The Rivers Come: Colonial Flood Control and Knowledge Systems in the Indus Basin, 1840s–1930s

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ABSTRACT

This essay traces the development of the physical and cultural infrastructure of colonial flood control in the Indus valley. Reconstructing investigations into the causes of a series of floods illustrates the conflict between the idiosyncratic, local knowledge-based, approach of generalists and the reductionist, technological mentality of engineers. Repeated attempts to protect towns from the Indus River illustrate the growing dominance during the second half of the nineteenth century of an engineering mentality, despite its practical shortcomings. Complex engineering works replaced traditional warning systems and mobility, undermining alluvial farming systems as well as a precautionary approach to environmental management.

KEY WORDS

Indus River, floods, British Empire, engineers, generalists, precaution

> [A] Murmuring sound was heard from the north-east amongst the mountains, which increased until it attracted universal attention, and we began to exclaim 'what is this murmur? Is it the sound of cannon in the distance? Is Gundgurh bellowing? Is it thunder?' Suddenly some one cried out 'the Rivers come!'

Ushruff Khan, a Zemindar of Torbella, noticed that water already filled all the dry riverbed channels. In a moment, he saw the river 'racing down furiously in an absolute wall of mud, for it had not at all the colour or appearance of water'. Only those who saw it in time escaped. 'It was a horrible mess of foul water, carcasses of soldiers, peasants, war-steeds, camels, prostitutes, tents, mules, asses, trees and household furniture, in short, every item of existence jumbled together in one flood of ruin.'[1]

The flood of 1841 was an important event not only in the lives of the people who lived along the banks of the Indus, but also in the British experience with the Indus basin that they would come to rule.[2] The flood dramatically introduced the British to the various problems of environmental management that they inherited when they annexed the territory. Although the massive barrages and dams serving vast irrigation schemes are the most prominent marks of British rule on the Indus valley today, flood control and navigation first concerned the British when they came to Sindh. Irrigation improvements early interested them, but the violent inundation, retreat, erosive force and westward drift of the Indus was unlike any river system they had ever met before.[3]

This paper traces the development of the physical and cultural infrastructure of colonial flood control in the Indus valley. It explores the process by which environmental managers of the British Empire in India increasingly created a bureaucratic and segmented mental landscape that profoundly affected the physical landscape. This occurred progressively, if almost imperceptibly, as specialists trained in narrow reductionist science replaced an older generation of generalists, whose knowledge was more qualitative and based in local relationships and experience; and engineering became the dominant mode for managing the environment of colonial South Asia. By following the investigations into the causes of a series of floods and engineering attempts to protect one town from the erosive force of the Indus, this essay illustrates the rise of the engineering paradigm and the concomitant ascendancy of techno-chauvinism[4] and technological optimism.[5]

I then discuss some of the limitations of this science and engineering approach to environmental management as well as some of the ways that the earlier generalist approaches may have offered effective alternatives. Moreover, the arguments associated with this earlier approach depended on sophisticated qualitative observation, the validity of which has largely been borne out by later scientific investigation. This generalist argument depended on the practical necessity of adapting to local custom or social-political technologies and a form of the precautionary principle. More importantly, these arguments declined in effectiveness and respectability as the 'engineering paradigm' ascended within the cultures of the Imperial civil services. Most generally, I argue that ideas matter. This is not an argument against the importance of material conditions and economic motives; rather, this paper offers an idealist supplement to the materialist perspective with its focus on state revenue concerns and land settlement. Epistemologies can have tangible effects on the environment.

THE RIVERS COME

TECHNOLOGICAL IDEOLOGIES OF DOMINANCE AND THE DECLINE OF LOCAL KNOWLEDGE

Historians of British imperialism have focused on the ideologies of dominance with which servants of the British Empire justified their rule. Thomas Metcalf identifies two divergent strategies by which the British justified their authority in India; one emphasised similarities between the British and their Indian subjects, the other presumed fundamental differences. Over time, the ideology of difference was the one that predominated.[6] This generally confirms the tone of the change over time favouring 'scientific knowledge' over 'local knowledge'. After all, an administration influenced by an ideology confirming kinship with the ruled would not be loath to borrow from their store of knowledge, their way of understanding. Conversely, an ideology of difference would make honest engagement with 'local knowledge' feel like a betrayal of one's own western 'scientific superiority'.

From about 1780, Michael Adas argues, the achievements of the industrial revolution increasingly established the machine as the symbol of the west and mastery of nature as the measure of all civilisations. Europe's capacity for change and progress, to apply the results of each scientific discovery to useful technology, constituted its civilisation and its uniqueness. This assumption shaped the ideologies of European imperialism – particularly the ideology of the civilising mission.[7] The British in India sought to extend their control over nature and local people and make them both 'productive'. In the British self-image dominance over the former legitimised dominance over the latter. Moreover, in colonial India, where the separation between state and Indian society was implicit in the definition of the British as a ruling community, as David Gilmartin has aptly observed, the British conceived of 'native' communities as parts of the natural environment to be controlled.[8] As engineering capabilities increased, a modern bureaucracy developed, changing its relationship to the communities it ruled, as well as the ideology that informed its rule. Nevertheless, no matter what the ideology, as Christopher Hill reminds us, imperialism was domination – domination of people and nature.[9]

This is particularly evident in efforts to control water. Grounded in Karl Wittfogel's theory of hydraulic societies,[10] Donald Worster describes the creation in the American West of 'an increasingly coercive, monolithic, and hierarchical system ruled by a power elite based on the ownership of capital and expertise'.[11] In David Gilmartin's extension of this analysis to the Punjab canal colonies, canal building involved not only technical innovation but also a political balancing act. The scientific concerns of British hydraulic engineers came into conflict with the 'social scientific' imperatives of imperial rule as expressed by British administrators. As technical 'experts' increasingly joined generalist administrators, they came into conflict over the relative values in state structure of 'local knowledge' and the 'universal principles of science'.[12] There has been considerable and excellent work on the social, political, economic and ecological effects of irrigation in colonial India, but very little work on flood control.[13] This paper is an initial contribution to filling that gap.

The power of the 'technological ideology of dominance' had important implications for framing the discourse of environmental management. A corollary of such a legitimising ideology based in science and technology was an almost religious commitment to the scientific method and scientific means of expression. This meant that certain forms of argument were more respectable, more acceptable and more influential than others. Numerical precision, already the bailiwick of the European man of science, became the often-arbitrary arbiter of credibility. The veneer of science occasionally substituted successfully for legitimate scientific investigation.

Another implication is the decline of 'local knowledge'. James Scott's self-described case against 'the imperialism of high-modernist, planned social order' and for the 'indispensable role of practical knowledge, informal processes, and improvisation in the face of unpredictability' examines the modern state's administrative and physical (re)ordering of nature and society.[14] Projects of legibility and simplification, he argues, inevitably lose sight of and frequently destroy the 'exceptionally complex, illegible, and local social practices' that have developed in intimate relationship with specific local conditions and practical local knowledge.[15] Few regimes could rival British bureaucratic rule in India in either high-modernist ideology or projects of legibility. The growth of technocracy and the concomitant minimisation and suppression of local knowledge is the backbone of the story presented here, since I argue that the exclusion of local knowledge led to unfortunate, costly, environmentally deleterious and avoidable decisions.

The British arrived at an approach to flood control that required ever more massive and complex technological systems designed to exclude 'natural processes' as much as possible. The next section explores the changes in mentality that made such massive endeavours possible.

THE SHIFTING RIVER

The Indus valley extends for a thousand miles from the Himalayas to the Arabian Sea and its watershed covers a large area. Punjab takes its name from the five rivers that descend from the Himalayan range, unite and empty into the Indus just before it leaves the Punjab at Dera Ghazi Khan and enters Sindh. 'The noble Indus is the characteristic geographical feature of Sindh', wrote Richard Burton, the famous adventurer and orientalist, after his incognito foray in to Sindh in 1849, 'It is at once the great fertilizer of the county, the medium of transit for merchandise, and the main line of communication for the inhabitants'.[16]

For the British who had just conquered Sindh, 'the changeable nature of the river' was primarily an impediment to navigation.[17] Charts and notes from exploratory voyages of just a few years earlier were useless to surveyors and explorers seeking to establish a standard route from the several mouths of the Indus up to Hyderabad. Captain Postans complained of the river's shifting in 'the lower part of Sindh, whose geography is thus in the course of a very few years completely altered'.[18] He observed that 'at Sukkur, Rori, below Hyderabad, and at Jeruk, rocky barriers interrupt on the western bank its progress at those particular spots, but elsewhere it has full liberty to choose its constantly changing course, through an under soil so light and friable, that it cannot withstand the action of such a mighty rush of water even for one hour'.[19] The westward drift of the Indus became the subject of almost obsessive conjecture on the part of British explorers, geographers and engineers. By 1851, Burton, at least, had become positively bored with the subject:

> The different opinions concerning its course in the days of Alexander, and the various arguments for and against the theory of its ancient channel having been to the eastward of the present bed, have been discussed *usque ad nauseam*.[20]

However, through the end of the century, amateur forays into speculative historical geography of the Indus proliferated.[21] Perhaps the continuing popularity of this subject of inquiry had something to do with the continuing impact of the river's shifting nature on British attempts to secure peace, prosperity and revenue in the area. It posed a legal problem in terms of land revenue settlement. Highly productive soil one year might be covered in sand the next. Riparian land surveyed at the time of settlement with a river as its eastern border might be bisected, giving to a landholder's neighbour property that once was his. The shifting and flooding of the Indus valley rivers continued to have significant implications for public works efforts in irrigation, transportation, flood protection, and even schemes to re-direct rivers into channels that better suited the convenience of government. 'The training of the Indus', wrote the Superintending Engineer of Punjab Irrigation in 1912, 'is akin to that of the Canals and Embankments (in both cases a knowledge of the character of the shifting Punjab rivers is the first thing required) and the work is generally supervised by the same Engineers'.[22]

Of course, the river system did not begin its wandering ways with the arrival of the British. People had occupied the valley for millennia and developed techniques, traditions and institutions that allowed them to farm the alluvium, graze animals in the hills, trade up and down the river, and avoid the worst effects of its periodic floods. The first British officers who came to manage the country depended on their relationships with local authorities for understanding and intelligence about the unpredictable Indus. An examination of the approaches to dealing with and ascertaining the cause of floods reveals significant changes in attitude over time toward nature and local knowledge.

THE FLOODS OF 1841 AND 1858

In August of 1858 the Indus flooded catastrophically, swamping Attock, washing away much of the town of Tarbella, and undermining building foundations at Dera Ghazi Khan. With no railroad bridge across the Indus at that time, Attock and Dera Ghazi Khan were important depots linking the rest of Punjab with the Sindh Railway and with down-river navigation. It was not as large as the flood of 1841, but all authorities agreed that it was 'in other respects very similar';[23] investigations of the 1858 inundation depended largely on comparisons to accounts from that of 1841. Captain Henderson, an engineer, hoped to find the common location at which the 'obstruction' must have taken place. He was sure that there was a 'natural law' governing flooding on the Indus, the discovery of which would enable British engineers to manage the river system.

It was assumed in 1842-3 and again in 1858-9 that an avalanche of glacier or rock had fallen into the river where it went through a narrow valley or gorge forming a natural dam. The water accumulated behind the dam during the entire winter until it breached the dam and rushed down on the valley below. Henderson placed the blockage for both floods 'in the upper part of the valley of the Shayok River or northern Indus'.[24] Having visited the area in 1855, he had been 'struck with the frequency and solidity of the glaciers which occupy almost every valley in the range'.[25] He presented no evidence but felt that 'we may pronounce with almost certainty that this [the obstacle] was the sudden irruption into a comparatively narrow valley of an immense fragment of a glacier'.[26] Although he was aware of evidence that pointed to the blockage of 1841 being on the Gilgit, he 'inclined to discredit it' since he did not 'find in the map alluded to glaciers marked so far west as the River of Gilgit'.[27] The editors of the journal in which his report appeared pointed out that 'there are however glaciers in every direction and some remarkable ones'.

Regardless of what might have been the actual causes of the catastrophic floods, Henderson's investigation reveals biases that had begun to dominate in his time and profession. 'Science' was as much a vogue as an investigative method. Observations and assertions couched in the language of science acquired credibility increasingly denied to narrative or other forms. A major implication of the veneration of science and of placing scientists and engineers on a cultural pedestal of unimpeachable impartial knowledge was the ability of scientific experts to cross the line from science to pseudoscience unquestioned and undetected. Henderson certainly considered his efforts scientific. His language was cautious and imbued with the authority of an engineer – an expert of practical physics. Yet in important ways, his approach was rather unscientific, demonstrating a commitment to a particular theory despite countervailing evidence. For Henderson, a printed map held on its surface truth that was more accessible than observation. He also had a vehement contempt for the veracity of native eyewitness reports.

Henderson went to the Shayok and Nubra valleys not in search of clues as to what had caused the 1858 flood, but for confirmation of a theory about glaciers. He was impressed with the degree to which Himalayan glaciers exceeded in magnitude those of Europe. Despite significant differences between European and Himalayan glaciers that his friend had once observed with regard to colour, composition and size, he assured the readers that the Indus valley flood was similar to one that had occurred on the Drance in Switzerland in 1818. Rather than an investigation of the glaciers he supposed had broken off and caused the blockage of the Shayok, he cited universal laws that regulate the motion of glaciers. This sort of over-generalisation was typical of engineers of the time, suggesting much about the culture of imperial engineers. The same year, Sir Arthur Cotton, arguably the grand old man of British Indian Engineering, had said 'A Delta is a Delta all over the world.'

> The nature of the country is the same… the nature of the work is the same, the difficulties are the same, and the mode of overcoming them the same. The result of my inspection is that I saw exactly what I knew I would see… I wish it to be particularly observed that as respects the essential part of the question, it was not necessary that I should have any personal acquaintance with this tract. All deltas require essentially the same treatment.[28]

As Christopher Hill has pointed out, despite disagreements on particulars, engineers were 'in complete agreement' on the efficacy of copying the patterns used in Europe and the United States in regulating rivers.[29] Typical of this tendency, Henderson evinced more interest in the work of one Professor Forbes on glaciers in the Swiss Alps, than on the direct evidence given by the Syuds of Kangra who had originally warned some boatmen at Attock of both the 1841 and 1858 floods.[30]

So keen was Henderson to validate his European understanding of rivers and glaciers that he devoted considerably more than half of his report to dismissing the 'native' evidence upon which Major Becher in 1858 and Captains Abbot and Cunningham in 1842-3 had based their investigations. Regarding the 'length of time the obstacle remained', Henderson explained that 'on this head the only information to be obtained is native, and that is always vague with regard to matters of time'.[31] From this he was able to reach broad conclusions about the size of the flood, 'because the period is almost certain to have been exaggerated'. He noted that 'natives appear also to have had a dread… of entering the water on account of the number of snakes and rats which were driven from their holds as the water rose'.[32] One would suppose that people living at that particular place for generations might have valuable experience with floods and local animals. However, since 'nothing of this sort was observed at Attock' Henderson considered this an example of native fearfulness. It is clear that Henderson considered European-ness to be an important test of veracity. While he used the native origin of Cunningham's evidence to dismiss it, he confidently enlisted 'an European Patrol Officer who could speak with certainty' to argue that Henderson's water velocity calculation 'may be accepted as an accurately observed one'.[33]

Major Becher, then Deputy Commissioner in Cashmere, responded with indignation to such ready dismissal of native sources. 'A little exertion', he concluded in a letter to the Government of the Punjab, 'will generate a valuable intercourse, and dispel the ignorance and marvellous [sic] indifference which now exists, and almost peoples with 'anthropophagi' the 'upper regions' of the Indus'.[34] Like Henderson, Becher had standards by which to determine credibility. His standard, however, was compatible with the local nature of his sources. Where Henderson dismissed evidence that came in the form of 'a general warning by the Syuds of Kangra or Kangri' (he never went beyond looking at a Surveyor General's map of the Punjab to find a village named Kangri), Becher gave a great deal of credence to their original letter based on his personal relationships and detailed knowledge.

> Syud Kasim, and Syud Jumal are brothers – Syuds, generally known and respected, living at 'kalinjur' in the Jagheer of Jehandad Khan near the Indus, in Huzara. *I know them both well*, and Syud Kasim had informed me of the general report that the river was obstructed somewhere in its upper course. The letter was at once acknowledged; they had written it to their marriage relations (*whom I also know*) on the authority of Jowala – a trader of their village who had received, and read in their presence a Hindee note from his brother Khuzana of Umb (Jehandad Khan's place) informing him that he (Khuzana) had learnt from intelligence which the Khan had received, that the river was shut up in its bed, and therefore he had sent off his property for safety [emphasis added].[35]

Becher represents an attitude appropriate for a British resident in a 'native state' like Cashmere, but also more typical of a political and administrative tradition associated with the early years of British rule in the Punjab and related territories. As we already see, this approach – valuing local knowledge and dependent on personal relationships rather than science and technology – differed greatly from that of the engineers. The conflict between Major Becher and Captain Henderson can reveal to us something about the different methods of inquiry, standards of truth, and attitudes toward nature and 'natives'.

Captain Henderson rejected the suggestion that the obstruction of 1858 occurred at Gilgit primarily because it was not likely to have been the location of the 1841 blockage. He started with the assumption that all major floods on the upper Indus must have the same cause. He was not the first to do so. Captain Alexander Cunningham investigated the 1841 cataclysm and suggested a site near the head of the Shayok branch of the Indus not far from where Henderson now placed it. Cunningham also used records of earlier inundations to illuminate the one (1841) he investigated. Quoting from the report of an earlier investigator, Cunningham placed the flood of 1833 in a valley of the Shayok where a bursting of a glacier was 'well known to the people', who expected another 'terrific visitation… at no very distant period'. 'The expected cataclysm occurred in June 1841', Cunningham added, 'but it was immensely greater in volume and more devastating in its effects than the previous inundation of 1833.'[36] Cunningham made the assumption that any major flood was *the expected* flood, and that it must therefore have the same source. Following the same logic but one step further removed from any actual evidence, Henderson asserted that the next great flood, that of 1858, shared a common source with all the earlier floods.

However, he had a problem. By all accounts, the flood of 1841 was considerably greater in volume, velocity and destructive power than those of 1833 and 1858. Moreover, by all accounts the flood of 1841 had a number of qualitative differences from that of 1858. Henderson, the engineer and man of science, dealt with his problem by disparaging those accounts. One consistent element of all accounts of the 1841 flood was the extended length of time that the river was unusually low:

> It is indeed a matter of tradition that in 1841 the river became very low previous to the flood, so much so, that men used to cross it by fording above Attok, and when I was collecting information on the subject, they told me that when the bridge of boats was up in February, the river fell in one night several feet, so much in fact that they had to remove boats from either side.[37]

Such specific information could have been immensely useful. Had he cared to, Henderson could have easily converted such descriptive evidence into approximate numerical measurements which, when coupled with estimates of contemporary river volume and velocity, might have provided a reasonable estimate of the storage capacity of the valley dammed in 1841 thereby suggesting its location. But rather than consider seriously such detailed and useful information, Henderson had 'considerable doubts as to the correctness of either story', and even 'presuming them both to be amplified from a real paucity of water, [he had] still no reason to think that they had anything to do with the fact of one of the feeders of the river being dammed up some six hundred mile off'. This is to say that he discounted the evidence because it contradicted his preconceived conclusions, and it only contradicted his conclusions because he had early committed to a single explanation for the floods of 1833, 1841 and 1858. As Becher pointed out, 'Captain Cunningham describes that of 1841 as 'immensely greater in effect', which is hardly to be explained, if the cause and the position was the same in both'.[38]

Major Becher was 'impressed with the idea that a conclusion was at once drawn that the origin of all the cataclysms of the Indus was from one cause, and at one and the same point, high up among the glaciers of a tributary stream where the waters are chiefly generated by the snows'. Stating that 'this opinion was not borne out by native statements', Becher suggested that the great flood of 1841 occurred about 400 miles below the site specified by Cunningham (and later by Henderson). Moreover he was convinced that the flood was caused not by a broken off glacier in the Shayok, but by the 'arrest of the main Indus, across which a mountain called Ultoo Kunn subsided at a narrow place about four or five *coss* south of "Ghor"'. He supported this by citing the 'most exact account' of a man who saw the actual dam. He asserted the credibility of his source in terms of personal relationships ('Boota Khan, a man of Ghor, in the service of the Raja of Nuggur'). Khan said that 'some men of his village chanced to be washing in the river for gold, and were buried by the fall of the soft soiled mountain… He also saw the spot after the waters had forced their way'.[39] He then 'directed Meerza Syfodeen, the Cashmere newswriter to refer to the reports of that time written by his father, Meerza Ahud, to Sir George Clerk at Umballa; and those of April and June 1841, before and just after the event, seem to refer it to the neighbourhood of Hussoora and Gilgit'. Note the extensive references to personal relationships, but also the credence given to observations of people on the spot. Becher had no problem believing that a glacier in the Shayok caused the inundation of 1833, but he considered it 'more local and comparatively harmless', pointing out (again depending on 'native' evidence) that it was 'not even known in the plain country of Huzara, Chuch, or Attok'. Convinced by similar testimony, he thought that the 1858 flood originated on 'the Hoonza branch, *which at least affords an example that the site can vary*' [emphasis in the original].[40]

Since the native accounts all indicated that the 1841 flood was different both qualitatively and quantitatively, suggesting a different damming site, Henderson had to commit to denigrating their credibility or admit the possibility of multiple sites. The 'prominent part of the tradition that the water was much warmer than usual; as if the snow-supply had been cut off', he thought 'as improbable as the other circumstances narrated'. This warmer water would have indicated a dam much farther down the Indus than he was willing to countenance – after all, he was certain of the glacial origin of the 1858 flood, high up the Shayok branch. Rather than explain why this observation was improbable, he '[illustrated] the probability of their being exaggerated into falsity' by showing this tendency with regard to another phenomenon universally insisted on by native informants. 'All accounts of the flood of 1841 particularize the wave or wall which swept down the channel of the river, and the noise occasioned by it, which was the first harbinger of the approaching destruction.' He even referred to the eyewitness account by Ushruff Khan as reported by Capt. Abbot with which we are familiar. Henderson then delivered what he must have considered the *coup de grace* to the corpse of 'native' evidence. He was 'on this last occasion [1858] on the river in row boat, which a wave one foot high would doubtless have swamped, but wave there was none, nor any noise either, nor any appearance of carcasses or any thing of the kind'.[41] One would think that this provided certainty of the dramatic differences between the floods of 1841 and 1858, but for Henderson, considering the unity of causes a given, this proved that his observations simply trumped those of 'natives'.

In short Henderson's argument went like this: Based on scientific theories established in Europe, Henderson's assumptions led to inevitable conclusions about the cause of all floods on the upper Indus; native evidence contradicting his assumptions was false because natives had a tendency to lie (he never suggests their motivation); he could demonstrate their tendency to lie by showing that their evidence was false; it was false because it was incompatible with his conclusions; his conclusions were true because they were based on established European scientific theories and the unimpeachable precision of the European engineer's powers of observation; these conclusions were incontrovertible except by eye-witness accounts, which, coming from 'natives' could not be trusted. He could get away with this sort of circular logic because it was dressed up in the style of science and deference due him as an engineer and European.

There does not appear to be a formal and final resolution to the dispute, but it is clear that Henderson's position made the transition from competing theory to undisputed fact during the ensuing two decades. Other sources on Indus flooding from the period cite Henderson exclusively, or, more often, leave a similar description of the causes of flooding uncited and unquestioned.[42] The 1893-97 edition of the Gazetteer of the Dera Ghazi Khan District embraces Henderson's single cause and location thesis, when discussing the 1857 flood. 'Great floods occurred in 1812 and 1833 A.D., and again in A.D. 1841, when a lake pent up by the fall of a glacier in the far Himalayas broke loose and poured down the Indus.'[43] Speculation – founded on Europe-based theories, buttressed by pseudoscientific method, enforced by contempt for local knowledge, but presented by an engineer versed in 'universal principles' – had become fact.

My intention here has not been to re-open a trivial debate about a series of floods from long ago. I think that it has been important to show the value of local knowledge, the aptness of 'non-scientific' observations, and to characterise the 'engineering paradigm' that was coming to dominance. However, Becher, Henderson, Abbot, Cunningham, and the governments of the Punjab and India did not engage in these investigations out of pure intellectual curiosity. Hydrological control had long been an important component of political control in the region. Understanding the cause of flooding in the lands they had so lately come to rule, they assumed, was the first step in devising a means to control them. How better to earn the gratitude and loyalty of a local population threatened by floods and dependent on the river water for survival than to predict and prevent catastrophic floods, to insure regular navigation (and hence inter-regional commerce dependent on British steamers), and to divert the river's inundations for agricultural purposes? The insistence on a single cause for Indus floods may have been a case of wishful thinking. Some proposed to arrange to remove the 'obstacle' in future accidental damming incidents, by 'our scientific efforts'.[44] Keep in mind that this was long before those scientific efforts involved the use of technology like the steamshovel, so such a proposal implied a tremendous mobilisation of manpower in a sparsely populated part of the Indian Empire. Becher, at least, considered the idea 'impracticable'.[45]

We should not imagine that people living along the Indus watershed had no means of dealing with floods. There is evidence of pre-British systems of embankments and diversions at many sites along the Indus, Ravi and Sutlej.[46] However, the persistent erosive and avulsive force of the Indus rivers has always limited the longevity and usefulness of such works.[47] Moreover, embankments may protect towns and villages, but they also deny fields the fertilising silt and moisture of the annual inundations. Native institutions – both formal and informal – had developed other ways of dealing with floods that, although perhaps only motivated by technological impotence, involved an implicit respect for and deference to the power of the river.

The chief approach for avoiding the negative impacts of flooding was avoiding the floodwaters. The banks of certain parts of the Indus known for particularly devastating or frequent flooding were 'not enlivened with villages, as they are higher up… and cannot be seen from the river'.[48] The large town of Tatta, though 'it may be said to be situated on [the river's] bank', was actually four miles away.[49] The lack of embankments or 'bunder corresponding to its size and commercial importance' perplexed one British observer in the early 1830s.[50] Dera Ghazi Khan once had to 'throw down' the defensive wall that surrounded the town in order to keep the water out.[51] Thereafter, the town was moved about four miles from the river.[52] Burton noted that 'most villages could be razed to the ground, transported to the requisite distance, and re-erected in a week, at an expense of probably a couple of rupees per house'.[53] This gives some idea as to the general mobility of towns along the Indus.

People were similarly mobile. Cultivation was restricted to a 3 to 15 mile wide strip on either side of the River. During the *rabi*, almost every alluvial or *hithar* acre was brought under cultivation without any need for irrigation. Jangli cultivators also arranged temporary systems of dams, channels and embankments to irrigate the *nakka* portion of the cultivation zone lying outside the area fertilised by inundations.[54] They grew a wide array of crops that ripened at different rates, required different levels of irrigation, or complemented each other in the growing season.[55] During the extremes of flood and dry, these same Janglis engaged in semi-nomadic pastoralism well suited to the sparse vegetation of the *doabs*.[56] While this ran counter to the British interest in consistent revenue assessments and settlement that lay behind most perennial irrigation schemes[57], the workability of the system for the Janglis themselves was apparent to some British observers.[58] Close embanking of the Indus may have protected irrigated fields and garrison towns, but it contributed to the decline of *sailab* cultivation in western Punjab.

Perhaps the most important flood avoidance technology was a social technology of communication. People living high up in the mountains communicated regularly to those downstream about the likelihood of flooding. Due to the multiple possible causes of floods, the only viable strategy for prediction was for those residing near the site of a natural dam (whether caused by landslide, glacier, or avalanche) to warn villages farther downstream and keep them apprised of the condition of the blockage. Traders, herders, doctors, newswriters and teachers formed a communication network linking villages and towns up and down the Indus and its tributaries and carried these warnings along with other news. The authenticity of these warnings depended on the social technology of relationships; kinship, clan connections and positions of respect leant credibility and urgency to the warnings.[59] C.A. Bayly's study of networks of surveillance, communication and information control in pre-British India emphasises implications for the political power of rulers,[60] but these networks and the shift to an increasingly 'literacy aware society'[61] may have also had an important application to environmental practice – if not actual policy. Indeed, because of the high levels of literacy recorded by European observers in the Himalayan hill states and Sikh Punjab, the use of written warnings were likely well established up and down the Indus.[62]

An example of this comes from the floods of 1841 and 1858. The primary sources of evidence used by the various British investigators were warnings sent by those above or near the blockage to those below. In 1858, the Syuds Kasim and Jumal sent warning to the head boatmen at Attock. This was not the only source of warning. A trader in Huzara read a 'Hindee note' from a Raja unknown to him that 'two tributaries of the Indus were closed high up the river'.[63] There were probably several indications of authenticity for flood warnings. One of these was writing on the bark of the birch tree. In 1840-41, 'Raja Kureem Khan of Gilgit sent a warning written on bark to the inhabitants of the plains, the bark being used to convey greater credit... It conjured all men, Hindoo and Musulman, to fly from the river's side.'[64] Some British officials were perfectly willing to rely on this type of device. Reacting to the letter from Syud Kasim, Becher made the warning 'generally known to all the villages of Huzara on the Indus, telling them to be on their guard and to make what arrangements they thought best … scarcely any loss occurred to property and none to life'.[65] In this Becher exemplifies the local-knowledge orientation of generalist administrators of the old 'Punjab school of administration'.[66]

How different this is from the engineering approach typified by Henderson! We might ask ourselves why the engineering paradigm so thoroughly overwhelmed the generalist and traditional approaches. After all, warnings were comparatively cheap and could be assured through relatively simple arrangements between government agents and local authorities. Embankments and river training diversions required unprecedented expenditure and technological expertise that never sufficiently developed until the 1930s. Prediction was even farther away – the science of meteorology would take many a wrong turn in the century following the 1858 flood, and even with our current understanding of such complex phenomena as El Niño–Southern Oscillation events we lack the predictive component. Why did the British have such confidence that science would supply in time the necessary techniques? Why, moreover, did they consider such an investment in dubious technology preferable to developing and expanding more adaptive systems?

The answer has a lot to do with the culture of science that rose to absolute prominence in the second half of the nineteenth century. Science had transformed the unknown into the yet-to-be-known.[67] British technological superiority not only enabled British rule over non-Europeans but provided an ideological legitimisation for it as well.[68] In addition, the British preference for settled agriculture was incompatible with a system that respects the vagaries of a river like the Indus. The flexibility and mobility necessary for a system of dealing with flooding by forewarning and evacuation implies a mixed economy typical of *sailaba* agriculture and the nomadic pastoralism of the Janglis and others.

Even in the sub-field of engineering concerned with flood protection and river training, we can discern an ideological arc, as the invasive and mechanistic approach of engineering rose from being one among a few approaches to a position of absolute dominance – from caution to confidence. There is a self-reinforcing mechanism in all of this – ideological path dependence. Once the British made the initial commitment to an engineering approach to the mastery of nature and people of the Indus basin, there was little opportunity to turn back.

RIVER TAMING AT DERA GHAZI KHAN

Flood control by embankments, diversions and other physical barrier methods remained a chief concern of engineers in the Indus valley. The town of Dera Ghazi Khan provides a case in point. What follows is a tale of a constant fight against the river. The town was important to the British as a seat of government. It held a cantonment and a garrison of infantry and cavalry. It served as a base during the Afghan wars and was a transhipment point for both river and railroad cargo. It was the administrative frontier.

In 1857-8 the Indus was more than three miles to the east of the city walls, but the flood that year[69] came down an auxiliary depression (the Jalpa) and washed away the cantonment and civil station, villages, cattle and crops.[70] The Punjab engineering department constructed an embankment the following year that held until 1878. By 1882, the Indus had drifted to within a mile of the town and overwhelmed another set of embankments. After yet another flood in 1888 in which the town of Mithankot was 'laid bare by the river',[71] the Punjab government realised the seriousness of Dera Ghazi Khan's situation.[72]

The embankment built to protect the city was cleverly designed to be self-replacing in a dynamic relationship with the erosive force of the river; but the river, ever capricious, avoided contact with the 5,221-foot embankment until

1895. In 1900, the river, cutting deeply to the west, washed away the embankment and the four spurs constructed in 1896 to protect it.[73] In 1901, following Viceroy Lord Curzon's visit, the engineers proposed to close the western stream of the Indus above Dera Ghazi Khan using 'hurdle dykes'. These were designed not to stop the flow of the water 'but to obstruct it so much that silt would deposit, the channel become choked up and the water find a course elsewhere'.[74] Begun in March 1902, work on the 'hurdle dykes' came to an abrupt halt in May, when an early flood carried away the first two dykes.

Few proposals illustrate better the mentality of Punjab's British Engineering division or the irony of their position than the proposal of 1910 to create an embankment of trees. Foresters, naturalists, botanists and some civil authorities had long extolled the virtues of trees in combating erosion on vulnerable hillsides.[75] It was only a matter of time until the engineers found a way to 'improve' on these natural processes. In 1892 it was suggested that 'trees *with their roots upwards*' [emphasis added] be laid along the river bank where they could accumulate 'a berm of tenacious silt'. Not surprisingly, the project failed.[76] This was not the end of proposals to use trees, not as parts of a natural system but as growing engineering material. The superintending Engineer of the Punjab irrigation department proposed to grow two belts of trees parallel to the river. Belasis suggested, 'Let anyone walking down an avenue of full-grown trees, 40 or 50 feet high, with great spreading branches, take note of them and consider what river could move a row of them *when chained to the other standing row* [emphasis added] or could continue to erode a bank which was lined with them.'[77]

Despite this series of increasingly invasive (and ambitious) engineering attempts at protective flood control, eventually the whole town of Dera Ghazi Khan had to be relocated.[78] It might have been cheaper and easier to have moved the town first and let the river have its way. In fact this more cautious approach was proposed in 1849 as a general principle for working with drifting and frequently flooding tropical rivers like the Indus.[79] Recognising the tendency of such rivers to oscillate, Cunningham, a political resident in Sindh, suggested a system of double embankments that allowed the river to do so while protecting only the most important land.[80] Close embanking of rivers had major drawbacks, he argued. Such embankments denied some agricultural land the water and silt necessary to sustain production. By forcing floodwaters into a narrow channel and thus to carry sediment farther down steam, 'embankments modify the tendency of rivers to raise their beds', making catastrophic floods and changes of course an inevitability.[81]

As we have seen with the case of Dera Ghazi Khan, such a policy, with its implicit deference to the tremendous kinetic energy of the river, never gained favour. This does not mean that extreme climatic events and the extreme vagaries of tropical rivers never re-opened the question. However, suggestions, in the first decade of the twentieth century, that perhaps close embanking might be causing more harm than good, provoked a vehement defence from professional engineers couched in terms of the vastness of their expertise. Their branch of the Indian civil service had by then achieved an intellectual hegemony.

THE CULTURE OF CIVIL ENGINEERING IN INDIA

Over the course of the second half of the nineteenth century, the community of hydraulic engineers in India transformed itself from a hodgepodge of military and civilian amateurs into a professional corps with its own bureaucracy, esprit de corps and training colleges. While engineers in India at mid-century usually learned their trade on the job, they often stayed to manage and expand public works in one region or on one river system. In this way, like other generalists of the time, they developed local relationships and a feel for the specific qualities of the river systems and people with whom they worked. By the end of the century, engineers were typically brought in to solve particular engineering problems and design works, staying only long enough to see a project begun before moving on to other assignments.

A prominent example of the earlier engineers was Sir Proby Cautley, the "father of the perennial canal system in northern India", who had come to the subcontinent in 1819 as a young artillery officer. He got into canal engineering by luck and necessity.[82] Thus, as Brown has observed, 'much of the engineering depended on knowledge gained empirically'. In this respect, Cautley was typical of British engineers in general. Before the establishment of a Department of Public Works in 1854, hydraulic engineering was carried out by military personnel under the control of the Military board at Fort William.[83] Cautley's assistants and collaborators in his work on the Ganges Canal, including Robert Smith, Robert Napier and Richard Strachey, were all army officers who later formed the core of the British engineering establishment of the Raj.[84] After retiring to England, Cautley continued to advise on Indian engineering projects and engaged in a protracted dispute with Sir Arthur Cotton, known as the 'father of Indian engineering' for his work on irrigation and flood control in Madras.[85]

Unlike the state-sponsored engineering training in France and Germany, Britain had no tradition of providing academic training to engineers outside of the military. British engineers were generally self-taught through formal and informal apprenticeship in British industries or in the course of constructing public works in India.[86] The Census of 1841 did not even include engineering as a profession.[87] Even as late as 1869, the idea of a college for engineering with its implicit emphasis on mathematics and theory was 'utterly abhorrent' to many British civil engineers.[88] In this, they held attitudes similar to those of other 'rough and ready' generalists (especially in Punjab), who operated based on personal relationships, local experience, and 'rule of thumb' principles.[89]

Although they had very limited formal training themselves (at Addiscombe Military Seminary and not specifically in engineering), Cotton and Cautley both pushed for the creation of civil engineering colleges to assure the supply of properly trained personnel. Roorkee College of Engineering opened in 1848, soon followed by three others at Calcutta, Madras and Poona.[90] They were intended to attract young men from Britain, but primarily ended up training local talent whose skills were mainly employed in maintenance and operation of public works.[91]

In 1870, the Royal Engineers established a special training college at Coopers Hill, near Windsor, for recruits intending to go to India. Although the college closed in 1906, for about thirty-five years Coopers Hill training dominated Indian engineering and was evident in the subsequent training of engineers from the four Indian engineering colleges.[92] Even after 1907, the Public Works Department adhered to a discriminatory recruitment policy, importing its senior engineers from Britain.[93] One idea that featured prominently in the Coopers Hill training was the universality of engineering principles. A textbook used at the college employed examples from Europe, America, India and elsewhere to illustrate through repetition the application of the same calculations.[94]

Engineers commonly solved problems on one river system by analogy to other rivers. Embankment strategies might be tested on one westward drifting river such as the Kosi in Bihar province. Edward Bellasis, a product of Coopers Hill who played a major role in designing flood protections for Dera Ghazi Khan, also worked extensively on embankments and canals on Punjab and other North Indian rivers. In his treatise on river and canal engineering (a standard work in the field for two decades), Bellasis routinely compared engineering problems on these and other South Asian river systems.[95] Because of the universalising tendency emphasised in the training engineers increasingly shared, their tendency to apply technological solutions from one river system to another, and the fact that individual engineers worked on many different projects and rivers in many regions of India, arguments about a superficially similar river would have resonated for engineers on the Indus. The following example relating to the Kosi River illustrates the cultural dominance of the engineering paradigm that prevailed throughout India. It also reveals some of the misgivings about imposing technological control over nature that arose around the turn of the century – confirming the chronology and character of western thinking about technology that Michael Adas describes.[96]

DISSENT OVER CLOSE EMBANKING

Disturbed by rising flood levels on the Kosi River that seemed a direct correlation of increased embanking, one commentator, Captain F.C. Hirst, suggested that ‘the natural inference is that the embankment is to blame for increases in floods under most circumstances’.[97] He argued that ‘embankments designed to keep every drop of flood water from protected lands are inadvisable’.[98] ‘An embankment', he wrote, 'with little or no waterway through it for the carrying off of flood waters, is a glove thrown in nature's face – an insult which she has not yet been known to leave unavenged'.[99] However, if the design of embankments permitted 'certain flood waters to wander over protected areas, those embankments may be of use, and nature may, not unreasonably, show no resentment to their growth'.[100]

W.A. Inglis, of the Bengal Engineers, responded with a fundamentally opposing sense of the human role in modifying nature – that as long as it was done 'scientifically' it was a positive good.

> It is, no doubt, the case that we can do nothing to control or alter the action of the great natural forces. We cannot cause the rain to fall, or the sun to shine, or the wind to blow. We can, however, and we do every day, interfere with and modify the operations of Nature. Every field that is ploughed and sown with corn is such an interference. We have, by selection and crossbreeding, modified very many plants and animals. We construct reservoirs to store water and we abstract water from streams and apply it to the irrigation of land without any regard to the apparent intention of Nature. We protect the banks of rivers from natural erosion and we dredge up sand and mud from places in which Nature intended it to remain.[101]

This remarkably perceptive assessment of the magnitude and pervasiveness of anthropogenic nature showed no hint of ambivalence. It had become easy for hydrological engineers to justify their activities on their own terms because their terms had become the default mental point of reference for consideration of human activities in managing nature.

Captain Hirst was not the only one who realised that close embanking on the Kosi left floodwaters too little room and that something would have to give. 'There were great armies of *lathials*[102] to guard the *bandhs* on each side of the Kosi, to make sure that no one from the other side would break the *bandh* on your side to cause flooding when the river rose.'[103] Since it was clear to the local inhabitants that the Kosi would breach its embankments, they had to engage in a difficult moral calculus to insure that the flood swept away someone else's village. Residents along the Indus may have engaged in a similar moral calculus. Belasis noted 'numerous cases have occurred in which new embankments have been breached with such regularity that it seems certain they were cut'.[104] Nonetheless, warnings from the likes of Hirst (not to mention the persistent wrecking activities of 'natives') were not heeded, and the engineering department continued to build, and rebuild, close embankments on the Ravi, Jhelum, Chenab, Sutlej, Beas and Indus, as well as the Kosi.

A problem with embankments has always been that while they may protect some land and communities from devastating floods, they more regularly deprive alluvial (or *sailaba*) land of the nutrients and water on which they depend. Indeed, hydrological engineers were fully aware of the conflict.

> An embankment may shut off the floods from land which has hitherto benefited from

> them and the people may prefer the old arrangement to the new. A single rabi crop in the year (the rabi is generally the more valuable crop), with freedom from canal assessments, may suit them best.[105]

Generally, embankments did not benefit the majority of older, established villages, which were 'usually placed on high ground or protected by local ring embankments'. Given the negative effects on riparian cultivation and the increased violence and volume of those floods that breached the embankments on their own, there may have been 'a temptation for the people to cut the embankment, an extremely easy operation because the men who watch it can be evaded or bribed'.[106] The Talai embankment in the Dera Ghazi Khan District, for example, which was constructed in 1903, 'breached every year for the first five years after construction'. Belasis noted, '[m]ost of the landowners affected do not seem to have gained by the breaching (though they did not lose much, if anything), but probably some of them gained and they may have caused the breaches'.[107] No matter how many embankments the British engineers built, either the local people or the rivers themselves conspired to cut them, breach them, circumvent them, or wash them away.

It is not my intention to argue that embankments cause floods (nor was it Hirst's, though Inglis lambasted him for it). They can exacerbate the violence and size of floods that do manage to breach the embankments. Embankments represent an attempt to control, to manage and to tame nature. They were integral to the British self-conception as legitimate rulers of volatile, and at times, unpredictable environment and society. Beyond that, however, embankments enabled the British to settle people on the land. Throughout the twentieth century, British commentators on the recurring flood damage to towns on the Mississippi suggested that Americans had it all wrong; instead of finding ways to keep the river away from the people, they should have worked on keeping the people away from the river. Yet, in the Indus Basin under colonial rule this very remedy would have been directly antagonistic to the basic drive of British settlement policy.

One possible explanation for the tendency of engineers to dismiss reasonable questions about the efficacy of engineered river systems might be the political pressures on them to satisfy the state's need to stabilise its revenue (and thus reduce annual variability in land productiveness).[108] The political imperatives deriving from settlement and revenue concerns had an important impact on the actions of the colonial state in dealing with the wildly shifting Kosi, its transformations of the landscape, and the people living in the Purnea district in Bihar, as Christopher Hill has explored in depth.[109] These considerations probably had even greater impact on the development of extensive irrigation systems in Punjab, where the state developed multiple and sometimes contradictory purposes for the Canal Colonies.[110] The need to stabilise revenue certainly was an incentive to move toward perennial irrigation, but it may have had less of an impact on decisions relating to close embanking of shifting rivers. Nonetheless, the technological ideology of dominance that underlay the engineering paradigm enabled and even required the vehement defence of technological solutions and engineering as a profession and cultural identity.[111]

There were, of course, other approaches to flood control available. One, proposed by Hirst, would have imitated (on a small scale and higher up the river) the land forming processes that alluvial rivers perform closer to their deltas.[112] The proposal was based on a system used extensively by local agriculturalists on the 'hill torrents' in the Dera Ghazi Khan district[113] and in Chota Nagpur. Hirst argued that 'from the methods of an Indian race only half emerged from savagery, we may learn at any rate some of the elements of one system which is perhaps applicable to the mitigating of the evil-doing of the Kosi River'.[114] Hirst demonstrates well the internal conflict between respect for native institutions and ingenuity and self-conscious racism.

Equally interesting is Inglis's dismissal of the technique, which reveals something about the culture in which Inglis operated. 'There is nothing novel in this system', he wrote. He pointed to examples of the system in England and Egypt and speculated on the likelihood of its application in Bengal. Then, perhaps for the sake of absurdity, he points out that 'Nature is, of course, acting in this manner on an enormous scale in the delta of the combined Ganges and Brahmaputra, and is constantly forming, removing and again reforming land'.[115] While this would seem to be an argument for the technique (it imitates the working of nature and has already been successfully adopted in a variety of climates), for Inglis this served as an indictment of the technique as un-innovative, and contributing to neither an improvement of nature nor native practices.

My point here is not to argue that Hirst's proposal would have been an appropriate technology for managing floods, or that Inglis was wrong to oppose it (although his blanket defence of close embankments did not turn out to hold water). What we see, instead, is the sort of argument that could be considered reasonable and endowed with a certain validity when mustered by a professional engineer, that had very little to do with the engineering question at hand. The subtext of his rebuttal, I believe, was that to learn from nature or natives was to abdicate the responsibility of European engineers to 'improve the world' and represented an assault on the legitimacy of their enterprise and methods.

Inglis, Belasis, Henderson and the other engineers whose common mental framework came to dominate flood control policy in British India were well aware of the failures of the engineering paradigm. Belasis' book is a litany of mishaps and engineering miscalculations. They were confident enough to concede that there were complex unsolved engineering problems, and to learn from failures. However, they never seem to have considered – at least in writing – the possibility that engineering could *be* the problem.

This article has described a generational transition from the dominance of generalists, who emphasised local relationships and knowledge gained from local experience, to a generation of specialists who emphasised universal engineering principles. This 'epistemic community'[116] of engineers and other civil servants in British India gained cultural dominance, thereby providing the problem frame[117] that determined the direction of flood control and other environmental management policy. While I have emphasised ideas linking European technological prowess with legitimacy, other economic and political considerations, such as revenue stabilisation, were important parts of the shared framework. We have seen the rise of the engineering paradigm over the course of the latter half of the nineteenth century, the positions of some of its critics, and some of the types of impact that it had on choices in flood management in the Indus basin. Further research should do more to expose the historical causes of this shift, and place it in a broader global context of flood management and other engineering regimes.

NOTES

[1] Capt. J. Abbot, 'Inundation of the Indus, Taken from the Lips of an Eye-Witness A.D. 1842', *Journal of the Asiatic Society of Bengal* 17 (1848): 230.

[2] For one thing, the river weakened Raja Gulab Singh's army: 'As a woman with a wet towel sweeps away a legion of ants, so the river blotted out the army of the Raja.' Thus helping to keep the Sikhs in disarray leading to British victory in the first Sikh War, and leaving the Amirs of Sindh without a strong northern ally facilitating the annexation of Sindh less than two years later. Ibid.

[3] Certainly, other rivers in India were similar. The Kosi was at least as violent and shifting in nature, but it was not as large. It was also not in as politically important a country. The Mahanadi was as prone to flood. The Brahmaputra meandered as slowly as the Indus at its end, both depositing a wide alluvial fan at their respective deltas. On the Mahanadi see: Christopher V. Hill, 'Ideology and Public Works: 'Managing' the Mahanadi River in Colonial North India', *Capitalism, Nature, Socialism* 6 (1995). On the Kosi see: Christopher V. Hill, *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994*, *Monograph and Occasional Paper Series; 55* (Ann Arbor, MI: Association for Asian Studies, 1997).

[4] 'Techno-chauvinism' is the tendency to prefer technological solutions to problems over other possible solutions.

[5] 'Technological optimism' is the belief, related to techno-chauvinism, that technical problems can be solved with better technology – in essence that all problems are engineering problems that are ultimately solvable. This is slightly different from the usage, current among neoclassical economists, that is a belief that the market will bring forth technological solutions to perceived and predicted problems.

[6] Thomas R. Metcalf, *Ideologies of the Raj*, ed. Gordon Johnson, *The New Cambridge History of India* (Cambridge: Cambridge University Press, 1995).

[7] Michael Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance*, ed. George Fredrickson and Theda Skocpol, *Cornell Studies in Comparative History* (Ithaca: Cornell University Press, 1989).

[8] David Gilmartin, 'The Irrigating Public: The State and Local Management in Colonial Irrigation', in *State, Society and the Environment in South Asia*, ed. Stig Toft Madsen (Richmond, Surrey: Curzon, 1999).

[9] Hill, *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994*, 1.

[10] Karl August Wittfogel, *Oriental Despotism: A Comparative Study of Total Power* (New Haven: Yale University Press, 1957).

[11] Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West*, 1st ed. (New York: Pantheon Books, 1985), 7.

[12] David Gilmartin, 'Scientific Empire and Imperial Science: Colonialism and Irrigation Technology in the Indus Basin', *Journal of Asian Studies* 53, no. 4, (1994): 1141.

[13] Gilmartin, 'The Irrigating Public: The State and Local Management in Colonial Irrigation.', David Gilmartin, 'Models of the Hydraulic Environment: Colonial Irrigation, State Power and Community in the Indus Basin', in *Nature, Culture, Imperialism*, ed. David Arnold and Ramachandra Guha (Delhi: Oxford University Press, 1995), Gilmartin, 'Scientific Empire and Imperial Science: Colonialism and Irrigation Technology in the Indus Basin.', Ian Stone, *Canal Irrigation in British India : Perspectives on Technological Change in a Peasant Economy*, vol. 29, *Cambridge South Asian Studies* (Cambridge; New York: Cambridge University Press, 1984), Elizabeth Whitcombe, 'The Environmental Costs of Irrigation', in *Nature, Culture, Imperialism*, ed. David Arnold and Ramachandra Guha, *Studies in Social Ecology and Environmental History* (Delhi: Oxford University Press, 1995), Elizabeth Whitcombe, 'Irrigation', in *The Cambridge Economic History of India*, ed. Dharma Kumar and Desai Meghnad (New York: Cambridge University Press, 1982). To my knowledge, the only history of flood control on the Indus is a rather cursory and simplistic treatment in an Indian government publication: India. Central Board of Irrigation and Power, *History of Irrigation in Indus Basin* (New Delhi: Central Board of Irrigation and Power, 1992). Christopher Hill's work on flood control and legal implication on the Kosi and Mahanadi Rivers is an important exception. Hill, 'Ideology and Public Works: 'Managing' the Mahanadi River in Colonial North India.', Hill, *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994,* Christopher V. Hill, 'Water and Power: Riparian Legislation and Agrarian Control in Colonial Bengal', *Environmental History Review* 14, no. 2 (1990).

[14] James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998), 6.

[15] Ibid., 2.

[16] Richard Francis Burton, *Sindh and the Races That Inhabit the Valley of the Indus* (Karachi, New York,: Oxford University Press (Reprint of the 1851 ed. published by W. H. Allen, London.), 1973), 10.

[17] Thomas Postans, *Personal Observations on Sindh: The Manners and Customs of Its Inhabitants and Its Productive Capabilities; with a Sketch of Its History, a Narrative of Recent Events, and an Account of the Connection of the British Government with That Country to the Present Period* (Karachi: Indus Publications (Originally published in 1843: Longman Brown Green and Longmans), 1973), 17.

[18] Ibid.

[19] Ibid., 18.

[20] Burton, *Sindh and the Races That Inhabit the Valley of the Indus*, 35.

[21] See for example Malcolm Robert Haig, *The Indus Delta Country: A Memoir, Chiefly on Its Ancient Geography and History, with Three Maps* (Karachi: Indus Publications (Originally published1894), 1972).

[22] Edward Skelton Bellasis, *Punjab Rivers and Works. A Description of the Shifting Rivers of the Punjab Plains and of Works on Them, Namely, Inundant on Canals, Flood Embankments and River Training Works, with the Principles for Designing and Working Them* (London: E. & F.N. Spon, 1912), preface.

[23] W Henderson, 'Memorandum on the Nature and Effects of the Flooding of the Indus on 10th August, 1858, as Ascertained at Attock and Its Neighbourhood', *Journal of the Asiatic Society of Bengal* 28, no. 3 (1859).

[24] Ibid.: 199.

[25] Ibid.

[26] Ibid.: 201.

[27] Ibid.: 201–2.

[28] Col. Arthur T. Cotton, Speech to the Bengal Chamber of Commerce, 15 June 1858; Cotton, 'Memorandum on The Lower Part of the Mahanuddy River in Orissa', 11 May 1858. Bengal Public Works Proceedings, Vol. P/16/33, January to February 1859. India Office Library and Records, London : Cited in Hill, 'Ideology and Public Works: 'Managing' the Mahanadi River in Colonial North India', 51.

[29] Ibid.: 54 et passim.

[30] Henderson, 'The Flooding of the Indus', 199,202. Syuds are local religious teachers and mystics, often claiming a direct line of descent from the prophet Mohammed, with high social standing but often without much wealth in land-holdings. See Hamida Khuhro, *The Making of Modern Sindh: British Policy and Social Change in the Nineteenth Century*, 2nd ed. (Oxford: Oxford University Press, 1999).

[31] Henderson, 'The Flooding of the Indus', 202.

[32] Ibid.: 218.

[33] Ibid.: 207.

[34] Major J. Becher, 'Letter Addressed to R.H. Davies, Esquire, Secretary to the Government of the Punjab and Its Dependencies', *Journal of the Asiatic Society of Bengal* 28, no. 3 (1859): 228.

[35] Ibid.: 220.

[36] Quoted by Ibid.: 225.

[37] Henderson, 'The Flooding of the Indus', 204.

[38] Becher, 'Letter to R.H Davies', 227.

[39] Ibid.: 226.

[40] Ibid.: 227.

[41] Henderson, 'The Flooding of the Indus', 204–5.

[42] e.g., Hugh Kennedy Trevaskis, *The Land of the Five Rivers; an Economic History of the Punjab from the Earliest Times to the Year of Grace 1890* (London: Oxford University press, 1928), 293.

[43] Punjab Government, 'Gazetteer of the Dera Ghazi Khan District. Revised Edition, 1893–97', (Lahore: 'Civil and Military Gazette' Press, 1898), 6–7.

[44] Becher, 'Letter to R.H Davies', 224.

[45] Ibid.

[46] Henry Pottinger, *Travels in Beloochistan and Sinde; Accompanied by a Geographical and Historical Account of Those Countries* (London: Longman Hurst Rees Orme and Brown, 1816), 344.

[47] Ibid, John Wood, 'Report on the River Indus by the Late Lieutenant John Wood, Indian Navy. 1838', in *Selections from the Records of the Bombay Government Part II*, ed. R. Hughes Thomas, Assistant Secretary, Political Department (Bombay: Bombay Education Society's Press, 1855), 575.

[48] J.F. Heddle, 'Memoir on the River Indus by the Late Assistant Surgeon J. F. Heddle, Bombay Medical Establishment. 1836', in *Selections from the Records of the Bombay Government Part II*, ed. R. Hughes Thomas, Assistant Secretary, Political Department (Bombay: Bombay Education Society's Press, 1855), 422.

[49] Ibid.

[50] Ibid.

[51] This was probably during the flood of 1819, as it was during the Governorship of Jubbar (Jabar) Khan. Wood, 'Report on the River Indus by the Late Lieutenant John Wood, Indian Navy. 1838', 575..

[52] Ibid.

[53] Burton, *Sindh and the Races That Inhabit the Valley of the Indus*, 39.

[54] Indu Agnihotri, 'Ecology, Land Use and Colonisation: The Canal Colonies of Punjab', *The Indian Economic and Social History Reveiw* 33, no. 1 (1996): 40.

[55] Himadri Banerjee, *Agrarian Society of the Punjab, 1849–1901* (New Delhi: Manohar, 1982), 67.

[56] Ibid.

[57] Agnihotri, 'Ecology, Land Use and Colonisation: The Canal Colonies of Punjab.', Imran Ali, *The Punjab under Imperialism, 1885–1947* (Princeton, N.J.: Princeton University Press, 1988), Neeladri Bhattacharya, 'Colonial State and Agrarian Society', in *The Making of Agrarian Policy in British India 1770–1900*, ed. Burton Stein, *Oxford in India Readings, Themes in Indian History* (Delhi: Oxford University Press, 1992).

[58] Mongomery, Lt. Col., *Settlement Report, Montgomery*, 1892–9: 4; Septimius Smet Thorburn, *Musalmans and Money-Lenders in the Punjab* (Edinburgh: W. Blackwood, 1886), 283.

[59] For the Punjab and the Northwestern Frontier Provinces, this system is described in some detail (in the context of creating Christian evangelical networks) by Herbert B. Edwardes, *A Year on the Punjab Frontier, in 1848–49*, 2nd ed., 2 vols. (London: R. Bentley, 1851), 436–8.

[60] C. A. Bayly, *Empire and Information: Intelligence Gathering and Social Communication in India, 1780–1870* (Cambridge, England ; New York: Cambridge University Press, 1996), 10–55.

[61] Ibid., 39.

[62] Ibid., 37.

[63] Becher, 'Letter to R.H Davies', 220.

[64] Ibid.: 221. Presumably, this indicated the veracity of the origin of the note since the particular species of birch could be found higher up in the valleys of Kashmir.

[65] Ibid.: 220fn.

[66] For discussions of the 'Punjab school' see: Banerjee, *Agrarian Society of the Punjab, 1849–1901,* N.M. Khilnani, *British Power in the Punjab 1839–1858* (New York: Asia Publishing House, 1972), P. H. M. Van den Dungen, *The Punjab Tradition; Influence and Authority in Nineteenth-Century India* (London: Allen & Unwin, 1972).

[67] The phrase comes from Wendell Berry, *Life Is a Miracle: An Essay against Modern Superstition* (Washington, DC: Counterpoint, 2000), 36–7.

[68] Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance*.

[69] The Gazetteer puts it at 1856, but this is clearly a mistake as all other sources, especially contemporary ones, place it at 1858.

[70] Punjab Government, 'Gazetteer of the Dera Ghazi Khan District. Revised Edition, 1893–97', 7.

[71] 'The whole of the garrison and all the available population of Dera Ghazi Khan town and neighbourhood were only able to keep the river flood out by constant work on the inner chain of embankments.' Ibid.

[72] Bellasis, *Punjab Rivers and Works*, 34.

[73] Ibid.

[74] Ibid., 35.

[75] See for example: B. H. Baden-Powell, 'Note on the Demarcation of the Forest Area in Districts Containing Hill or Mountain Ranges', *The Indian Forester* 2, no. 3 (1877).

[76] Bellasis, *Punjab Rivers and Works*, 39.

[77] Ibid.

[78] The new town was founded in 1911 after as series of floods washed most of the old town away. Government of India, 'Reports of the Census of India 1911', (Lahore: Civil and Military Gazette Press, 1912).

[79] J.D. Cunningham, 'On the Embankments of Rivers, and on the Nature of Overflowing Rivers in Diluvial Plains', *Journal of the Asiatic Society of Bengal* 18, part 2 (1849).

[80] Ibid.: 697.

[81] Ibid.: 702.

[82] Joyce Brown, 'Sir Proby Cautley (1802–71), a Pioneer of Indian Irrigation', *History of Technology* 3 (1978).

[83] Arun Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', in *Technology and the Raj: Western Technology and Technical Transfers to India, 1700–1947*, ed. Roy M. MacLeod and Deepak Kumar (New Delhi: Sage Publications, 1995), 217.

[84] Brown, 'Sir Proby Cautley (1802–71), a Pioneer of Indian Irrigation', 43, 53 and 59.

[85] Ibid.: 77–83.

[86] Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', 216.

[87] Gordon Wynne Roderick and Michael Dawson Stephens, *Scientific and Technical Education in Nineteenth-Century England* (New York: Barnes & Noble Books, 1973), 18. cited in Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', 229n.

[88] Public Works Department (Establishment, General), Part-A, Prog. Nos. 19–21, March 1870. National Archives of India. Cited in Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', 216.

[89] John Beames, *Memoirs of a Bengal Civilian* (London,: Chatto and Windus, 1961). Also see Ian Talbot, *Punjab and the Raj, 1849–1947* (New Delhi: Ramesh Jain, Manohar Publications, 1988), Van den Dungen, *The Punjab Tradition; Influence and Authority in Nineteenth-Century India*.

[90] Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', 217–8.

[91] R. A. Buchanan, 'The Diaspora of British Engineering', *Technology and Culture* 27, no. 3 (1986): 517.

[92] Ibid.

[93] Kumar, 'Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947', 227–6.

[95] Thomas Claxton Fidler, *Calculations in Hydraulic Engineering ; a Practical Text-Book for the Use of Students, Draughtsmen, and Engineers, with Numerous Illustrations and Examples* (London, New York and Bombay: Longmans Green, 1898).

[95] Edward Skelton Bellasis, *River and Canal Engineering, the Characteristics of Open Flowing Streams, and the Principles and Methods to Be Followed in Dealing with Them* (London: E & F. N. Spon ltd., 1913).

[96] Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance*, ch. 6.

[97] F.C. Hirst, 'The Kosi River, and Some Lessons to Be Learnt from It', *Journal of the Asiatic Society of Bengal* 7 [N.S.], no. 9 (1908): 466.

[98] Ibid.

[99] Ibid.

[100] Ibid.: 467.

[101] W.A. Inglis, 'Some of the Problems Set Us by the Rivers of Bengal', *Journal of the Asiatic Society of Bengal* 5 [N.S.], no. 10 (1909): 404.

[102] People armed with *lathis*, the long steel tipped flexible clubs that were the weapons of choice for the Indian Police both under colonial rule and after.

[103] Geoffrey T. Allen, assistant manger for the Darbhanga Raj at Gondwara in 1935, interviewed in England, August 25, 1983 in Hill, *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994*, 15.

[104] Bellasis, *Punjab Rivers and Works*, 27.

[105] Ibid.

[106] Ibid.

[107] Ibid.

[108] An anonymous reviewer helpfully pointed this out.

[109] Hill, *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994*.

[110] Agnihotri, 'Ecology, Land Use and Colonisation: The Canal Colonies of Punjab.', Ali, *The Punjab under Imperialism, 1885–1947,* Inderjit Sharma, *Land Revenue Administration in the Punjab* (New Delhi: Atlantic Publishers and Distributors, 1985).

[111] Gilmartin, 'Scientific Empire and Imperial Science: Colonialism and Irrigation Technology in the Indus Basin.'

[112] Hirst, 'The Kosi River...Lessons', 482.

[113] The hill torrents coming out of the Suliman Range were heavily laden with silt and descended with a force 'too great to admit of it's being entirely dammed up by any embankment such as the agriculturalists of the Pachad could construct. All that can be done is to erect at suitable intervals earthen embankments extending about half way across the distributary channels which open immediately above the embankments.' '… when the water has been let into a field it is allowed to slowly soak in and deposits its silt, and when the ground surface is dry it is ploughed lightly and the seed is sown. In a field of good loam the first watering is sufficient for the maturing of a crop, but if the soil is clayey a second but less copious watering is desirable…The fields gain steadily in level by the yearly deposit of silt, and many of the Sangarh village sites now lie in deep hollows in the middle of cultivated land, though when the sites were originally chosen thy must have been level with or higher than the land then under cultivation.' Punjab Government, 'Gazetteer of the Dera Ghazi Khan District. Revised Edition, 1893–97', 103–4.

[114] Hirst, 'The Kosi River...Lessons', 482.

[115] Ibid.

[116] This term was introduced to the political science literature by Peter M. Haas, *Saving the Mediterranean: The Politics of International Environmental Cooperation* (New York: Columbia University Press, 1990).

[118] The concept of problem and policy frames is elaborated in Donald A. Schön and Martin Rein, *Frame Reflection: Toward the Resolution of Intractable Policy Controversies* (New York: BasicBooks, 1994).