In this study, based on calculations from known parameters of two existing reservoirs, I include a 3 or 11% SOC mineralization. The literature on methane emissions shows that methane may be produced deeper in soil/landfill profiles, which would imply that more SOC could be mineralized. If sediments are dredged from the reservoir, a greater fraction of the total SOC might be mineralized. Additionally, it is important to remember that dredging can create different conditions in a reservoir and how they affect the share of CH_4 produced and released. If oxidizing conditions are present, part of the CH_4 is converted into CO_2, and the 1:10 ratio that was applied in this analysis should be reassessed.

1.E+09
5.2E+07
1.4E+07
5.0E+06
2.0E+06
max.
8.0E+05
min.
1.E+06
Mg of CO2 eq.

1.E+03

1.E+00
construction operation decommissioning
life cycle phases

Fig. 4 Life cycle emissions of Glen Canyon Dam

The difference in carbon found in the reservoir or flowing through the river is the timing of mineralization because the carbon that would be mineralized in a river bed is otherwise held in the reservoir to be mineralized later on. If the SOC in the bottom of the reservoir is being fixed from the atmosphere instead of being transported through run-off, there is a positive effect on global warming. This is because carbon is taken up from the atmosphere in the form of CO_2 and later released as CH_4, which has a higher GWP than CO_2. Water always runs through the thalweg and the ultimate destination of carbon in the soil is the ocean. A reservoir prevents carbon from reaching the ocean and eventually sends it back to the atmosphere, which contributes to enhancing the earth's radiative forcing.

The total filling of reservoirs by sediments may take more than 1,000 years. Therefore sediment accumulation per se may not justify the removal of dams. Other reasons, such as structural aging and environmental problems, may lead to the decommissioning of dams and force water agencies to take some action to prevent negative environmental impacts. Dams are not eternal structures. Thus, the end-of-life for hydroelectric plants needs to be

1000
890

750
g of CO2 eq./kWh

Max. value
500 454 Min. value
380 Avr. thermo.

263
250 194
157 148 128
104
72 53
43 40 35
0
Fort Peck Fort Randall Garrison Glen Canyon Hoover Oahe Natural Gas Coal

Fig. 5 Emission factors for decommissioning versus GWE of fossil fueled power plants

factored into the assessment of this energy source and its global climate change implications should be accounted for.

This study calculates the global climate impacts of hydroelectric plants at the end of their life cycle. The hydropower industry should recognize the impact of a reservoir's sediments and incorporate these results into their assessment of hydroelectric power plants. Decision makers also need to consider the potential impacts from decommissioning dams when reviewing the relicensing of hydroelectric power plants or the construction of new ones.

If the accumulation of sediments in reservoirs is a function of the installed capacity of hydroelectric plants, it makes sense to support the installation of a chain of smaller power plants on the same river instead of one larger hydroelectric plant so that harmful GHG emissions are minimized. In addition, because small hydroelectric plants trap less sediment, they favor management actions that can effectively limit sediment accumulation by flushing smaller sediment amounts downstream. Thus, instead of becoming a carbon source, sediments return to the stream flow that reaches the oceans, which is the ultimate global carbon sink.

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How Hydroelectric Energy Works

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How Hydroelectric Energy Works, part of the Energy 101 series. Information on renewable energy, including wind and solar power; nuclear-power safety issues and work ...

By taking advantage of the water cycle, we have tapped into one of nature's engines to create a useful form of energy. In fact, humans have been using the energy in moving water for thousands of years. Today, exploiting the movement of water to generate electricity, known as hydroelectric power, is the largest source of renewable power in the United States and worldwide.

Unfortunately, hydroelectricity has its drawbacks. By blocking rivers with massive dams, we have created a number of serious environmental and social problems, including habitat destruction, prevention of fish passage, and displacement of local communities. Still, if it's done right, hydropower can be a sustainable and nonpolluting power source that can help decrease our dependence on fossil fuels and reduce the threat of global warming.

On Earth, water is constantly moved around in various states, a process known as the hydrologic cycle. Water evaporates from the oceans, forming into clouds, falling out as rain and snow, gathering into streams and rivers, and flowing back to the sea. All this movement provides an enormous opportunity to harness useful energy.

The United Nations estimates that the total "technically exploitable" potential for hydropower is 15,090 terawatt-hours per year, or 15 trillion kilowatt-hours, equal to half of projected global electricity use in 2030.[1] Only about 15 percent has been developed so far.[2] While much of the remaining potential may not be economically or environmentally suitable to develop, there are still significant opportunities for new development in regions like the former Soviet Union, South Asia, and South America.

Hydropower provides one-fifth of the world's electricity, second only to fossil fuels. Worldwide capacity is 776 gigawatts (GW), with 12 percent in the United States, nine percent in Canada, and eight percent in Brazil.[3] When completed, China's Three Gorges Dam, poised to become the largest hydroelectric project in the world with 18.2 GW of capacity, will move China ahead of Brazil. Globally, hydroelectric capacity has more than doubled since 1970, and another 100 GW is currently under construction.

In the United States, hydropower has grown steadily, from 56 GW in 1970 to more than 95 GW today.[4] As a percentage of the U.S. electricity supply mix, however, it has fallen to 10 percent, down from 14 percent 20 years ago, largely as a result of the rapid growth in natural gas power plants. In terms of electricity production, hydropower plants account for about seven percent of America's current power needs.[5]

In some parts of the country, hydropower is even more important. For example, the Pacific Northwest generates more than two-thirds of its electricity from 55 hydroelectric dams.[6] The Grand Coulee dam on the Columbia River is one of the largest dams in the world, with a capacity of nearly 6,500 megawatts (MW).

In addition to very large plants in the West, the United States has many smaller hydro plants. In 1940 there were 3,100 hydropower plants across the country, but by 1980 that number had fallen to 1,425. Since then, a number of these small plants have been restored; there are currently 2,378 hydro plants (not including pumped storage) in operation.[7] These plants account for only a tiny fraction of the 80,000 dams that block and divert our rivers. As a result, there is a significant opportunity for growth according to the National Hydropower Association, which estimates that more than 4,300 MW of additional hydropower capacity can be brought online by upgrading existing facilities.[8]

Worldwide there is a great deal of growth in small hydro projects. The World Energy Council estimates that under current policies, installed capacity of small hydro will increase from about 48 GW today to 55 GW by 2010, with the largest increase coming from China.[9] More than half of the current global small hydropower installed capacity is in China, with plans to develop a further 10,000 MW in the next decade.[10]

An important issue now in the United States is the re-licensing of hydropower plants. Hydro plants have very long lives; the Grand Coulee dam, for example, has been in operation since 1942. The federal government issues licenses for all dams for a 30- to 50-year period. In 1993, for instance, over 200 licenses were due for renewal, amounting to 2,000 MW of capacity. Re-licensing some of these dams should require dam owners to find ways to reduce environmental impacts. Unfortunately, in the 2005 Energy Policy Act, the hydropower licensing law was amended as part of the Energy Policy Act of 2005, making it more difficult for the public to participate in the re-licensing process.[11]

In order to generate electricity from the kinetic energy in moving water, the water has to be moving with sufficient speed and volume to turn a generator. Roughly speaking, one gallon of water per second falling one hundred feet can generate one kilowatt of electrical power.

To increase the force of moving water, impoundments or dams are used to raise the water level, creating a "hydraulic head," or height differential. When water behind a dam is released, it runs through a pipe called a penstock, and is delivered to the turbine.

Hydroelectric generation can also work without dams, in a process known as diversion, or run-of-the-river. Portions of water from fast-flowing rivers, often at or near waterfalls, can be diverted through a penstock to a turbine set in the river or off to the side. The generating stations at Niagara Falls are an example of diversion hydropower. Another run-of-the-river design uses a traditional water wheel on a floating platform to capture the kinetic force of the moving river. While this approach is inexpensive and easy to implement, it doesn't produce much power. The entire Amazon River, if harnessed this way, would produce only 650 MW of power.

Another type of hydropower, though not a true energy source, is pumped storage. In a pumped storage plant, water is pumped from a lower reservoir to a higher reservoir during off-peak times, using electricity generated from other types of energy sources. When the power is needed, it is released back into the lower reservoir through turbines. Inevitably, some power is lost, but pumped storage systems can be up to 80 percent efficient. There is currently more than 90 GW of pumped storage capacity worldwide, with about one-quarter of that in the United States. Future increases in pumped storage capacity could result from the integration of hydropower and wind power technologies. Researchers believe that hydropower may be able to act as a battery for wind power by storing water during high wind periods.[12],[13]

There are a variety of turbines employed at hydropower facilities, and their use depends on the amount of hydraulic head at the plant. The most common are Kaplan, Francis, and Pelton wheel designs. Some of these designs, called reaction and impulse wheels, use not just the kinetic force of the moving water but also the water pressure.

The Kaplan turbine is similar to a boat propeller, with a runner (the turning part of a turbine) that has three to six blades, and can provide up to 400 MW of power.[14] The Kaplan turbine is differentiated from other kinds of hydropower turbines because its performance can be improved by changing the pitch of the blades. The Francis turbine has a runner with nine or more fixed vanes. In this turbine design, which can be up to 800 MW in size, the runner blades direct the water so that it moves in an axial flow.[15] The Pelton turbine consists of a set of specially shaped buckets that are mounted on the outside of a circular disc, making it look similar to a water wheel. Pelton turbines are typically used in high hydraulic head sites and can be as large as 200 MW.

The ability to meet power demand fluctuations is an advantage of hydro plants with reservoirs. Unlike run-of-the-river plants, which produce power around the clock, hydro plants with dams are typically used only when the power is most needed. Utilities save up the water, letting it loose only during peak times. Hydro plants, especially the large older plants built from the 1930s to the 1950s, are commonly the least-expensive source of electricity.

Although an inexpensive and nonpolluting energy resource, the environmental damage caused hydropower can be serious. The most obvious effect is that fish are blocked from moving up and down the river, but there are many more problems.

When a dam is constructed, a river habitat is replaced by a lake habitat. While this may not sound so bad -- fish and birds like lakes, too -- it can cause a number of environmental problems. In the Pacific Northwest, large federally owned dams have blocked the migration of coho, chinook, and sockeye salmon from the ocean to their upstream spawning grounds. The number of salmon making the journey upstream has fallen 90 percent since the construction of four dams on the lower Snake River. Some steps are being taken to help the fish around the dams, such as putting them in barges or building fish ladders, but this only helps so much. Also, when young fish head downriver to the ocean, they can be chewed up in the turbines of the dam. As of 2002, 71 percent of the area of Washington and 50 percent of Oregon contain watersheds with salmon and other related species that have been listed as threatened or endangered.

Dams can create large reservoirs submerging what used to be dry land, producing many problems. The Balbina dam in Brazil, for example, flooded 2,750 square kilometers (965 square miles), an area the size of Rhode Island. This land is often composed of wetlands, which are important wildlife habitats, and low-lying flood plains, usually the most fertile crop land in the area. Population density is typically higher along rivers, leading to mass dislocation of urban centers. The Three Gorges Dam in China is expected to dislocate up to 1.9 million people.[16]

Wildlife habitats destroyed by reservoirs can be especially valuable. In South America, 80 percent of the hydroelectric potential is located in rain forests, one of the most rich and diverse ecosystems on Earth. The Rosana dam in Brazil destroyed one of the few remaining habitats of the black-lion tamarin, a rare and beautiful species of long-haired monkey.

Another problem can occur when the land area behind the dam is flooded without proper preparation. In Brazil, the Tucurui dam was built creating a reservoir in a rain forest region, without the forest first being cleared. Later, as the plants and trees that were submerged began to rot, they reduced the oxygen content of the water, killing off the plants and fish in the water. Moreover, the rotting plants gave off large quantities of methane, a powerful global warming gas.

A similar problem has occurred in Canada, in hydro projects built by Hydro Quebec. The stones and soil in the flooded area contain naturally occurring mercury and other metals. When the land was flooded, the mercury dissolved into the water, and then into the local fish populations. The creatures that eat the fish—from bears and eagles, to the native Cree people—are suffering from mercury poisoning. Mercury poisoning can cause brain damage, birth defects, liver disorders, and other ailments.

Impoundments used for hydropower can cause many other effects on water quality and aquatic life. Rivers and lakes can be filled with sediment from erosion. Water falling over spillways can force air bubbles into the water, which can be absorbed into fish tissue, ultimately killing the fish. By slowing down rivers, the water can become stratified, with warm water on top and cold water on the bottom. Since the cold water is not exposed to the surface, it loses its oxygen and becomes uninhabitable for fish. And as illustrated by the Colorado River in the Grand Canyon, fast-moving rivers can be filled up with sediment when they are slowed down. In an effort to mitigate this problem, the Department of Interior has flushed huge amounts of water out of dams in an attempt to clear away the sediment.

Another important habitat disruption comes from the operation of the dam to meet electric demand. Water is stored up behind the dam and released through the turbines when power demand is greatest. This causes water levels to fluctuate widely on both sides of the dam, stranding fish in shallow waters and drying out the habitat. There are many competing pressures on dam operators -- to produce power, to provide water for recreational use both on the reservoir and downstream, to provide drinking and irrigation water, to allow Native Americans to carry out traditional religious practices, and to preserve habitat for fish and plant species. In many cases, nature loses out to boaters, farmers, and electric customers.

The risk of a dam breaking should also not be ignored. The great Johnstown flood in Pennsylvania was the result of a dam break (although not a hydroelectric dam); 2,000 people were killed. In northern India and Nepal, in the Himalayas, huge hydroelectric projects are planned that would create large reservoirs in a geographically unstable region. Frequent earthquakes make the dam a risky venture for heavily populated areas downstream. This is compounded by the fear that large, heavy reservoirs would put additional pressure on the plates in the region, causing even more earthquakes. Finally, breakage could also result from war or terrorism, as dams have been considered potential military targets in the past. The environmental and social effects of hydropower can be immense. But while hydropower has its problems, it can still be a safe and sustainable source of electricity if proper measures are taken. By upgrading and improving the equipment at plants, by increasing fish-friendly efforts at dams, and by improving run-of-the-river turbine technology, it may be possible to reduce the environmental effects of hydropower. Nonetheless, remediation may be impossible at some sites, and wild rivers should be unshackled.

It is also important to compare the environmental effects of hydropower with alternatives. The damage to aquatic habitat from dams may be significant, but acid rain, nitrogen deposition, and thermal pollution from coal plants also lead to aquatic damage, as well as to air pollution and global warming. Provided we dismantle the worst hydropower facilities, and improve the sustainability of the others, we will be better off.

Hydroelectric facilities that meet certain standards to minimize their effect on rivers, fish, and wildlife can now seek recognition as low impact under a voluntary certification program developed by the Low Impact Hydropower Institute (LIHI). Criteria standards are based on the most recent and stringent mitigation measures recommended for the dam by state and federal agencies.

To be certified, a facility must adequately protect or mitigate its impacts in the following areas: river flows, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resource protection, and recreation. The incentive for certification is the ability to market a more sustainable energy source to consumers, especially those participating in voluntary green power programs. In addition, Pennsylvania requires hydroelectric projects to be LIHI certified in order to be eligible to count towards the state's renewable electricity standard. Currently, more than twenty hydropower facilities have been LIHI certified.[17]

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Small Hydroelectric Dams Not So Green

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RIO DE JANEIRO -- The combined impacts of numerous small hydroelectric dams in one river basin can be at least as harmful as one large dam, warn experts ...

Often included among "clean" sources of energy, small hydroelectric dams have been constructed without proper consideration of their effects.

RIO DE JANEIRO -- The combined impacts of numerous small hydroelectric dams in one river basin can be at least as harmful as one large dam, warn experts, environmental activists and indigenous groups, who face a flood of new projects along the rivers of the western Brazilian state of Mato Grosso.

Hydraulic energy from small dams "is interesting because of its low environmental costs, but everything has its limits," says AndrÃ© Villas-Boas in reference to their proliferation along the tributaries of the XingÃº River, in the Amazon.

At least six small dams are concentrated on the rivers in northeast Mato Grosso, points out Villas-Boas, coordinator of the XingÃº Programme of the non-governmental Socio-Environmental Institute (ISA). Two have already been built and a third has been given the green light by the energy and environmental authorities for the Culuene River alone, the main tributary of the XingÃº.

Such projects should not be authorised without an integral assessment of the river basin in its environmental and social aspects, for a planned exploitation of the water resource as a whole, and limits on the number of hydroelectric dams, according to Villas-Boas, who notes that more than half the area of the XingÃº is indigenous territory.

The dams are located around the XingÃº Indigenous Park, a symbol of Brazil's indigenous policy that is home to some 5,000 people from 14 different ethnic groups.

Often included among "clean" sources of energy, small hydroelectric dams have become an attractive business for the "soft legislation" under fiscal and financial control and incentives, without duly considering that "they seriously alter biological dynamics" if there are many in one watershed, says Villas-Boas.

As a result, there are 240 small hydroelectric dams planned in Brazil, according to the National Electric Energy Agency (ANEEL). The 81 dams already under construction will produce 1,342 megawatts, or 17.29 percent of the total power supplies.

An example of a more unsustainable panorama is the Juruena River, according to Raul do Valle, an attorney who coordinates ISA's political and legal actions. In the Juruena basin, in northwest Mato Grosso, 83 hydroelectric dam plans have been registered. ANEEL suspended 30 projects in early July and decided to pursue integrated environmental assessments for them.

There have been several cases where indigenous people have taken government officials or construction company employees hostage, in a bid to bring the work on dams on the Juruena and the Culuene rivers to a halt. In other efforts, lawyers have tried to do so through legal channels, obtaining temporary suspensions of construction permits. There are many cases where a final decision is still pending.

"We predict that there will be fewer fish" as a result of the energy projects on local rivers, begun around 10 years ago, because the dams "block the fish from swimming upriver to breed," said Paulo KamaiurÃ¡, who has taken as his surname the name of his tribe, who live in the XingÃº Park.

The affected rivers, which are already polluted by agro-chemical runoff, flow towards the Park where they form the XingÃº River, and as a result "the problems will be aggravated," said KamaiurÃ¡, adding that it is essential to mobilise indigenous communities to raise awareness about the threats.

Because of their presumed limited ecological impact, environmental permits for small hydroelectric dams are granted by state, not federal, agencies. And the state bodies are more vulnerable to local economic pressures, says Valle.

But the permits must be issued by the national Brazilian Environmental Institute when the projects affect Indians, he explains. In the case of northern Mato Grosso, it is a matter of survival of native peoples, who rely on fish for subsistence, he adds.

That is the main argument against the dams in the legal cases that are still pending. The counter-argument set forth by the construction companies and state authorities is that the indigenous groups do not suffer direct impacts, given that their lands are dozens of kilometres away from the dams.

But Valle stresses that there is no need for local production of electricity, given that the nearby cities are connected to the power grid, so there is no justification for this "destructive activity" in benefit of private enterprise. But the slow pace of justice favours the "consummated fact," he admits, noting that it is nearly impossible to stop dam operations after they have been built.

The dams reduce the quantity of fish in the rivers because they alter currents and nutrition, in addition to eliminating migratory species. Attempts to reestablish reproduction have not been successful, according to Juarez Pezzuti, a biologist who conducted a study of the effects of Paranatinga II, a small hydroelectric dam operating on the Culuene.

The impacts could be mitigated if there are prior studies and planning, and with the participation of local communities, who are the ones left facing the threats and often do not even benefit from the energy generated in their backyards, says Pezzuti, professor of advanced environmental research at the Federal University of ParÃ¡.

In another area of Brazil, in Santo Amaro da Imperatriz, a town in the southern state of Santa Catarina, a project involving six small dams triggered reactions that led the local council to ban hydroelectric dams in the district, with only one dissenting vote.

The ban is unconstitutional, admits Environment Secretary Joao Renato Duarte. But "99 percent of the population is against" the dams and the project will only be approved if it can be verified that they will not harm the hot springs, waterfalls and rapids that attract tourism and provide recreational and cultural activities for local citizens, he said.

The dams are to be built using the latest European technologies, channeling only a portion of the river flow through tunnels, without affecting the landscape or river rafting, which is what feeds local tourism, says engineer Helio Machado, head of the project. The people opposed to the endeavour are talking about ridiculous threats like flooding or the drying up of the CubatÃ£o River, because they don't know the details, Machado says.

"It doesn't make sense to destroy the natural heritage" of the city in order to generate just 14 megawatts, retorts Eliazar Garbelotto, who runs a rafting business on the CubatÃ£o.

The tourism sector is radically opposed to the small hydroelectric dams. There are five rafting businesses that bring in about 10,000 tourists a year, and employ just 50 people, but feed other tourist activities as well as providing environmental education, Garbelotto says.