HIMALAYA
The Journal of the Association for Nepal and Himalayan Studies

Himalaya, the Journal of the Association for Nepal and Himalayan Studies

Volume 34 | Number 2 Article 9

December 2014

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Kelly D. Alley
Auburn University, alleykd@auburn.edu

Ryan Hile
University of Utah

Chandana Mitra
Auburn University

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Acknowledgements
Earlier drafts of this paper were presented at the BAPA-BEN International Conference on Water Resources in Dhaka, Bangladesh in 2013 and for the AAA panel on Developing the Himalaya in 2012. The authors appreciate the comments and support provided by members who attended these sessions. Our mapping project has been supported by the College of Liberal Arts and the Center for Forest Sustainability at Auburn University.

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This paper introduces the busy field of hydropower development in the Himalayan region of the GBM basin to press the urgency for greater information and data exchange. The paper provides an example of a mapping method and a database that will add to the existing online sources of information and analysis offered by nongovernmental agencies and some government departments.

This project contributes to the general aim of many citizen groups to limit, monitor and regulate the practices of hydropower companies and the management of their infrastructure in the GBM. The monitoring pressure from citizen groups and science projects continues to serve as an important replacement to the weak functioning of the country environment ministries and corrects the corruptions of the license raj that plaque project deals and environmental clearances.

These citizen motivated knowledge exchanges, especially through online portals and social media, can even push for better transnational instruments for formal governmental data sharing.

Keywords: Ganges-Brahmaputra-Meghna basin, hydroelectric, dams, hydropower, India, GIS.

Introduction

As the discussion widens on the types of commissions, citizen organizations and nation-state treaties needed to ensure sustainable river basin management and solve common problems in the transnational Ganges-Brahmaputra-Meghna (GBM) river basin, the lack of access to reliable data will be the first challenge to address. All country governments in the GBM basin are hesitant to share their hydrological data on the shared rivers and information on the construction of hydroelectric projects is harder to find. Data and information on land use changes, river bed and flow regime changes, and actual stages of hydropower project construction should be available to all river basin residents, scientists, civil society, and governments through online resources, satellite imagery, and aerial photography to facilitate the most conscientious use of these shared hydrological resources.

This paper introduces the busy field of hydropower development in the Himalayan region of the GBM basin to press the urgency for greater information and data exchange. The paper provides an example of a mapping method and a database that will add to the existing online sources of information and analysis offered by nongovernmental agencies and some government departments. This project contributes to the general aim of many citizen groups to limit, monitor and regulate the practices of hydropower companies and the management of their infrastructure in the GBM. The monitoring pressure from citizen groups and science projects continues to serve as an important replacement to the weak functioning of the country environment ministries and corrects the corruptions of the license raj that plaque project deals and environmental clearances. These citizen motivated knowledge exchanges, especially through online portals and social media, can even push for better transnational instruments for formal governmental data sharing.

This paper takes the GBM river basin as the hydrosphere, following Johnston and Fiske (2013), for this documentation and examination of hydroelectric facilities. The GBM basin contains all the water that drains the three large river systems and situates the understanding of human life in the hydrosphere. This is a hydrosphere of glaciers that hug the world's tallest mountains, of snow melt and precipitation that form the vibrant and sometimes wicked flows of rivers, and of intimately connected river and cultural life ways. The 5,000 or more glaciers that make up this hydrosphere are the 'Third Pole,' the largest glacial field outside the North and South Poles (Bahadur 1993; Immerzeel et al. 2010). Aesthetically spectacular, they are critical to the sustainability of the water flows necessary for all life. But as these rivers are progressively dammed to meet the energy demands of growing populations, the emerging hydro-complexity is posing serious risks for basin residents, especially when climate-induced extreme rainfall and flooding smash up against the obstructions and diversions created by the hydropower industry (Khan et al. 2010; Mustafa 2013). Therefore, a greater public awareness of these concrete structures, their pathways, and their implications for river flows needs to be facilitated.

Infrastructure Growth and Regulatory Decline

The widespread engineering of river systems can be conceptually framed in a number of ways, and this paper follows from the historical, iterative, and dialectical water-society understandings engendered by the notions of hydrosocial cycle (Linton and Budds 2013), hydrosphere (Johnston and Fisk 2013), water worlds (Barnes and Alatout 2013) and waterscapes (Truelove 2007; Sultana 2013). This paper is focused on creating an approach, a method, and a public database that bring the hydropower infrastructure to the center of this water-society discussion. There are coffer dams and barrages, tunnels and power houses, storages, spillways, canals, muck sites and eroding riverbanks, all carved out of the terrain and interfering with the hydrosphere of the region.

Participatory GIS (Geographic Information System) in this context can help to make these hydropower assemblages more visible to the public. Nongovernmental organizations in South Asia have spent considerable time mapping hydropower facilities but without GIS software and exact locational data. This project follows the strategy of mapping infrastructural assemblages as a way to critique the functioning of the industry and associated agencies, to activate the oversight neglected by state agencies. This is a part of the bottom-up resistance to energy infrastructure (Strauss et al. 2013). When the locations, attributes, and problems of specific dams are documented and then examined online by the public, the broader trends in development across the Himalayas can be cataloged and key risks and abuses to communities, as they are related to these material infrastructures, can be identified.

Participatory GIS has been used since the 1990s to improve governance across many sectors of public life (McCall 2003). GIS tools and open source modeling have been used in tsunami management (Merati 2007), marine oil spill response information (Shishuang et al. 2012), flood monitoring systems in international river systems (Katiyar and Hossain 2007), and SWAT in an open source GIS format (George and Leone 2008). Projects have tended to be context and issue-driven, emphasizing community involvement in the production or use of geographical information (Dunn 2007: 616). In this project, the technical work of entering locational data will be centralized at the university, but input and verification can be done by citizens using an Internet connection. This kind of division of labor also exists in projects connected with water quality monitoring and REDD (Reducing Emissions from Deforestation and Degradation) where citizens use a handheld device, phone or computer to upload information to an online database. While this approach can maintain divisions in access to GIS between what may be considered resource-rich and resource-poor, it takes advantage of the public service arm of the university and seeks to bridge the divide between the groups by offering access to expensive GIS software and trained personnel.

This water-society focus also requires a critical approach to governance, one that foregrounds the roles of citizen monitoring and judicial review vis-à-vis the functions of the state in South Asia. Currently government agencies in each of these basin states are waiving environmental protocols under neoliberal demands for industry incentives (Rajshekhar 2013; Narain 2014). As state regulatory functions wither, citizens are taking up monitoring exercises and pushing judicial authorities to enforce appropriate environmental policies and laws. Meanwhile, investors are lured by incentives for open access and the freedom to sell power on a merchant basis, the possibility of transferring hydrological risks to the public, trading in Clean Development Mechanism (CDM) carbon credits, and speculation on 'memoranda of understanding' and clearances (Dharmadhikary 2008, 2010; Yumnam 2012; Rajshekhar and Sukumar 2013). In the current phase of government administration in India, the regulatory bodies are becoming 'hollowed out,' to borrow the metaphor from Milward and Provan (2000), retaining their functions but performing them poorly, and in the process forcing the courts to take stricter actions against government agencies and industry agents. In Nepal, Bhutan, and Bangladesh, the regulatory agencies are even weaker but citizen action is slowly pushing for accountability and monitoring. In China, the citizen is severely constrained and the push for information on the construction and functioning of dams on the Yarlung Tsangpo is building from nongovernment groups and the media housed in neighboring countries or from transnational networks such as International Rivers.

Background on the GBM Basin

Before outlining the hydropower complex, the paper provides some background on the basin as hydrosphere. The GBM basin is bound in the north by the Tibetan Plateau, in the east by the Yunnan and Sichuan Provinces of China, in the south by India, and in the west by Pakistan. The transnational population of the basin now exceeds one billion. The Brahmaputra sub-basin is gifted with water wealth, hydropower potential, and high biodiversity, while the waters of the Ganga, Barak, and Meghna are intensively utilized for agricultural and industrial production, urban settlements, power and everyday sustenance. Nepal and Bhutan, the smaller upper riparian countries, have significant hydropower potential and favorable ratios of per capita water availability. Bangladesh accounts for 8 percent of the total basin territory but the hydrological catchment covers most of the country.

Given the water wealth of the Ganga, Brahmaputra, and Meghna rivers, the religions of the region have granted their tributaries and main stems a revered position in cultural narratives and practices. The river Ganga is the most revered and she is worshipped as a Mother Goddess and eternal purifier. The tributaries to the Brahmaputra are worshipped by Tibetan Buddhists and Hindus and the main stems of the Brahmaputra and Barak rivers are considered sacred by indigenous peoples. But as water enters a new phase of global commodification, even more is at stake for these sacred rivers, their tributaries and the human populations that depend upon them. In the Ganga sub basin more than 30 major cities of more than 300,000 and hundreds of industries dump their municipal effluent into the river, after only partial and incomplete wastewater treatment. This jeopardizes water quality for all uses and puts the practices of religious reverence for the river at great risk (Alley 2002; Sanghi 2014).

The Brahamputra is fed by several tributaries, including the Yarlung Tsangpo in the Tibet Autonomous Region of China, which then becomes the Siang in Arunachal Pradesh. The Teesta River enters northwestern Bangladesh from India, the Barak River enters the system from eastern Bangladesh and then forms the Meghna in the lower basin. These rivers are used intensively for agriculture and fisheries and are tapped for prolific urban and industrial development. Across all river basins, industrial and urban effluents are creating an almost irreversible deterioration of surface water quality. Over-pumping of groundwater for agriculture (Rodell et al. 2009; Scott and Sharma 2009) depletes sources across the basin. The Delta plains and flood plains of the Ganges–Brahmaputra river system are moderately to severely arsenic-enriched, affecting more than 60 percent of tube wells (Ahmed, K. Matin et al. 2004; Sultana 2013). Shallow aquifers in the Meghna river basin and coastal plains are extremely enriched and there more than 80 percent of tube wells are affected. In India groundwater supply will need recharge from adequate river flows to continue to meet high water demands.

People living across the GBM region face extreme fluctuations in water availability and river basin conditions on an annual weather cycle. The weather alternates between high water availability—through extreme rainfall and flooding during the monsoon—and extended low flow during the nine-month dry season. With the use of hydropower technology, the water source and availability is modified in time and space through storage ponds and reservoirs, in an attempt to meet year-round demand. In addition, hydropower is attractive for contemporary societies, for unlike coal and nuclear power it can generate 'peaking power.' While large storage dams can hold a massive amount of water behind a barrage and facilitate far-reaching water redistribution and reallocation schemes, run of the river dams halt the river flow for a short period and hold water in a small storage pond. Water is then released through a head race tunnel to generate power on demand. With run of the river projects, the downstream flow regime alternates between diminished flow at some hours of the day and rushes of water at others. During the monsoon, flooding can occur during a heavy or extreme rain event or by sudden releases of water from the dam reservoir to relieve water pressure. This puts residents downstream at significant risk from changes in stream flow and also from changes and increases in sediment deposition, especially when sediment includes the muck or debris of a dam construction site (Alley 2013). This means that residents living downstream from one or many dams and diversions are constantly responding to these changes in the river's rate, direction and volume of flow, and all these create cumulative challenges to human adaptation and resilience (Bosshard 2010; China Dialogue 2010; Malone 2010; Schwarzenbach et al. 2010; Lahiri-Dutt 2012).

River flows that are altered by hydroelectric dams and canals and diverted to needy urban centers are also affecting the groundwater recharge rate. In Bangladesh surface water is and will remain in high demand to offset the inability to use arsenic-contaminated groundwater for human consumption. In all areas of the basin the warming climate will induce faster glacial melt and bring more water into the river system at some times of the year. This can lead to flash floods especially at times when heavy rainfall combines with glacial lake outbursts or GLOFs within the glacial formations (Alley 2013; Dobhal et al. 2013). Not only are dams disembedding the river from ecological and hydrological systems (Mustafa and Wrathall 2011), but they are subjecting the river's flow to nested infrastructures that require engineering control. When additional water enters the system from a glacial lake outburst, the pressure on the reservoirs quickly increases. At those moments of crisis, water has to be released suddenly from reservoirs by opening the barrage gates and this puts everyone and everything downstream at greater risk of flooding. Increased rainfall and glacial melt may help to recharge groundwater and dilute pollution in the river stream but both can lead to dangerous and even deadly hydro-hazards (Dobhal et al. 2013; Mustafa 2013).

Hydropower Development in the Basin

Hydropower is an important energy strategy that reshapes the hydrosphere as it becomes a functioning part of it. Large dams were built just after Indian Independence as part of national development and despite major oppositions to them, projects grew in number over the following three decades (Gilmartin 1995; Singh 1997; Baviskar 2005; Dharmadhikary 2005; Chellaney 2012; Wagle et al. 2012). Large hydropower projects have received criticism across the world for their debilitating consequences: the massive displacement of people, the redirection of water in ways that create new forms of scarcity, and the hydrologically and ecologically destructive interventions in river and terrestrial systems (McCully 1996; World Commission on Dams 2000; Bosshard 2010). The current wave of dam investment in India is motivated by interests in powering industrial growth and urban expansion in the face of dwindling gas reserves and problems with coal block development. In 2002, the Government of India announced a 50,000 megawatt initiative to narrow the gap between supply and the growing demand for power. The hydropower initiative is active in the Indian Himalayas where the steep drops of tributaries to the Indus, Ganga, and Brahmaputra rivers can generate larger outputs of power. Sites of development are spread across northern India, Nepal, Bhutan, and lower Tibet. Construction in all these basin countries will increase in the coming decade. This infrastructural growth may not improve access to energy for people living in Himalayan cities and towns; generally citizens living near these facilities get the end of the trickle down effects of a power supply that is directed to high end consumers such as industries and urban blocks (Sreekumar and Dixit 2010; Wagle et al. 2012). These high end users consume this increase in energy while also withdrawing water and returning wastewater to the river system.

Along the northwestern tributaries of the Ganga River in the State of Uttarakhand, the Tehri dam and several run of the river dams were completed in the first decade of the twenty-first century to provide energy and water supply to the northwestern states of Uttar Pradesh, Delhi and Rajasthan (Alley 2011). In Sikkim, a series of dams is under construction along the Teesta River and along the Rangit that flows into it. In the northeastern state of Arunachal Pradesh, the government has sketched up a blitz of projects along the main tributaries of the Brahmaputra, along the Siang, Subansiri, Lohit, and Dibang rivers (Menon and

Kohli 2005; Vagholikar and Saikia 2009; Vagholikar and Das 2010; Alley 2012; Yumnam 2012). There are also many projects proposed on the Tawang and Nyamjang Chhu tributaries to the Manas River that flows from Arunachal to Bhutan (see Figure 1).

The state of Arunachal Pradesh is poised to outpace the states of Himachal Pradesh and Uttarakhand in terms of megawatt production. However, the state lacks the roads, bridges, transmission lines, and supporting infrastructure needed for private sector participation. This has slowed the destruction of the hydrosphere to some extent but enabled a lively game of speculation through 'Memoranda of Agreement' or 'Memoranda of Understanding' between politicians, government officials and specific investor companies. Since projects listed by the Central Electricity Authority are allocated to private companies through preliminary memoranda of understanding or agreement, there is ample opportunity for private deals, covert decision-making and corruption (Rajshekhar and Sukumar 2013). These are agreements that entail a particular channeling of private capital through individuals holding specific government and private company posts; this capital may not be invested in local economies (Bosshard 2010). As many have recently noted, the process creates an unofficial protocol and pricing system, and while following government rules and procedures to some extent, adds the incentive of profit making from paper clearances and permits. This is a remaking of the license raj that plagued the early years of India's infrastructure development. The procurement of these memoranda and clearances, as one media source noted, is the riskiest part of the long gestation period in the hydropower industry (Rajshekhar and Sukumar 2013).

The media and informed observers have known about China's plan to develop four run of the river projects along the Yarlung Tsangpo for several years and their push forced the Chinese government's recent announcement in its energy development plan for 2015 (Watts 2010; Krishnan 2013a). One dam has been completed at Zangmu and three more are under construction at Dagu, Jiacha, and Jiexu. There are also basic infrastructure projects near Motuo at the Great bend, indicating that a dam larger than the Three Gorges dam could be constructed there in the future.

The vulnerability of Bangladesh as a downstream country in the GBM cannot be remediated by the method and online database proposed here but the mapped information can help citizens keep track of constructions upstream. Bangladesh's nearly complete lack of control of the upstream flows of 54 rivers shared with India undermines the viability of the country's water interests. Boxed in on three sides by Indian control of the Barak, Brahmaputra, Teesta and Ganges rivers, Bangladesh's citizens are completely enveloped by the hydropower industry spanning Lower Tibet, the Indian states of Sikkim, Arunachal Pradesh, and West Bengal and more broadly the entire GBM mega basin.

Politics of Data and Water Sharing Among Basin Countries

All basin country governments are promoting hydropower development while citizens groups are working to monitor and limit. While Bangladesh is the most vulnerable downstream country, the government has also worked hard to initiate discussions with the Indian government on sharing investment and proceeds from the Tipaimukh dam planned for the Barak River in Manipur. In April 2013 the Indian government offered Bangladesh an equity stake in that dam project. The Bangladesh government has also weighed in on proceeds from proposed projects on the Nyamjang Chhu, Siang, Lohit, Dibang, and Subansiri rivers in Arunachal Pradesh. According to *The Hindu*, Bangladesh also sought joint participation in nine more projects.[1]

Bangladesh had also hoped for an agreement with India on the Teesta river flows but that was dashed when the Chief Minister of West Bengal failed to attend an important meeting to decide treaty parameters in 2011. The Bangladeshi government still makes regular requests to complete a treaty for sharing water of the Teesta but the country's citizens complain that the government is too timid in negotiations and in pressing for disclosure of information and data. While the Indian central government has expressed interests in deal making, the West Bengal government remains quiet on the issue, immersed in developing hydropower projects in its own state. Looking at the effects of two decades of flow reductions downstream, this delay constitutes a human rights abuse in water management for people living in northwest Bangladesh.

At the same time, the Chinese government has dismissed proposals to enter into a "joint mechanism" with India or a multilateral river agreement with India and Bangladesh over the Brahmaputra and its tributary waters.[2] China shares some hydrological data on the Yarlung Tsangpo with India but does not disclose information on technical designs for dams or progress in construction plans. India's National Security Advisor recently spoke about meetings between senior officials of China and India to *The Hindu*:

"We mentioned the fact that we have a forum, we are exchanging data on transborder rivers, and that we would like to expand what we are doing," Mr. Menon said here last month. "We are also measuring flows," he said. "So far so good; so far, the flows are what they were. The question is, if they have a structure which can control flows. So far, it doesn't exist. They say nothing that they are doing is going to affect the flows. They are sharing data with us, and we will keep working with them (Krishnan 2013b).

The Indian government is hesitant to demand regulation of China's run of the river dams because they do not want anyone to regulate theirs. This is the same situation with measuring water quantity and streamflow so consequently there is a lack of flow data in all countries and an interest in keeping it underrepresented in the scientific literature. To compensate modelers and hydrologists have to reconstruct streamflow data from meteorological and other climate data.

Opposition to Hydropower and Restrictions on Data

While country governments are promoting growth in this industry, on the ground the development has been fierce and controversial with energy and industrial interests in water pushing out allocations and uses for farmers and residents. Citizens have mounted various campaigns and movements for and against specific dams (Kumar 1996; Mawdsley 2005; Bisht 2009; Drew 2011, 2012, 2013; McAnaly 2012; Wagle et al. 2012). The push-back against hydropower development works on the assumption that more hydro-development in the Himalayas will have wide-ranging and mostly negative effects for capital relations, agricultural and livelihood subsistence, ecology, and biodiversity (Ahmed et al. 2004; Dharmadhikary 2005; Menon and Kohli 2005; International Rivers 2008;

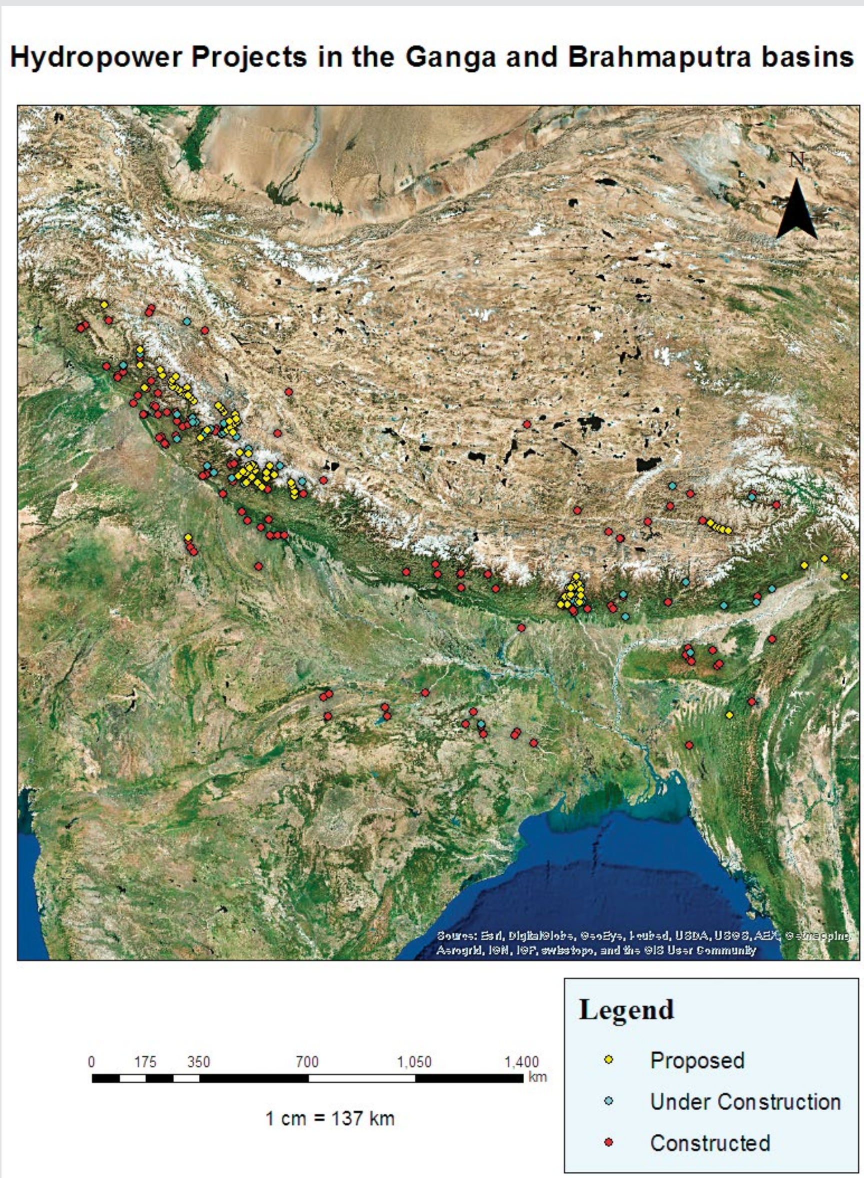

Figure 1. Dam sites (constructed, under construction, and proposed) within the Ganges and Brahmaputra basins.

(Base map source: ESRI World Terrain Base. Map by Samriddhi Shakya)

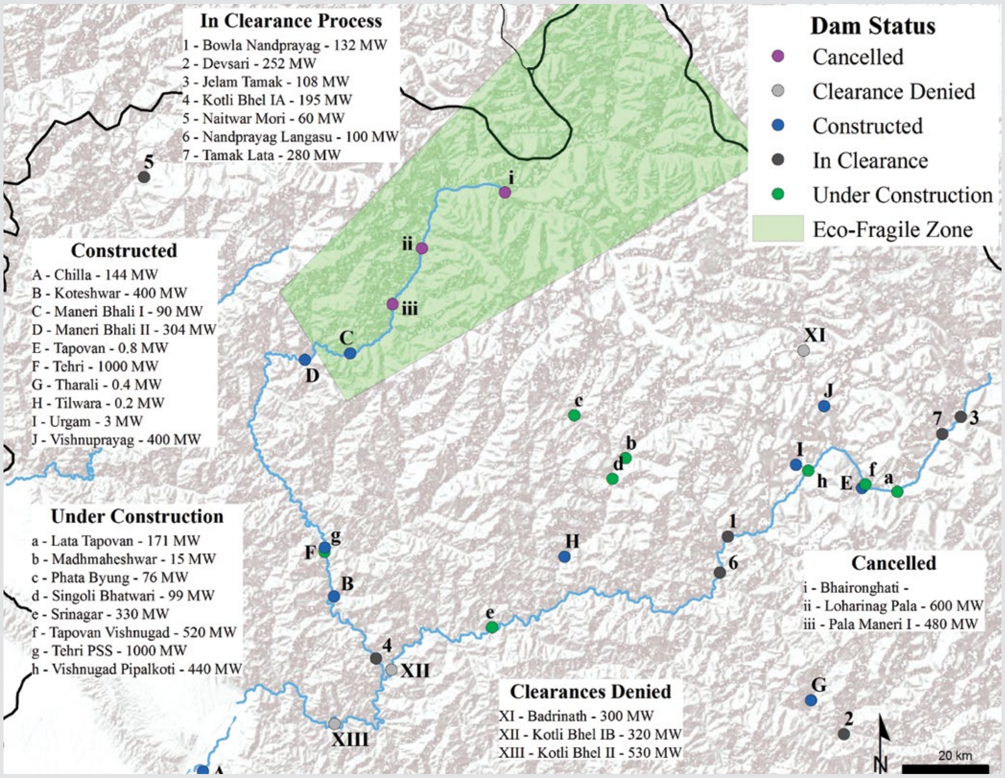

Figure 2. Map of hydropower projects with project names in Uttarakhand.

(Base map source: ESRI World Terrain Base. Map by Ryan P. Hile)

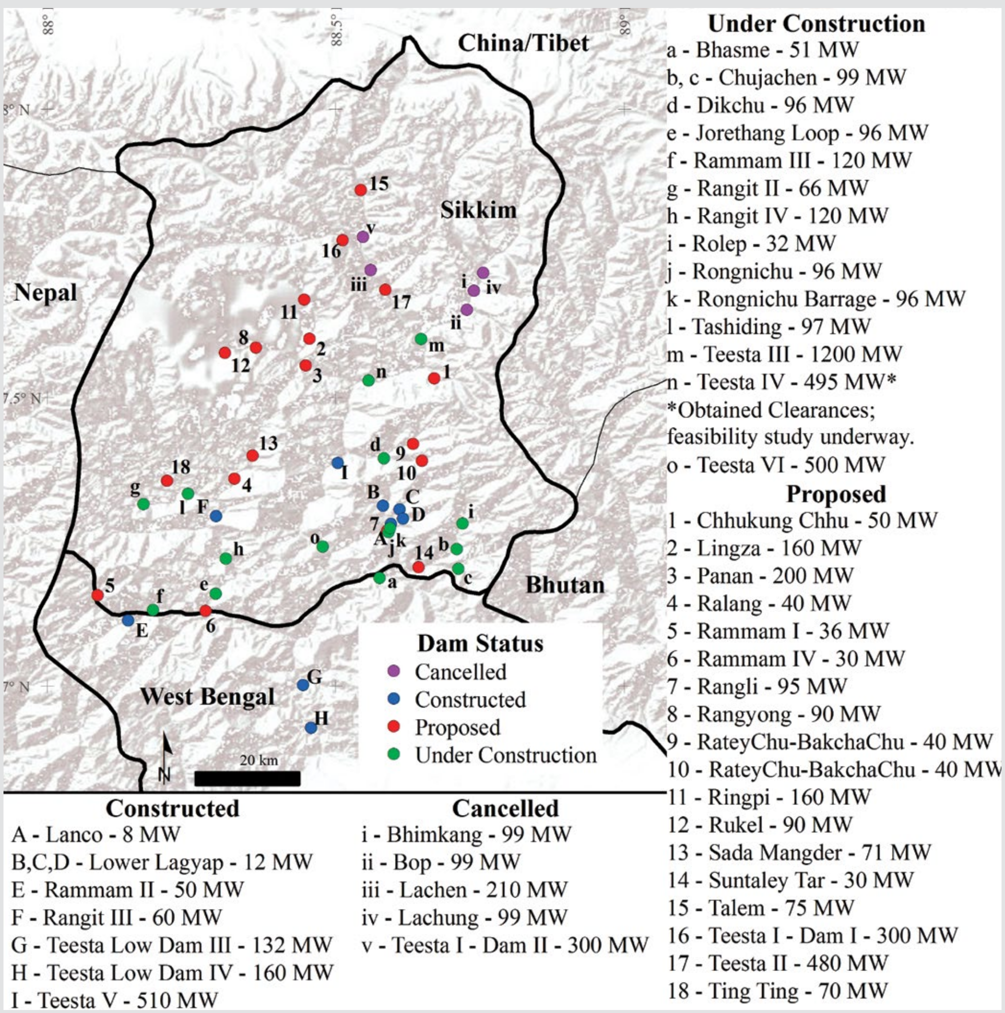

Figure 3. Dam projects in Sikkim.

(Base map source: ESRI World Terrain Base. Map by Ryan P. Hile)

Vagholikar and Saikia 2009; Grumbine and Pandit 2013). All the pushbacks involve sustained civil society movements and confrontations and exhaust community health, time, and resources to a significant extent.

Activists, critical journalists, and scientists have had some success in pushing for assessment reports, additional expert monitoring committees, and court orders that aid in checking or halting the practices of industry and government agencies and public sector companies, especially in India. This means that there are active avenues to sharing information and data outside government ministries and departments and this expertise is informed and scientific. The mapping project described in the next section of this paper is motivated by the activities of these nongovernmental and science communities. Eventually pressure from these groups builds up through information sharing, media reports, letters to government authorities, banks and funding agencies, and petitions to the courts. These strategies are able to force incremental change within formal institutions (Ahmedet al. 2004; Alley 2004; Bhaduri 2012; Zawahri and Hensengerth 2012). University and science groups have the potential to bring more ecological and climate expertise into the planning and assessment process (see Gangapedia). The Bangladesh Poribesh Andolo and Bangladesh Environment Network provide scientific information and learning workshops to citizens in Bangladesh. The International Center for Integrated Mountain Development coordinates numerous scientific and community capacity initiatives across the Hindu-Kush region and also has an online map of river and glacial features. Expert committees are also created via court orders to provide monitoring and analysis of hydropower projects including feasibility and detailed project reports.

Some of the most active and successful citizen attempts to monitor construction and halt faulty and corrupt practices have occurred in the states of Uttarakhand, Himachal Pradesh, Sikkim, and Arunachal Pradesh. In 2002, the Indian Ministry of Power charted out an over-ambitious plan to dam all the tributaries of the river Ganga at more than 60 places in Uttarakhand. Maps of these plans began circulating through civil society networks as people in and outside the state grew worried about their cumulative effects on water availability downstream and water quality in low flow situations (see South Asia Network for Dams, Rivers and People 2011). In the upper Ganga basin, local resistance movements formed, dissipated, and then reformed, and anger against company malpractices and non-compliance to regulations and court orders was expressed through letter writing to government offices, through media articles, and Gandhian fasting and resistance (Drew 2011, 2012, 2013). Eventually the multiple pressures from these local, national, and transnational groups forced the final cancellation of a run of the river dam at Loharinag Pala and two in the advanced planning stage (Pala Maneri and Bhairon Ghati). In 2010, the Comptroller and Auditor General of India (CAG) issued an audit report titled "Performance Audit of Hydropower Development through Private Sector Participation." It charged that the government of Uttarakhand had pushed the state toward a major environmental catastrophe by following a highly ambitious hydropower policy (Tripathi 2010).

After the cancellation of these three dam projects, citizen groups continued to push the Ministry of Environment and Forests to issue the Notification for an Eco-Sensitive (or Eco-Fragile) Zone on the Upper Bhagirathi to protect the ecology of the upper Bhagirathi and ban additional hydropower projects. The flood of 2013 that devastated Uttarakhand brought all these activities under greater scrutiny. The loss of river beds and flood plains to dam construction and urban construction, the constant erosion from road building, the buildup of dam debris or muck, and the removal of sediment from the riverbed through sand mining have contributed to the devastation of the river system. During an extreme rain event or even a glacial lake outburst, the degraded river channels cannot contain the excess water and the wicked flows cause extensive damages to homes, property, and infrastructure (Mustafa and Wrathall 2011; Alley 2013; South Asia Network for Dams, Rivers and People 2013).

Cognizant of these risks and their magnification during extreme rainfall and flooding events, government officials have kept hydropower projects a prominent part of the energy agenda in India's Twelfth Five Year Plan. In theory, the government has closed the upper Bhagirathi to additional dam construction, but the Ministry of Environment and Forests continues to grant clearances for projects on the Mandakini, Dhauli Ganga and Pinder rivers, some in the fragile upper reaches (Alternate Hydro Energy Centre 2011; Rajvanshi et al. 2012; Alley 2013). Moreover, the Ministry has allowed sloppy rehabilitation of the Vishnuprayag dam on the upper Alaknanda, after this dam was completely buried by boulders and sediment during the flood of June 2013 (see Basu 2013; Upadhyay 2013; Alok Panwar and Vimalbhai 2014). In August 2013, the Supreme Court ordered that all further clearances for hydropower projects in the state be stopped until an expert committee assesses the role of hydroelectric infrastructure on the behavior and impact of the June flood (Supreme Court 2013). After this order, the National Green Tribunal began issuing directions to the company operating the Vishnuprayag dam to correct its muck dumping and rehabilitation practices.

While considerable attention remains on Uttarakhand, construction is ramping up in Sikkim and Arunachal Pradesh and these projects are facing more intense local and regional resistance. In Sikkim the Rangit III dam is operating on the Rangit River, the right bank tributary to the Teesta. The Teesta V at Dikchu has been operating on the Teesta River since 2008, and now the large Teesta III is under construction at the confluence of the fragile headwater streams to the main stem. In addition, the Teesta VI is in progress downstream of Teesta V (see Figure 3). The five dams proposed for the two fragile headwater tributaries to the Teesta, the Lachen, and Lachung were opposed by indigenous Lepcha communities from the Dzongu region and from communities across the state. For several years these residents used fasting, legal action, and control of land and river spaces and eventually forced their cancellation in June 2012 (Arora 2007, 2008). Citizens are also opposing the Panan dam on the Rangyong River, another headwater tributary to the Teesta. In Arunachal Pradesh, citizen groups have held up construction of the controversial Lower Subansiri project for several years over concerns about the dam's height and the inadequate safety measures and flood cushioning. Calls are made to reframe the hydropower mission away from the developmental and strategic interests of member states and toward the interests of the development and security of people living in the region (Tsering 2003, 2012).

NGOs, citizen groups and activists in India and Nepal have argued that the environmental impact assessments (EIAs) required for hydropower projects should calculate safe levels of ecological and hydrological change through the guarantee of minimum flows, the protection for biodiversity and eco-fragile/sensitive regions, and the support for cultural practices vital to local and national economies. For example, a cumulative impact assessment report created in 2013 by the Wildlife Institute of India offered a more critical review of developments and requirements for river flows, countering previous reports issued by university and government departments (Rajvanshi et al. 2012). The Prime Minister appointed an inter-ministerial committee to examine this report along with the others and provide recommendations. That committee came out with a series of recommendations on minimum environmental or river flows that advocated a minimum of 30 percent to 50 percent of lean season flows. The report was not made public until a question about it was posed in the Rajya Sabha (Upper House) of Parliament several months later. The government was then obligated to post a summary of the recommendations to the Press Information Bureau of the Government of India website. The release listed the main recommendations and the specific recommendation on minimum flow as: "Environmental flow of 20 percent to 50 percent of the daily uninterrupted river flow during various seasons from hydro power projects" (Ministry of Water Resources 2013). In the midst of the time delay in making the report public, citizen groups were already circulating drafts of the report obtained from their own sources as they prepared to continue the important debate.

Visualizing Hydropower

GIS software allows large amounts of geospatial data to be linked with associated non-geospatial data known as 'attributes.' When using GIS for a project, the scientist and the citizen can visualize data with minimal effort in a geographic space. The information contained within the GIS software can be easily updated and may also include a wiki feature for citizen contributions. The biggest challenge for this hydropower mapping project involves confirming geographic information and locations since most of the original data and maps have been hand drawn and are not regularly updated. Several basemaps were utilized to aid with hydroelectric power (HEP) site locations, including the Bing Maps Aerial basemap, ESRI World Terrain basemap, the National Geographic basemap, and the imagery base found in Google Earth. For this project, the file geodatabase format found in ESRI's ArcGIS platform was selected because it provides the benefits of visualization and a large database size allowance. Access and processing speeds and flexibility determine what can be stored in the database. The long-term goal of the project is to build the databases for each dam and for regional data. In this way, data storage can be extended beyond the basic geospatial forms to include such things as tables, documents, and media links that lack geospatial data. The database can also include the regulations, policies, and laws that relate to each dam, state, or country. The information can enhance citizen access to and understanding of data, policies, laws, and ongoing industry regulations that impact them.

With the database serving as a foundation for the project, the addition of new HEP sites, including new attribute fields, and the dissemination of data become easier. Attributes for flow rates or government regulations associated with the HEP sites or the sub-basins and basins of the GBM region can then be added. An application that enables the citizen to collect data, including photo documentation, and upload those materials to the site can also facilitate validation.

While advancing citizen oversight and monitoring activities, an online map can also assist in the measurement of the externalities of hydropower projects. One method for measuring the externalities—that is, the negative or positive effects of dam projects—is to calculate the total proposed land use and river system changes and then

Figure 4: Erosion of muck disposal site at Srinagar Dam, after the flood of June 2013.

(Kelly Alley, 2013)

plot out the geomorphological and hydrological effects to the river system. This would include the calculation of carbon fluxes from land use and river system changes and estimations of methane emissions from the newly created dam reservoirs. Documentation of sediment loads and land and hydrological changes can be plotted using ground and satellite data collected through citizen participation and by research teams working in the region. Handheld GPS devices and GPS-enabled cameras can be used by citizens to take pictures of dam construction sites, including the muck disposal sites that are created along the river's edges. These can be understood as sediment loads that will enter the river stream during monsoon and extreme flood events to disturb flood patterns (see Figure 4). In addition, areas of land use change, catchment and forest loss can be plotted in the same way. Finally, the values created for biodiversity and human cultural practices can be added to the understanding of the total ecosystem 'benefits' or 'services' for the river system.

This calculation procedure for energy, water, land uses, carbon, biodiversity, and cultural values can extend the scope and understanding of the costs and benefits of a project. This calculation can also be done in a more technical and holistic way using the IDAM model developed by scientists in the US (Brown et al. 2009). Any metric must list the carbon tonnage 'saved' by switching from coal to hydropower and then subtract all the carbon fluxes and emissions ensuing from land uses and hydrological changes. Then the losses to livelihood and economy connected to agriculture, commodity markets, pilgrimage, and tourism practices, including losses to the sacred meanings of these rivers, can be included. All these values can be represented in some fashion in the database to assist in public evaluations of water uses and trade-offs between various uses. This also ensures that the metric of EROI, the energy returned on energy invested, does not just calculate energy, but all the ecological, hydrological, and socio-cultural costs incurred by these projects in the hydrosphere (Lerch 2009).

Some of the best public information sites are now provided by nongovernmental organizations and International Rivers and the Circle of Blue are among the best in North America. Many good maps are produced in the public domain by smaller organizations and independent scientists such as the South Asia Network for Dams, Rivers, and People. Online resource groups are emerging very quickly, with ICIMOD, India Water Portal, Climate Himalaya, and Bangladesh Environment Network leading the way. Science-based organizations are posting important research and outreach projects online as well. However, many maps used on these public domain sites lack exact locational data and imagery that could reveal infrastructure projects in the GBM basin may be blocked on Google Earth and other sites (Alley et al. 2012). More accurate and accessible information on hydropower projects can aid in flood alert and weather warning systems and in overall human responses to climatic and anthropogenic river flow changes.

To facilitate participatory GIS, the database can be published online in a variety of formats. ESRI offers both subscription-based and free resources for web mapping applications that can accommodate multiple users and allow for management hierarchy. Other free and open source software options exist to accomplish this. Regardless of how the GIS database is published to the Internet, the core philosophy and design is to enable NGOs, citizen scientists, researchers, and others to access and modify the database to maintain accuracy in the data as changes in the world are experienced and known. This simple access approach to participatory GIS can reduce barriers to GIS technologies.

Conclusions

This paper has outlined the scope and trends of hydropower development across the GBM hydrosphere to press the urgency for public access to information and data via online portals. Hydropower project attributes can be geospatially mapped with information and datasets to create visualizations on a landscape map. By using GIS and mapping exercises, alternative and more holistic ways of measuring impacts and externalities can be carried out and these more complex knowledge frames can help identify the benefits, costs, and consequences of rapid hydropower development. The aim of this visual and citizen-reviewed online platform and the accompanying system of information and data verification is to find a way to limit the development of energy projects to a safe and beneficial range. New ways to think about and regulate the insatiable temptation to overbuild on the Himalayan landscape and alter riverbeds and flows in irreversible ways are emerging from citizen science and awareness. Since neoliberal industry incentives, weak regulatory agencies, and climate policy and assessment reports for the region are not adequately enforcing guidelines and limits on rapid development, citizens are taking up the cause. A river basin organization or citizen group that works in this field would have another method for information and data exchange at its disposal, to enable a more robust knowledge platform for decision-making and water sharing agreements.

To view the GIS database and platform described in this paper, go to <http://cla.auburn.edu/gangabrahma/>.

Kelly D. Alley is professor of Anthropology at Auburn University. Her research focuses on religion, activism, politics, energy, policy and law related to rivers in India. She is the author of, *On the Banks of the Ganga: When Wastewater Meets a Sacred River* (University of Michigan Press, 2002).

Ryan Hile is pursuing his PhD in Geography at the University of Utah. He works as a GIS Analyst for the DIGIT Lab in the University of Utah Geography Department. His research interests include GIS and GIScience, human dimensions of environmental hazards, and social justice.

Chandana Mitra is a climatologist, GIS analyst and physical geographer. She is Assistant Professor of Geography at Auburn University. Her research focuses on urban climate, mesoscale modeling and climate change in the US and South Asia.

Earlier drafts of this paper were presented at the BAPA-BEN International Conference on Water Resources in Dhaka, Bangladesh in 2013 and for the AAA panel on Developing the Himalaya in 2012. The authors appreciate the comments and support provided by members who attended these sessions. Our mapping project has been supported by the College of Liberal Arts and the Center for Forest Sustainability at Auburn University.

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