THE FUTURE OF THE TUTTLE CREEK RESERVOIR PROJECT, KANSAS

JON ARCHER

B.A., Chester College, England, 2001

A THESIS

Submitted in partial fulfillment of the requirements for the degree

MASTER OF ARTS

Department of Geography

College of Arts and Sciences

Kansas State University

Manhattan, Kansas.

2003

Approved by

Charles Martin
Major Professor

ABSTRACT

River fragmentation in the form of dams and reservoirs has changed the environment nationally. These reservoirs are only temporary, because sedimentation will cause many to become unusable by the middle of the twenty-first century. A number have become multi-resource facilities, and as such require holistic management. Despite the continued change of processes impacting dams and reservoirs, and uses of them, there is generally a lack of forward planning beyond the next five-to-ten years on the part of the federal and state organizations involved. This lack of planning leaves the far-reaching benefits, and populations used to the presence of the dams and reservoirs, as vulnerable, and recreational users under threat of losing a much-enjoyed resource.

Using the case of the Tuttle Creek project in northeastern Kansas, this thesis investigates the background situation of big dam construction in the United States of America, including policies and changing perceptions. Investigating the dynamic factors impacting the project, including sedimentation, seismic activity, global climate change, recreational uses and wildlife habitation, alternative future uses are discussed. In this thesis, three possible futures are identified and evaluated, including removing the dam, reengineering it, and a no-action alternative.

The U.S. Army Corps of Engineers and the Kansas Department of Wildlife and Parks are the major management organizations involved in the project. Successful execution of ensuing decisions for the future requires collaboration, something that could be difficult in the face of differing structures and management strategies.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to give great thanks to Professor Chuck Martin of the Kansas State Geography Department, who admirably took the role of Major Professor through the duration of this thesis. His knowledge of fluvial geomorphology and Tuttle Creek, as well as his evaluations and suggestions were very much appreciated. Professor John Harrington and Professor Kevin Blake, also of the Geography Department, served on the committee and were a much-valued resource, giving invaluable guidance and expertise.

Significant parts of this research project would not have been possible without the assistance of officials at the US Army Corps of Engineers Kansas city and Tuttle Creek visitor center offices. For their assistance in answering those out of reach questions, I am grateful.

My extended thanks goes out to the Geography Department, as full funding for this program of study came from my teaching assistantship. For answering those endless questions via e-mail and telephone before flew over the pond, I thank Professors Karen De Bres, David Kromm, John Harrington and also Lisa Percival and Johnny Coomansingh. Without your guidance through the application process, I would not have had this opportunity.

Additional gratitude goes to my parents, whose support in this venture has been unequivocal. As has the assistance and light relief from my fellow graduate students and other friends.

Chapter 1: Introduction

The availability of freshwater, in whatever form, is of paramount importance to societies for drinking and for agriculture. The necessity of water has led many civilizations to retain seasonal flows and rainfall in reservoirs for later use in times of water shortage (Petts, 1979). Water, though, can be as disruptive to societies as it is essential. For instance, too much water makes living difficult, such as in the case of seasonal floodwaters. In some societies, floodwaters are held back behind dams to protect settlements; this water is retained in reservoirs and then similarly available for diverse uses or simply to release at a more agreeable rate.

The assurance of water availability provided by reservoirs encourages existing uses to increase and even for additional uses to develop. As demands exceed available resources across the World, rivers are further fragmented with dams to meet the needs of increasing populations. These efforts to control habitually combat the propensity of rivers to flood, transport sediment and meander (Petts, 1979; Trush, *et al.* 2000). Although instigated for socio-economic benefit, river regulation has come at growing socio-ecologic costs.

Alteration of watercourses is currently widespread in the United States of America (USA). Massive dams and reservoirs can be found all over the country, holding back seasonal high flows and retaining water for municipal, agricultural, energy production, navigational and recreational uses. Such massive fragmentation of river systems into a series of lakes can only be temporary, as the water attempts to reach a state of equilibrium on its journey from higher elevations. The temporary nature of reservoirs can be seen in sediment build up. This and other problems face the dams and reservoirs in the USA, and indeed around the World.

This paper uses a specific example to get a handle on some of the diversity of problems faced, how these might change and develop, the different stakeholders and interested parties that need necessarily be consulted, and how best to mitigate for the future.

Research Problem

River fragmentation in the form of dams and reservoirs has changed the environment nationally. Despite many of these reservoirs aging because of sedimentation (Graf, 2001), there is the lack of forward planning for their use beyond the next five-to-ten years on the part of the federal and state organizations involved (B.Empson, pers. comm., 2003). This lack of planning leaves settlements accustomed to the existence of dams and reservoirs as vulnerable (Cutter, 1996). The vulnerability develops over time, as populations learn to trust in flood control structures and forget life without them. The structures, however, are only temporary and will someday need alteration if not a complete removal or reconstruction. This leaves planning for the future of dam structures as necessary, but there is little evidence that such planning is in progress. There is, therefore, a need for the future to be considered by consultants outside of the established organizations.

In order to assist flood control and navigation downstream on the Missouri River, the United States Army Corps of Engineers (USACE) altered the Big Blue valley of Kansas by constructing Tuttle Creek Dam and Reservoir. As with all lakes, and especially anthropogenic lakes (reservoirs), Tuttle Creek Reservoir is only a temporary structure, since sediment will eventually fill it in.

In the most recent projection by the USACE (2001c), 60 years remained in the economic life of the project and 75 years remained until sediment deposits extend to the dam, at the 327.7m elevation of the multipurpose storage pool (USACE, 2001d). This means that by 2061 the scheme will be economically nonviable and by 2076 it will unusable for the present project purposes, to store water in order to assist navigation downstream and to provide for recreational uses, although significant flood storage may continue to exist (USACE, 2001c; 2001d).

There is a lack of significant planning to sustain the project; either planning in the light of recent changes like sedimentation of marinas and state parks with lake access, or planning for after the area has served its purpose as a flood control system in its current state. This leaves a niche for necessary investigation of the processes that are changing the project area, and how they are affecting the multiple uses of the project. Furthermore, exploration of possible developments of the site after its dwindling usefulness 60-75 years from now has yet to be quantified, as they should be.

Objectives

There are a number of problems with many dams and reservoirs, both in the USA and across the World. So initially, it would seem pertinent to inaugurate an investigation into the problems faced, with specific interest placed on the area of study so as to give real and objective suggestions. As such, the primary objective of the study is to:

Augment an understanding of dynamic processes that currently impact the Tuttle Creek Dam and Reservoir, or that could in the future, and how these processes might affect future planning, development and mitigation of the scheme.

The study examines the factors affecting the dam and the reservoir and how they have, and might continue, to develop. The factors are considered with the future of the dam and project in mind.

So as to balance the discussion, the stakeholder organizations and their future plans are investigated. So to that end the second objective is to:

See the extent to which the findings can be identified in, or are contrary to, different organizations' current plans for the future of this multi-resource facility.

In identifying the processes affecting the project, ideas can naturally be developed for the resolution and management of the problems they may cause. These recommendations as to how the facility can be managed are presented as part of the discussion. The discursive conclusion to this report covers whether such consideration has been made by the organizations involved, to incorporate the findings of the research into plans for the future of the project.

Justification

Similarly to the necessity to consider all the interested parties when planning for the future, successful reflection and mitigation of such large-scale projects should include interdisciplinary perspectives. Geography, being 'the mother of sciences' (Barrows, 1923: 1), and a particularly integrated discipline (NRC, 1997), is an ideal standpoint from which to do this.

Geographic thought can be quite simply labeled as looking at the interaction of people and places, seeking patterns and the causes of them. Looking at people in the landscape follows the human-environment interaction line of geographic inquiry (Barrows, 1923; Abler, 1971; Pattison, 1990). This method of analysis will be adopted for the research paper to develop an understanding of the local situation, looking at how organizations have developed the Tuttle Creek project in the Big Blue River Basin and how populations have reacted to using the resource.

The research paper will further embrace Barrow's (1923) constitution of Geography as the most integrated of sciences by incorporating many subfields into the investigation. Some of the subfields of Geography embodied in the thesis include Human Impacts, Natural Hazards and Fluvial Geomorphology, as a background to impacts and issues on the dam are probed; Environmental Perception is incorporated as policy and public perception are discussed; Geology and Fluvial Geomorphology, as the cause of sedimentation is explored, with the addition of Seismology and Natural Hazards as the threat of earthquakes and floods are considered; additionally, Climatology will be broached as climate change is researched and its impact reflected on.

The thesis particularly contributes to geographic knowledge as it shows how geographic thought can be useful for water management strategies on local, and indeed global, scales. Specifically for the Tuttle Creek project, this research provides reasonable insight for the USACE and the Kansas Department of Wildlife and Parks (KDWP), making them aware of the necessity of planning beyond the first decade of the twenty-first century.

Chapter 2: Literature Review

Origins of Dams and Reservoirs in the USA

The necessity for a clean and regular supply of water is of paramount importance to all living things, for which humans are no exception (Mitchell, 1999). Seasonal and annual changes in water supply and growing population demands are just two factors limiting the availability of this precious resource for individuals. The uneven distribution of water temporally and spatially leads societies to seek control of it (Petts, 1984; Atkins *et al.*, 1998); indeed, by the 1800s the concern for a safe water supply had led many municipalities in the USA to develop plans for water safety and conservancy (USEPA, 2002).

Utilization of natural resources progressed through the nineteenth century, and yet molded by arguments from preservationist John Muir (Weiss, 1999) and conservationist Gifford Pinchot (USDA-FS, 2003), the notion of protecting the environment found its way into the national psyche. The ethic of conserving whilst using natural resources even found its way into legislature, so that the Forest Reserve Act of 1891 was passed to protect areas of forest, recognizing that the quantity and quality of the flow of water was altered by land cover changes (USNPS, 2000). At the start of the twentieth century, President Theodore Roosevelt came to symbolize the national campaign for the use and retention of natural resources, an agenda that steadily gained political popularity, ultimately becoming a government preoccupation (USEPA, 2002; Weiss, 1999).

Natural resource measures progressed to include the Soil Conservation Service, founded in 1935, which applied scientific practices to agricultural soil erosion reduction, promoting wise land use in order to benefit soil, air, water, plants, animals and humans (USDA-NRCS, 2003). Animal life and habitat depletion was recognized in the 1937 Pittman-Robertson Act, establishing a fund for state fish and wildlife programs from the proceeds of federal taxes on hunting and fishing equipment (American Rivers, 2003).

One of the more ambitious conservation and resource utilization programs was alteration to the Missouri River Basin. Despite the earlier environmental messages from Muir, Pinchot and Roosevelt, extensive economic loss and suffering from recurring floods and drought throughout the basin led to a call for flood control programs overseen by the USACE (Ferrell, 1993; Tobin and Montz, 1997). The notion of large and expensive federal projects was made more palatable with the prospect of high potential benefits (Ferrell, 1993). The Pick-Sloan plan for the Missouri Basin was, and to a great extent still is, seen as necessary management of a 'great natural resource for the benefit of the American people' (Ferrell, 1993: vii). Human management of the entire river system was an early response aimed at alleviating flood and drought hazard to the people of the Plains States, allowing irrigated crop production and habitation in the floodplain with less risk.

The USACE developed a tradition of military and civil works missions in the early history of the USA, a tradition that continues to the present (Ferrell, 1993; USACE, 2002d). Although not a comprehensive national program, the original Flood Control Act of 1917 authorized the USACE to construct levées and remove debris in order to control floods in areas of the south and southwest (Moore and Moore, 1989). In the light of mounting monetary costs of flood alleviation, the cost-benefit analysis was incorporated into the flood control act in 1936, whereby accruement of benefit had to outweigh the cost of construction (Tobin and Montz, 1997; Moore and Moore, 1989). The 1936 and future amendments to the act saw the program go national, with the management of much of the USA's river systems and construction and maintenance of some 80,000 dams (Moore and Moore, 1989; Graf, 1999 and 2001).

From the 1930s to the 1960s, the big dam era developed a case of megalomania. The concentration on economic benefit was considered to require dams to produce money to cover the cost of construction (Tobin and Montz, 1997), such as with hydroelectric power (HEP) production. Per se, bigger dams have the potential to generate a higher income and faster. With an interest in economics and technology, enormous dams were constructed throughout the southwest to control water supplies. Two of the largest, last built projects built under the premise of economic benefit, were the Glen Canyon Dam and the Tennessee valley project.

Glen Canyon Dam typifies the perspective of the early-to-mid twentieth century, built in the time of mass dam construction. Erected along part of the Colorado River to flood Glen Canyon, so named by John Wesley Powell, construction was on a grand scale (Jones, 1984). Holding 35.2 km² of water, the 175m high dam was constructed for the purposes of HEP, regulation of flow, recreational uses and a water savings bank for downstream settlements. This massive interruption to the Colorado River has altered downstream sediment and flow rates, dramatically changing the ecology of the river (Collier *et al.*, 1997).

Quite different, although built at a similar juncture in the USA's history, the Tennessee valley project had regional employment as its justification (Freudenthal, 1933; Barbour, 1937). Terrifyingly, the project viewed nature not only as a free resource to be plundered, but also suggested that it is reasonable to alter, manipulate and spoil the natural environment for reasons of poor regional economic conditions and high unemployment.

The Glen Canyon and Hoover Dams, and the Tennessee valley project are prime examples of huge alteration to the flow of rivers, with economic benefit intrinsically in their designs (Jones, 1984). With such huge construction, though, came massive destruction of the natural environment and interruption of natural systems.

Changing Objectives

Concern about environmental damage from the construction of so many dams between the 1930s and1960s resulted in the development of the National Environmental Policy Act (NEPA) in 1969 (Moore and Moore, 1989; USEPA, 2002). Important elements to the NEPA are the inclusion of environmental restoration and enhancement, the environmental impact statement (EIS) and the "no action" alternative (USEPA, 2003). The principles of this act were mirrored by later federal action, such as the amended Flood Control Act of 1970 (Moore and Moore, 1989).

The requisite of the NEPA for federal agencies included consideration of potential environmental effects of proposed actions and their alternatives and mandatory public understanding and scrutiny, leading to a decline in dam construction during the latter quarter of the twentieth century. Concern in the USA coincided with a global decline, illustrated in Figure 2.1 & 2.2. The total storage capacity of reservoirs nationally is indicative of the decline in dam construction; Figure 2.3 shows reservoir storage in the USA leveling off in the same period as dam construction declined.

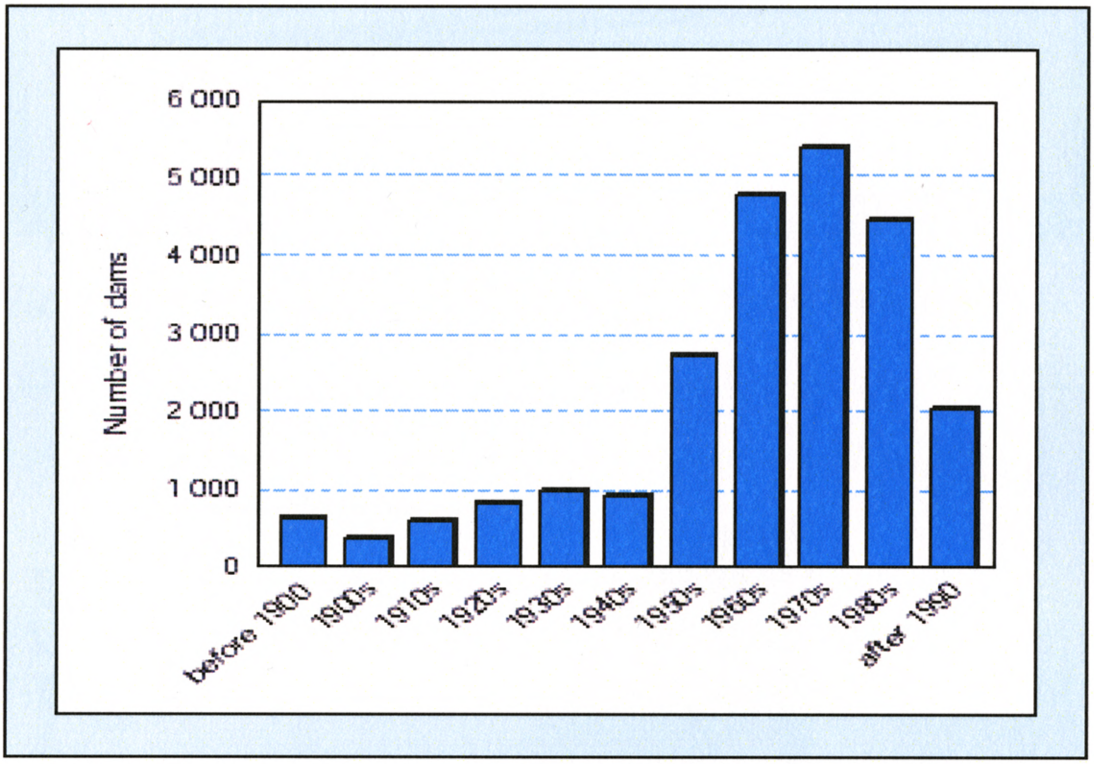


Figure 2.1: Global Construction of Dams by Decade (1900-2000). Source: WCD (2000).

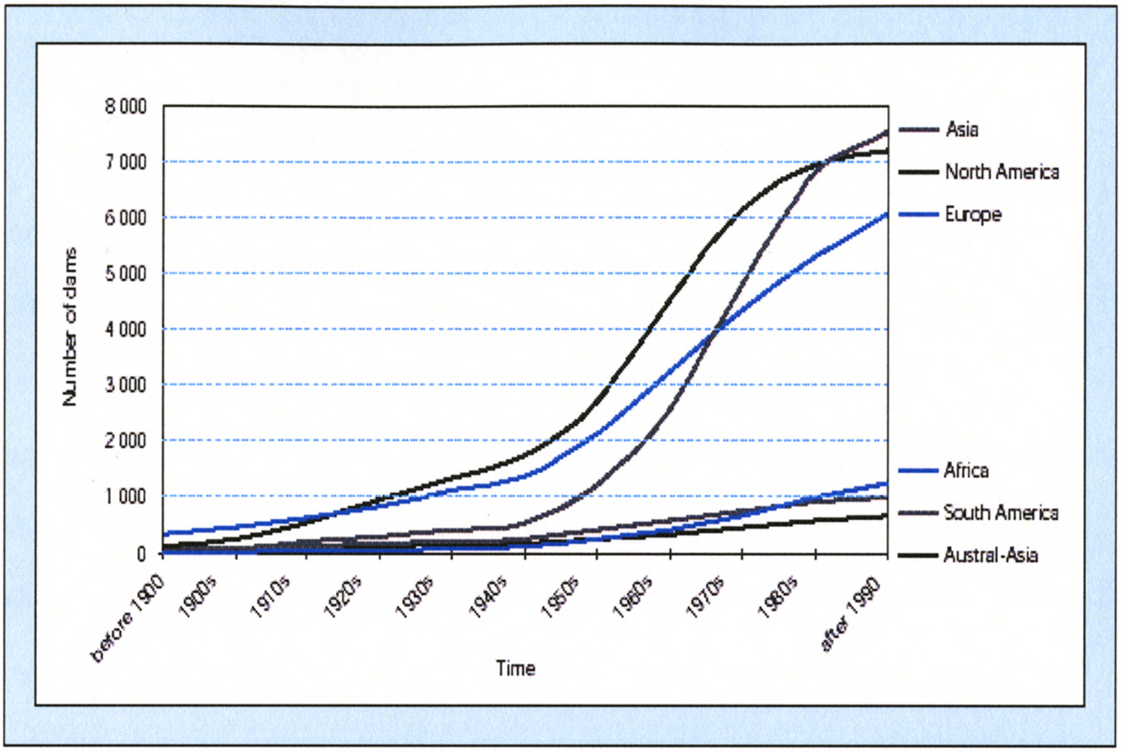


Figure 2.2: Dams Constructed by Region (1900-2000). Source: WCD (2000:9).

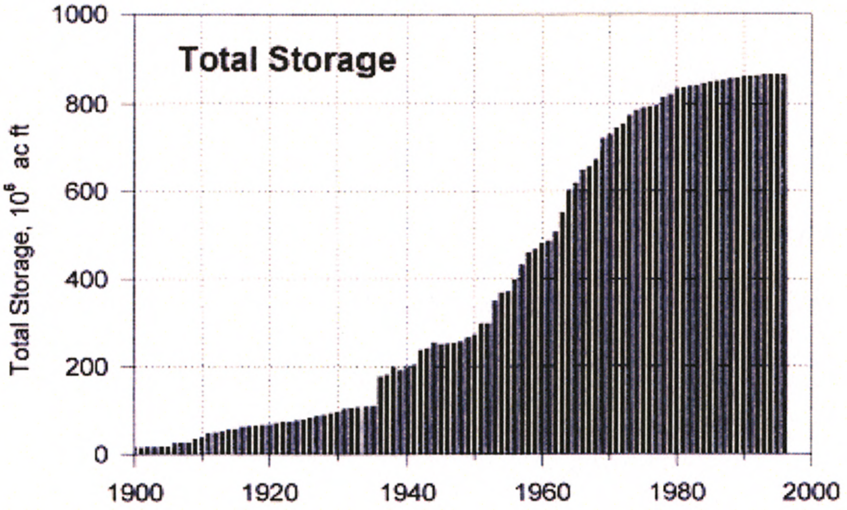


Figure 2.3: USA's Cumulative Reservoir Storage Capacity (1900-1996). Source: Graf (2001:4).

In May 1977, President Carter presented a revised water policy with a much more environmentally conscious slant (White and Waterstone, 1977). Conscious that future generations might think less than kindly of so many large dams on the landscape, painfully aware of the stress of construction costs on the federal budget, and with a recently found likeness of canoeing and rafting (Reisner, 1987), this environmental message to Congress, which favored natural wetland protection rather than new construction projects, represented a marked change from the fiscal bias of inclusion of the cost-benefit analysis. The fundamentals though, are juxtapositional, if you extend the consideration of "cost" to include non-monetary forms such as cost to the environment. Then such contemplation is an analysis of the total cost-benefit ratio for all human and natural interests; an assessment of what is environmentally and economically affordable (Graf, 2001; Midttømme *et al.*, 2001).

Such large-scale water resource management schemes as dam construction require identification of the "optimal" solution and must consider all monetary and environmental costs (Jamieson, 1980). This can lead to conflict of interests, and compromise is not always acceptable if there are a multitude of possible solutions, or the processes are complex. Therefore, as Tobin and Montz (1997) advocate, it is much more commonplace today to consider through the "with and without" principle, where reflection is given to benefits and costs with or without a project, and certainly not solely in terms of economic viability.

President Carter's message in 1977 (White and Waterstone, 1977) was even more judicious because it rendered wetland protection of greater importance than the technological response to flood hazard, and advocated the consideration of a broad range of economic and life losses. In short, Carter's message was that wetlands and flood plains are part of the natural fluvial system for a reason: they are natural floodwater "sponges" (Schmid, 2000).

Dams and reservoirs interfere with the natural fluvial system in order to benefit humans (Saha and Barrow, 1981; Petts, 1984; Gore and Petts, 1989). Contemporary insight raises the issue of spatial and temporal sustainability of such flood protection programs. The concept of sustainable development is proposed by the World Commission on Environment and Development to be 'development that meets the need of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987: 44-45).

Jobin (1998) extensively develops the idea of incorporating sustainable management strategies into these diverse and complex water management systems, a perspective of increasing relevance because the effects of any alterations are often experienced after some time and in areas away from the source. Lakes and their anthropogenic cousins, reservoirs, may be relatively temporary features on the dynamic landscape, but it is possible to make them sustainable despite their dynamism (Saha and Barrow, 1981). This sustainability could prolong the life of the feature, or exhibit more sustainable use by encouraging uses including recreation that can change as the reservoir ages.

Alternative and International Perspectives

Other cultures, with differing economies and different administrative structures to that of the USA, offer fresh ideas outside of the potentially automatically technocratic response to hazard and vulnerability of many western societies (Midttømme *et al.*, 2001). The disparity in our response to situations and dissimilarity in our societies is not as simple as being better or worse than one another, but rather just different (Bankoff, 2001). Moreover, identification of some of these opposing management systems to complementary situations can give fresh suggestion to our own situation.

Clearly some nations and cultures have, or at least had in the past, similar technocratic responses to those endured in the USA through most of the twentieth century. The popular Dutch saying, “God created the World, but the Dutch created Holland” (Atkins, 1998: 104), suggests that it is far from just a pass-time of the USA to control nature for human and even economic benefit. In southeastern China the Three Gorges Dam on the Yangtze will be the World’s largest hydroelectric dam after its completion in 2009 (IRN, 2003). Its development has been controversial both nationally and internationally. The government of the USA refused association with the scheme on understanding the magnitude of environmental damage that will result. Despite this, alternative funding and involvement were found from various countries including Germany and Canada, and contribution is even evident from the USACE in the form of consultation (Probe International, 2003).

There are, however, many cases of different approaches to water resource management being taken. Sustainable development of water resources is being increasingly highlighted, particularly for urban areas with a water supply deficit (Bai and Imura, 2001; Varis and Vakkilainen, 2001). Parts of northern China suffer scarcity of water, and the ever-increasing population worsens the situation beyond that of even Egypt's situation of aridity (Varis and Vakkilainen, 2001). The problem of increasing demand and pollution has sparked concern of resource and environmental capacity, and the application of an integrated approach to problem solving (Bai and Imura, 2001). Damming and reservoirs were an earlier response to the water shortage and flooding hazard, but are beginning to be seen as shortsighted because of a dramatic effect on the groundwater level, especially after the controversy of the Three Gorges Project (IRN, 2003). Management now comes in the form of residential controls and structural changes in the industrial sector to less consumptive uses of water. Although there are still problems, changing perceptions have been important, as the water is being seen as a resource rather than as a cause of natural disasters (Bai and Imura, 2001; Jun *et al.*, 2001). These perception dynamics show dichotomy to the situation in the USA.

Supplementary notion to the debate is given by Rasid and Mallik (1995), who present information on some additional indigenous responses to the natural flooding hazard in Bangladesh, a country where floods are more often positively perceived as bringing fertile alluvium to agrarian soils with only the severest of floods seen as disastrous. Two important alternative systems to damming as a response to flood hazard are identified, and seem poignant. Firstly the indigenous methods, typified by floating seedbeds that vastly reduce possible food shortage through crop damage by rising with the floodwater and producing crops transplantable as soon as floodwater sufficiently subsides. The second is a technological approach being applied to the same situation: the compartmentalization scheme, aimed at retaining a regulated seasonal flood cycle essential to rice cropping and many other national socioeconomic activities. Despite the scheme's well-meaning attempt to incorporate a "natural" flood cycle, necessary to rejuvenate the fertility of the Bangladeshi lowlands, Rasid and Mallik (1995) critically appraise the compartmentalization scheme in terms of its core concepts and local and wider negative impacts.

The two Bangladeshi responses to flooding differ immensely. The first succeeds in working with the natural system and does not remove the knowledge of existing with floods from local people. The second significantly reduces the risk of flooding to the inhabitants, but it also removes awareness of the potential severity of the situation and creates additional problems associated with stagnant surface water.

Thomas and Adams (1997) assess the Hadejia-Jama'are wetlands, part of the Hadejia-Jama'are flood plain in Nigeria. The flood plain was important for rice farming and recession agriculture. But since the construction of several dams, changing river discharge patterns have had an impact on ecosystems and economics of the area. This situation signifies and amplifies the need to perceive wetlands as not just dull wastelands, but as an ecologically important part of the landscape (Atkins *et al.*, 1998). Dams and other fragmentations of water resources have far-reaching environmental consequences on fragile, but important, wetland environments. It is necessary to be aware of the spatial and temporal facets of water resources; there are implications for sustainability of feedback and interdependence of natural systems and uncertainties about the ways environment systems will respond to perturbations (Thomas and Adams, 1997). In this awareness, compromise of the integrity of aquatic systems can be limited, as advocated by Mitchell (1999).

Water resource management in the Alps brings an additional factor into the discussion: tourism. The multifunctional nature of water resources has led to conflict from the various users. Coordinated planning of the different social activities using the resource, including residential, tourist, industrial, HEP and irrigation, has reduced conflict (Reynard, 2001). Land use planning is used as a tool to convalesce the conflict of interests between stakeholders, a policy that could be applied to other multifunctional water resource management schemes. Walmsley *et al.* (2001) give important addition to this concept, suggesting that effective study and practice of efforts towards sustainable water resource development cannot occur without input from all stakeholders (Ring *et al.*, 1999; Savory, 1999).

Midttømme *et al.* (2001) give examples of dams in Europe that are applicable to this paper. In Melton Mowbray, England, implementing a silt trap upstream, and operating sensible planting and cultivation practices in the surrounding urban and rural areas, tackled the sedimentation problem in a modest-sized reservoir. Midttømme *et al.* (2001) also introduce the case of dam risk management at downstream valleys in Portugal. Succinctly, great importance is given to consultation with inhabitants of the valley, to incorporate their experiences and ideas into the planning process.

Perceptions of Water Resource Management

The western perception of the natural environment has evolved, from a free resource, to an increasing integrity and acknowledgement of human reliance on the natural life support system (Dale and Robinson, 1996). This integrity and awareness may have grown from preceding environmental concerns and crises (Rees, 1990), developing environmental awareness and augmenting a sense of societal responsibility. Wetland and water resource conservation has developed as part of this environmental awareness (Schmid, 2000).

As early as 1973, studies looked at national environmental awareness, public opinion and willingness to contribute (Viladas, 1973). Consciousness of the importance of public opinion is paramount to the success of sustainable development of projects with wide reaching impacts. The advance of ecological sympathy and value in the public perception has repercussions as society begins to demand actions and development to be environmentally sensitive, perception made active through public pressure (Tellegen and Wolsink, 1998). Figure 2.4 shows a simple progression of environmental management change through incident induced alteration of societal attitude.

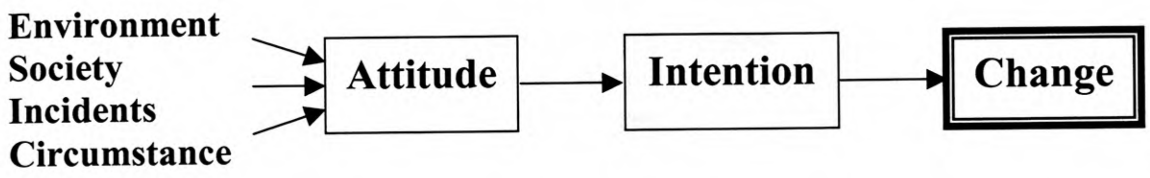


Figure 2.4: Societal Attitude and Environmental Change. (After Tellegen and Wolsink, 1998)

Public consciousness of environmental conditioning has led to suggestions of dramatic amendment to water resource management. As an example, the plight of pacific salmon that annually migrate up the Columbia River to spawn has sparked suggestion to breach the dams that play a part in threatening the species (Mann and Plummer, 2000). Moreover, when the public is potentially affected or aware and concerned about an issue, public support and input are helpful, if not necessary.

The multifunctional nature of large water resource projects has inherent ecological, economical and social aspects (Ring *et al.*, 1999), and therefore decision makers have to be aware of the bioethical criteria and constraints, and of community grassroots involvement. Whilst economic assessment continues to be important (Winpenny, 1991), the alternative approaches to water resource management show this importance of holistic input to an effective and sustainable organization strategy (Ring *et al.*, 1999; Savory, 1999). Incorporation of these recommendations for holism into management policies can be seen diagrammatically in Figure 2.5. These same issues are apparent in USA water management and are increasingly being incorporated to some extent through changing perceptions.

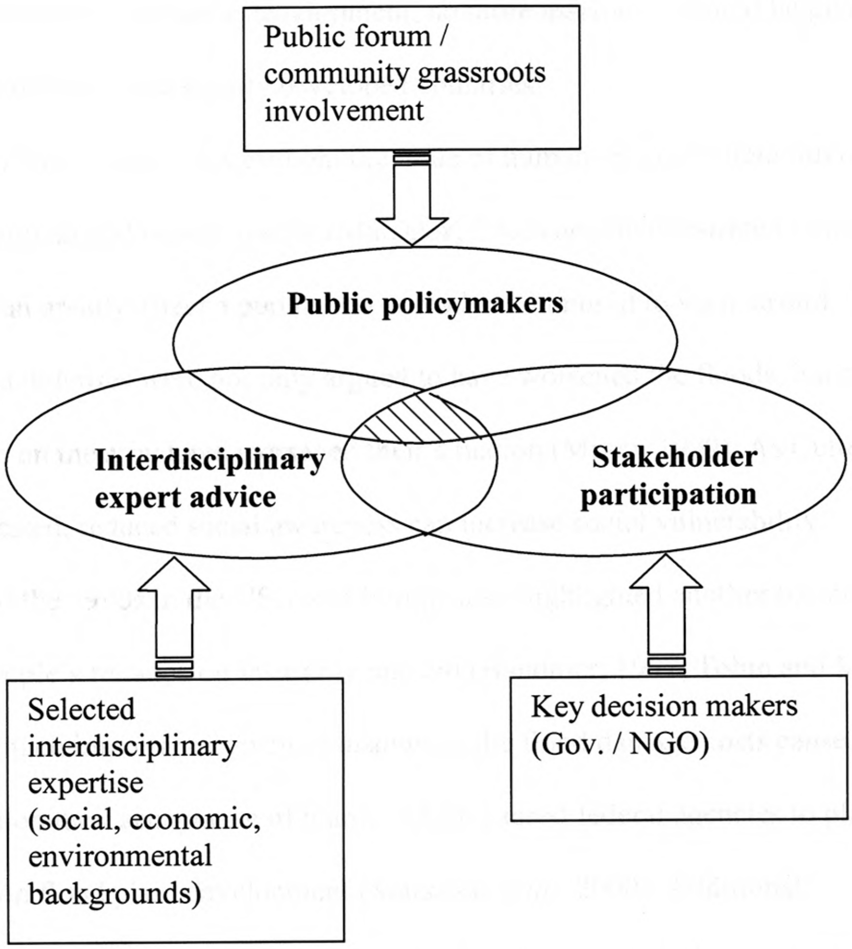


Figure 2.5: Holistic Decision Making. (after Dale and Robinson, 1996)

If the USA's federal water resource management is to be sustainable, collaborative resource management must be practiced. Government opinion must develop to value incorporation of all stakeholders, as must the opinion of each of the stakeholders. Indicative of the changing perspectives within the USACE is inclusion of Native American Indians perspectives and representation in the Missouri River Basin Association (Ferrell, 1993). Furthermore, the USA's public perceptions and federal policies are changing; this change must be reflected in overseas activities. Although help should be given toward sustainable development, no more assistance should be given for big dam projects in less economically developed countries.

The floods of 1993 in the USA brought the issue of human-induced alteration of flood process to the political and public agenda (Marsalek, 2000) and demonstrated how flood defense failure can greatly affect a population unready and unused to such hazard. The constructed flood defenses were not only argued to have worsened the floods, but also people's reliance on the structures worsened their situation (Mileti, 1999). As Cutter (1996) has suggested, reduced social awareness can increase social vulnerability.

The floods of the 1990s in the USA and Europe also highlighted another social vulnerability: people's reliance on insurance and aid (Handmer, 1987; Tobin and Montz, 1997). With so much importance given to insurance, the flood damage costs caused insurers to question their acceptance of blame, which caused federal agencies to place tighter controls on flood plain development (Marsalek *et al.*, 2000). Additional implementation of mitigation to flood plain dweller's vulnerability is the succession of non-structural developments, including improvement of prediction and warning systems (Dane and Steinhacker, 2003; Marsalek *et al.*, 2000).

Positive and Negative Consequences of Flood Control

Flood control undoubtedly provides an effort towards its purpose of relieving the extent of affects to populations from the hazard. In fact the USACE suggest that flood controls north of Manhattan, Kansas, considerably reduced the flow of floodwaters in

1993 and with it the damage that they might have caused. However, there are undesirable effects of flood control structures. A direct negative impact is social vulnerability (Cutter, 1996). This can take the form of overconfidence of the dam's integrity, with more pronounced suffering should the dam fail.

The build up of water behind a dam has considerable effect on the localized water table. The consequently raised level of ground water subsequently affects ecosystems and uses of previously drier locations. The buildup of water also has an effect on the local climate, and has even been suggested to have further-reaching climatological affects (Graf, 1999).

Dams not only collect water from upstream, but also anything that was in suspension or other form of transit with the stream. As such, many reservoirs suffer extreme sedimentation rates as well as pollution. The retention of materials upstream is at the expense of the river system downstream; as the river is "hungry" when it exits the impoundment, increased erosion rates are experienced (Petts, 1979). The diagram overleaf (Figure 2.6) offers interpretation of various impacts of dams on the environment.

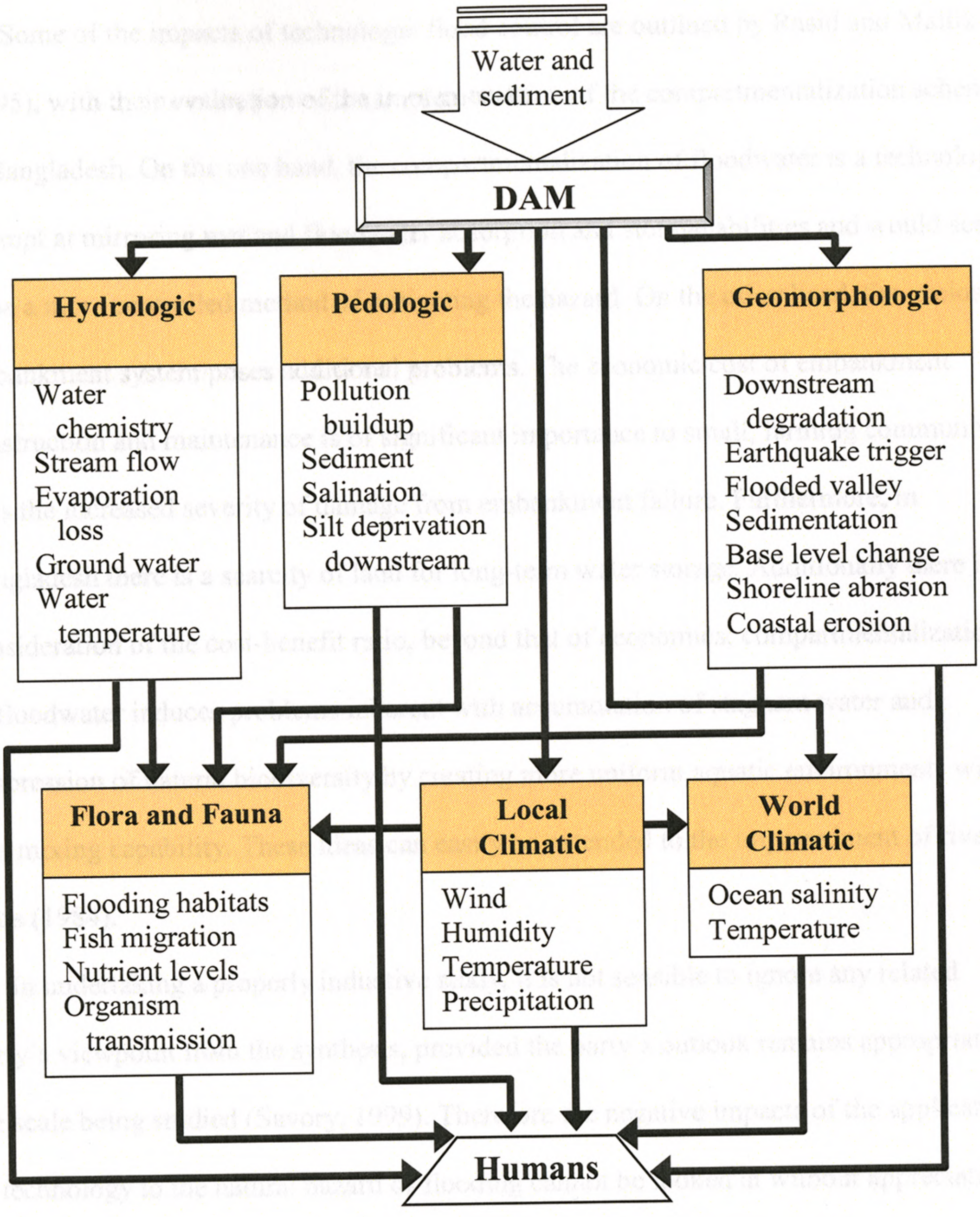
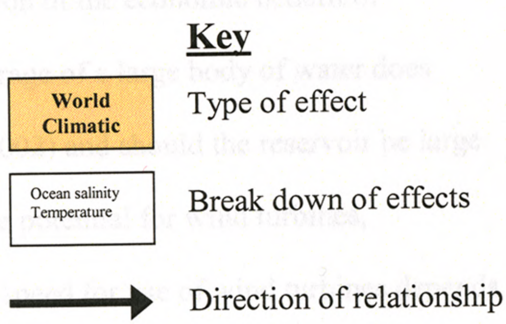


Figure 2.6: Generalized Representation of the Possible Physical Effects of Dams on Environmental Components and Humans (After Goudie, 2000).



Some of the impacts of technologic flood control are outlined by Rasid and Mallik (1995), with their evaluation of the implementation of the compartmentalization scheme in Bangladesh. On the one hand, the compartmentalization of floodwater is a technologic attempt at mirroring wetland floodwater absorption and storage abilities and would seem to be a more controlled method of mitigating the hazard. On the other hand, the enclosed embankment system poses additional problems. The economic cost of embankment construction and maintenance is of significant importance to small, farming communities, as is the increased severity of damage from embankment failure. Furthermore, in Bangladesh there is a scarcity of land for long-term water storage. Additionally there is consideration of the cost-benefit ratio, beyond that of economics; compartmentalization of floodwater induces problems inherent with accumulation of stagnant water and suppression of natural biodiversity by creating more uniform aquatic environments with less mixing capability. These ideas can easily be extended to the impoundment of rivers Petts (1984).

In undertaking a properly inductive study, it is not sensible to ignore any related party's viewpoint from the synthesis, provided the party's outlook remains appropriate to the scale being studied (Savory, 1999). Therefore the negative impacts of the application of technology to the natural hazard of flooding cannot be looked at without appreciating the positive impacts. Lindeborg (1973) offers opinion of the economic benefit of multipurpose water resource development. The storage of a large body of water does additionally offer the possibility of HEP (USDE, 2002) and should the reservoir be large enough, the lake-effect breeze can only enhance the potential for wind turbines, especially in the Great Plains. The necessary wind speed for use of wind turbines depends on the type of apparatus, with the minimum wind speed that can be used productively for one example given as 2.2 meters/second (ms^{-1}), it being most productive with a wind speed over 4.5 ms^{-1} (Proven, 2001).

The impoundment of rivers and the resultant reservoir of water have a complex effect on physical, human and other biological systems in the environment (Petts, 1984). Positive effects of anthropogenic alteration of rivers should not be given any less attention than the negative impacts. Flood control systems are, after all, designed to control the hazard of flooding. Differing perspectives view the positive and negative effects of dams differently, but the views of both groups need to be considered.

Graf (2001) highlights the paradox of the current situation in the USA when he notes that there are a multitude of technological impacts of streams, whilst policy states a requirement for restoration of rivers. Because of the development of multiple uses for rivers in general, and now for dams and reservoirs, a multilateral breaching of all dams or a reverse decision on current policy is not a plausible solution. Any decision must therefore be an inductive synthesis of as many influencing factors as possible; a collaborative approach of applying findings from other studies with the aim of attaining the best outcome for all concerned, as advocated by Gober (2000).

In the light of these findings, it would seem pertinent to develop a deeper, broad based understand of the situation of the study area, especially in considering the proposed life span of dams and reservoirs, which in many cases is within this century.

Dams at the End of their Lives, Relevant USA Examples

It is apparent from the literature that a significant proportion of the numerous dams across the USA are facing the end of their usable lives, either for water storage, flood control, or because considerable environmental damage is inflicted by their existence (Graf, 2001). USACE officials are aware this issue faces the nation's dams and reservoirs, but admit that there is no unilateral plan or specific plans for most individual structures. There are, though, specific noteworthy examples where a unique plan was implemented either because they epitomize the situation of dams across the USA, or for the innovative way that the problem of the end of a project has been addressed.

The Hoover Dam was one of the largest built in the USA, over 60 years ago. As a multi-resource facility, it holds back 35.2 km^3 of water in the largest man-made lake in the USA, Lake Mead, for agricultural, industrial and municipal use, flood control and HEP production (USDI-BR, 2001). This storage capacity was greatly reduced in the first 35 years after construction, as sediment accumulated by a greater volume than 98% of the reservoirs in the USA are filled with water (Reisner, 1987). Lake Mead's sedimentation slowed considerably later with Flaming Gorge, Blue Mesa and Glen Canyon Dams upstream retaining much of the sediment that would otherwise transport and deposit behind the Hoover Dam (Reisner, 1987).

Although it is too costly to remove sediment from large reservoirs, not to mention the problem of where to put the sediment, there are recent examples of mitigative alternatives. For instance, sediment deposition was reducing the water storage capacity of the Overholser Reservoir, Oklahoma. To combat this, a technological response was applied, using a bypass canal when the stream sediment load is excessive (Stout *et al.*, 1985). Similarly, the city of Los Angeles and its Department of Water and Power has commissioned and built many small sediment retention reservoirs around the basin to maintain the storage of water necessary for its extensive population and industries (Reisner, 1987). This move to prolong the life of its reservoirs continues to the present day with the construction of sediment bypass systems like that in the Mono Basin, CA (LADWP, 2003). It is this harmonized approach that Saha and Barrow (1981) advocate, in water resource management, for the success of economic gain and sustainability of equilibrium in the natural hydrological system. However, this system is far from ecologically sound.

There are examples of far more environmentally friendly solutions, including the suggestion of dam removal (Baish, 2002). The reduction of salmon numbers in the Pacific Northwest has been noticed for decades, with links made to fragmentation of rivers and salmon inability to leap the huge dams constructed (Hedgpeth, 1944). The standoff between fish and power production has reached an extent in the Pacific Northwest where proposals have been made in the State of Washington to breach and remove some dams (Marts and Sewell, 1960; Mann and Plummer, 2000). Efforts have been made in the past to make allowances for both fish and power, with lower dams or divertive rapids systems (fish ladders), but with dramatic reductions of fish stocks, dam removal is becoming a favored alternative (Mann and Plummer, 2000).

Plans to remove some 63 dams in 16 States in 2002, including the Glines Canyon and Elwha Dams on the Elwha River in the State of Washington, is indicative of a new concept of dams at the end of their lives (Graf, 2001; American Rivers, 2002). Most of the planned removals of dams are because of ecological concern like that of their impact on fish migration. Many dams in the USA were built decades ago with flood control or other socioeconomically beneficial purposes in mind, but perspectives have changed, leaving many of these dams with their original purpose no longer considered important enough to merit the environmental damage they create (Graf, 2001; Higgs, *et al.*, 2002). Our increased environmental understanding and expertise, partnered with public environmental awareness, has given water resources management a new agenda.

These examples offer just some of many tribulations and resolutions of dams and reservoirs in the USA, but these few allow coverage of a variety of aspects. In turn the concepts discussed in this section will allow extensive evaluation of the study area of this thesis: Tuttle Creek Dam.

Chapter 3: Methods

The study area of Tuttle Creek Dam and Reservoir was chosen because it is one of the largest reservoirs in the state of Kansas, and with its uniquely long, thin shape suffers from high rates of sedimentation (Holden and Emmert, 1998). The dam is also situated near a seismic fault, the fact of which has been brought to light by numerous papers and recent redevelopment proposals by the USACE.

The Tuttle Creek project is run by the USACE, in-depth documented background and research by whom allowed for easy comparison with other waterbodies across the country. Similar discursive possibility was permissible by means of the reservoir and surrounding parkland's diverse recreational uses, organized by the KDWP. The plethora of documents and web-based information on the project make for a shrewd choice of study area.

In order to fulfill the objectives of this study a holistic approach was adopted. Expanding the sustainable and collaborative management strategies suggested by Jobin (1998) and Savory (1999), a proposal for the future of Tuttle Creek Dam was heuristically developed. The holism in this study takes spatial and temporal forms.

To offer development of plans for the future, a background of Tuttle Creek Dam was researched, specifically why it was constructed and the purposes of the project. Sources for this background were largely found in books and from Internet sources. Such initial account of literature helped to propagate an understanding of the processes behind the development of the Tuttle Creek project to its current state. With an understanding of the present situation, and the build-up to it, the goal to develop plans for the future is better met.

Temporal and Spatial Investigation Components

A history of the Tuttle Creek project through to the current situation and plans for the future was backed-up by getting a handle on the national situation. Specifically, every effort was made to understand the development of the concept of river fragmentation in the USA and what perceptions and processes led to the implementation of dams and reservoirs. The technocratic response was paradigmatic during the era of mass dam construction, but perceptions have changed and it proved instrumental to explore this change in perception. A literature search on the development of the national position was carried out, bolstered with some Internet sources.

This temporal holism was assisted by spatial integration, offering a rounded argument with pragmatic responses and perceptions to flood control nationally and alternative international cases and perspectives. The review of national water resource management also helped to assess how the technocratic response developed and how that perspective is changing. Journal articles were a more prevalent resource for inquiry of perceptions and in investigating examples of water resource management.

Research Process

The path of inquiry, from a background of the Tuttle Creek project to development of plans for its future, required a significant review of literature. Figure 3.1 shows the main goal of developing future management strategies for Tuttle Creek Dam and Reservoir, and how accomplishment of this necessarily followed a path from a background of the project through an extensive literature review of national and international water resource management approaches.

The objectives of this study quite clearly required a significant accumulation of information. This essentially takes the form of an extensive literature review. Assistance was also gained from consultation with representatives of the USACE and KDWP, in the form of informal interviews. Specific and guided questions left unanswered by the online information were directed to both organizations.

Whilst consideration of an holistic approach to management considers opinions of every stakeholder and user (Savory, 1999), being the management organization of the project and the main user and management organization of the surrounding parkland, the USACE and KDWP, respectively, require significant concentration of this study's investigation. As such, an analysis of themes was compiled as to the management strategy of these two organizations for, and beyond, 2076, the purposeful life of the project (USACE, 2001d). These provide a good foundation to offer argument for the necessity of future planning.

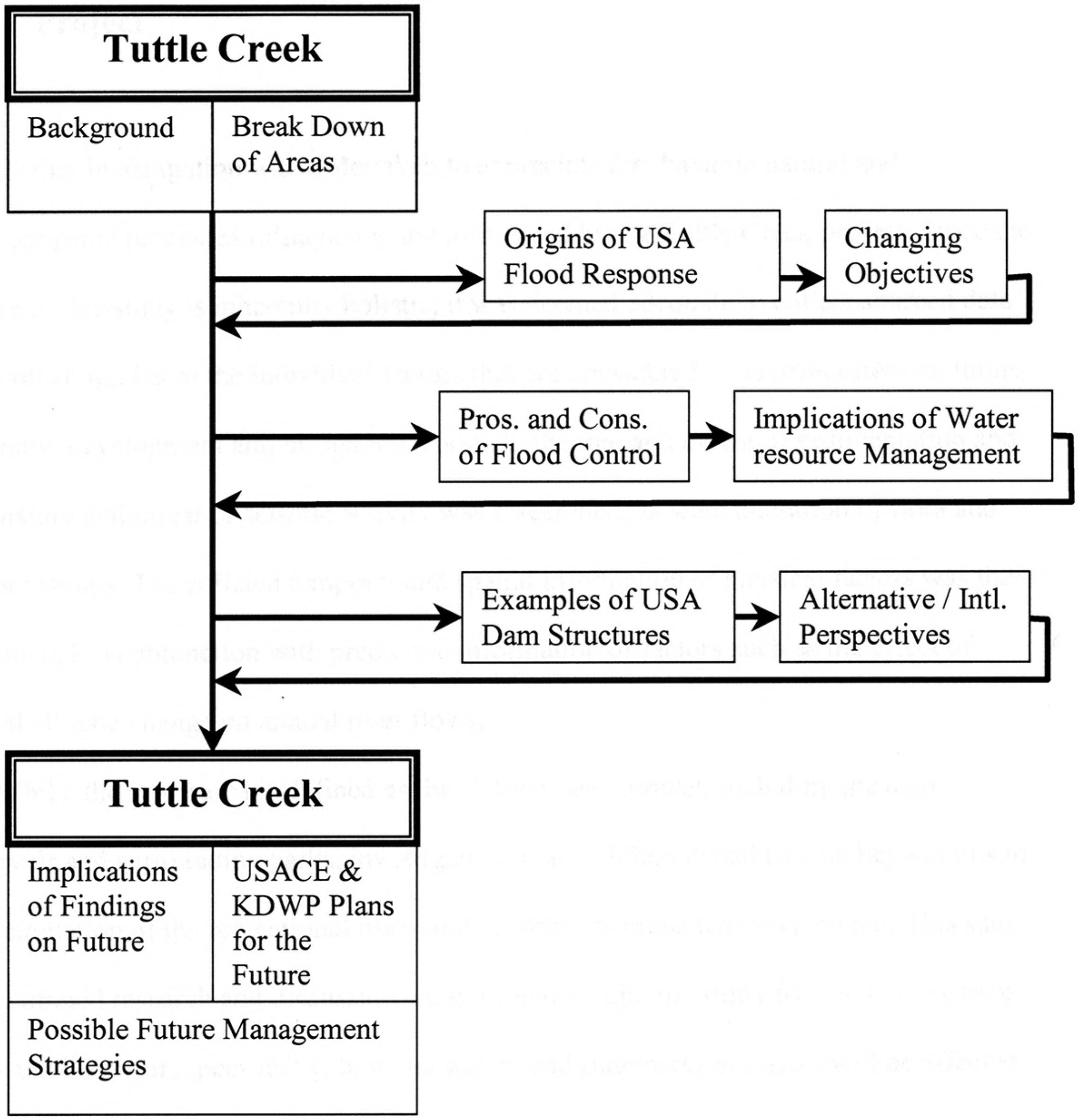


Figure 3.1: Path of Investigating the Future of Tuttle Creek.

Investigation of Physical and Social Process Impacting the Project

Further investigation was undertaken to appreciate the dynamic natural and anthropogenic processes influencing and influenced by the Tuttle Creek project. Since the nature of this study is inherently holistic, it was deemed adequate to collect sourced data from other studies of the individual factors that are considered to have an effect on future planning, development and mitigation. As such, the rate and extent of sedimentation and the history and threat of seismic activity was researched, as were alteration of flora and fauna habitats. The collated temporal and spatial information of physical factors was then considered in conjunction with predictive information of factors such as the effect of global climate change on annual river flows.

Whilst the study area is defined as the Tuttle Creek project, including the dam, reservoir and surrounding parks, investigation of social factors had to look beyond this to contemplation of the recreational users and settlements impacted downstream. This said, concentrated research and discussion were formed around the study foci of Tuttle Creek dam and reservoir; specifically, how the waters and state parks are used, will be affected by predicted changes to the area and how these changes might be planned for.

Summary of Methods

The strategy of this research paper permits an understanding of the process behind the development of the dam, allowing us to understand how the dam can be used in the future. Development of governmental and public perception from river fragmentation to ecologic conservancy allows better holistic plans for the multi-resource facility. Future possibilities are then developed and offered, with a 2061-2076 deadline in mind.

It is reasonable to be able to give conclusive suggestion for planning and mitigation of the scheme in the light of the collated findings. Suggestions are then compared to current authoritative planning for the future of this multi-resource facility, particularly that of the USACE and KDWP.

Certain terms and phraseology used in this paper may be unique or uniquely used. In acknowledgement of this, a description of important words and frequently used acronyms/initials can be found in the Appendix I on page 89. This should ease understanding for the reader, maintain literary and argument flow, and also develop additional appreciation of early key points.

Chapter 4: Study Area

Location Background

Tuttle Creek Dam is situated in the Big Blue River Basin, 14 kilometers upstream from the Big Blue River's confluence with the Kansas River. The Big Blue River Basin stretches south from Grand Island, Nebraska, to Manhattan, Kansas. It is in the lower reaches that the Big Blue River confluences with the Little Blue and Black Vermillion Rivers. The Tuttle Creek Dam was created to take advantage of this important meeting of these three rivers before the flow enters the Kansas River.

The subsurface structural geology of the Big Blue River Basin is of marked contrast to the surface (Chelikowsky, 1972). The near-surface rock unit to the east of the basin dates to the Mississippian period; to the west Permian rocks are overlain unconformably with successive Cretaceous, Tertiary and Quaternary rocks. Beneath all these layers is a more complex subsurface structural geology of well-defined synclines and anticlines of much older rock. This irregularity of substructure-to-surface compaction is argued to have caused the reactivated crosscutting tectonic structures, including the Nemaha anticline (Chelikowsky, 1972). The faults are in close proximity to the dam; the rock-cut wall of the spillway exposes a fault.

The basin is underlain by several thousand meters of sedimentary rocks, most of which are Cretaceous shale and chalky limestone. An area of protruding Permian rocks is covered in part by Pleistocene glacial deposits. To the north, the Cretaceous bedrock in Nebraska is covered by unconsolidated Pleistocene loess and alluvial sands. Land use practices on these deposits provide considerable material for the constituent rivers to transport downstream, promoting high levels of sedimentation in Tuttle Creek Reservoir (Holden and Emmert, 1998).

The dam and the 13,587 hectares of land and water around it are operated by the USACE (USACE, 2003). This land is situated in Riley, Pottawatomie and Marshall Counties in northeastern Kansas (Figure 4.1). The dam site is situated 7 kilometers north of Manhattan, Kansas, and 85 kilometers west of the state capital, Topeka.

For the purposes of this research paper, the study area includes Tuttle Creek Dam, Reservoir and the adjoining parks. This can be clearly seen in Figure 4.2, as can three sites where parks once were, but that are no longer used. These sites that were previously parks do not appear in recent USACE literature, but the significance of them will be revealed later in this thesis. Additionally, it is important to recognize Tuttle Creek Dam and Reservoir as part of the Big Blue River Basin, and as such, some mention will be given to other locations that can be found in Figure 4.1, the smaller scale map on page 38, such as the city of Manhattan.

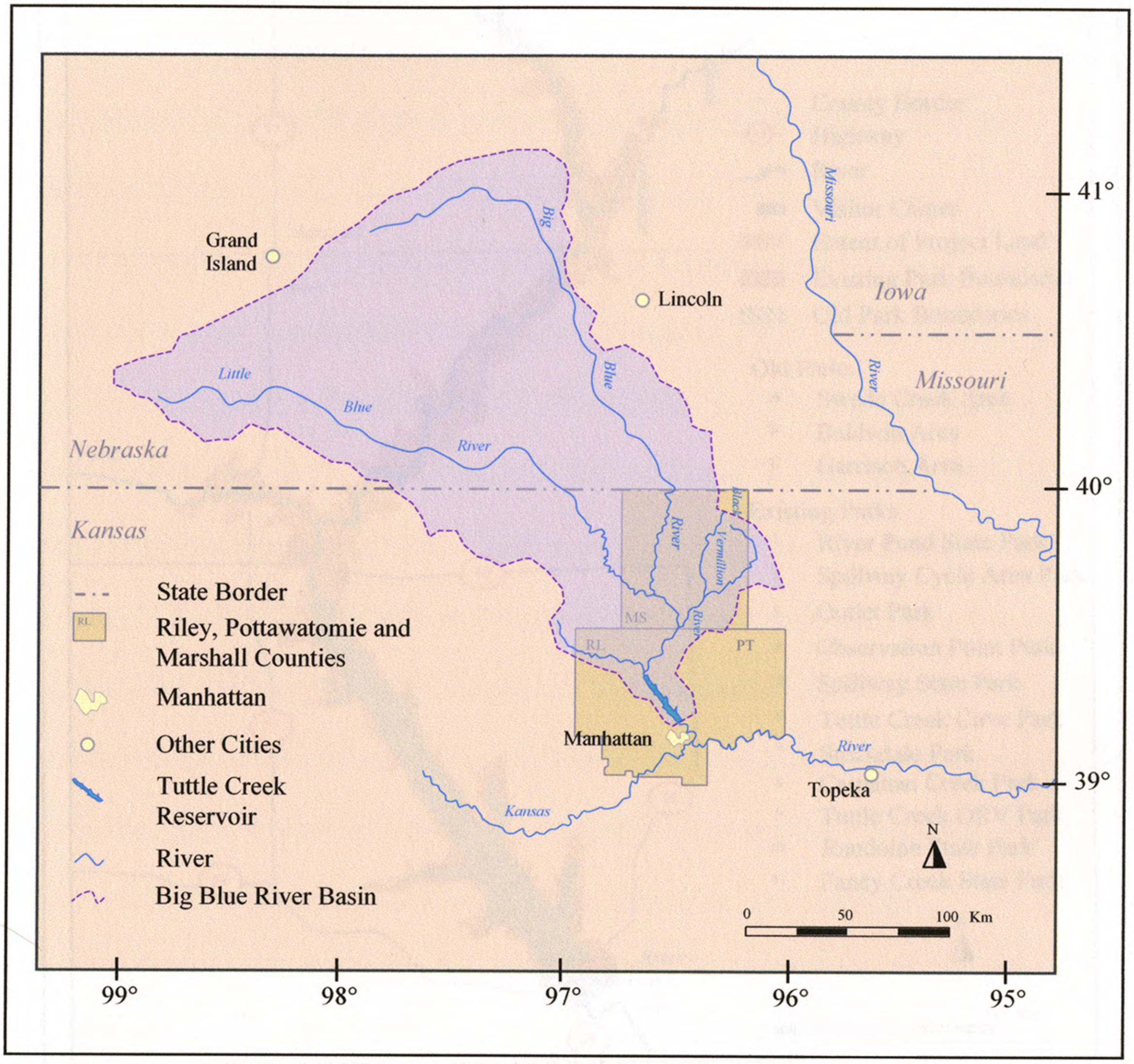


Figure 4.1: Tuttle Creek Dam Project, Big Blue River Basin

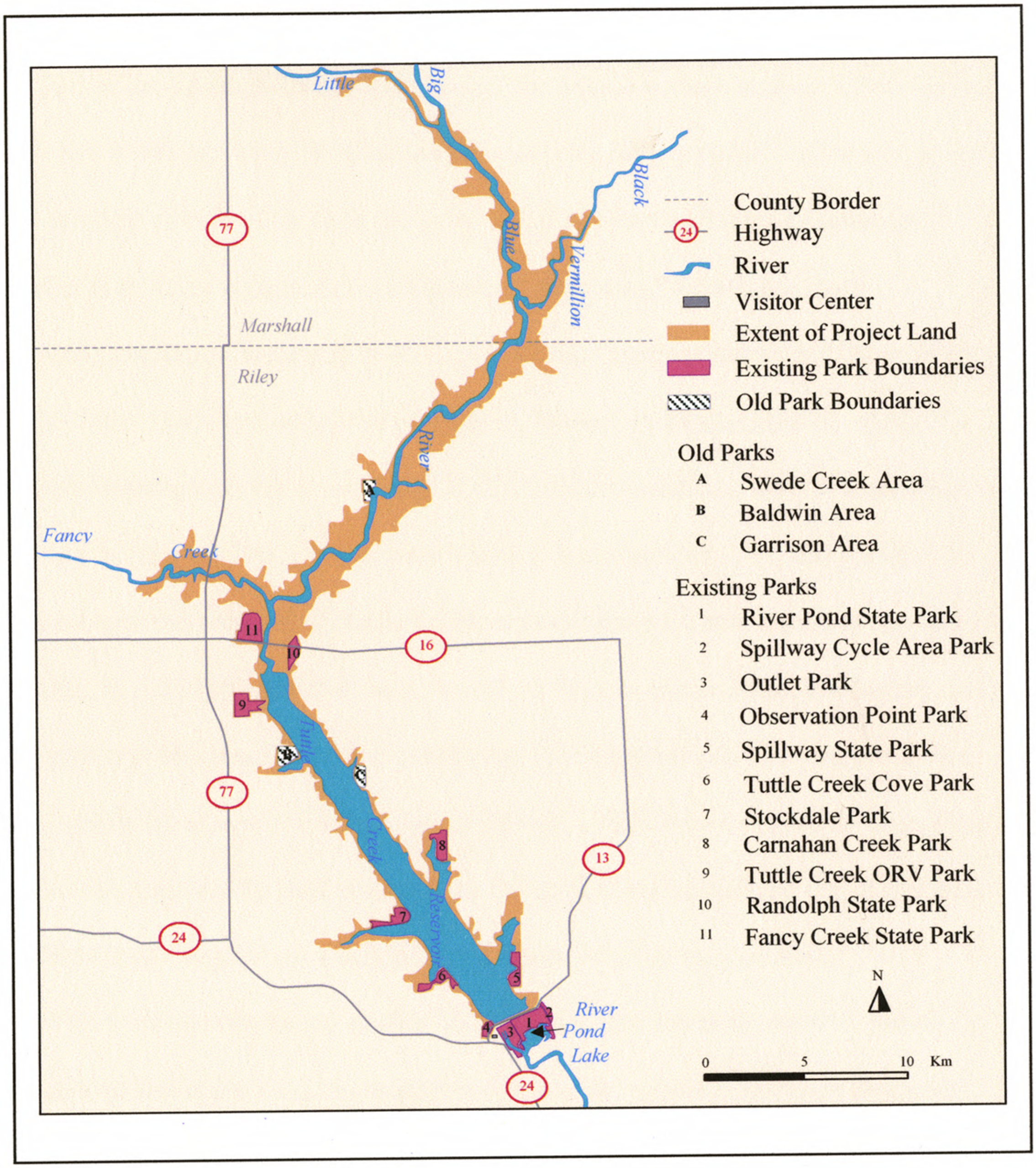


Figure 4.2: Small Scale Map of Tuttle Creek Project Component Parts

Background to Tuttle Creek Dam

Part of the Lower Missouri River Basin and tributary to the Kansas River, the Big Blue River was part of the Pick-Sloan Missouri Basin Program of 1933 (Ferrell, 1993). The political culture of the time led to the USACE constructing many dams and reservoirs in order to control flooding; one of these was Tuttle Creek Dam.

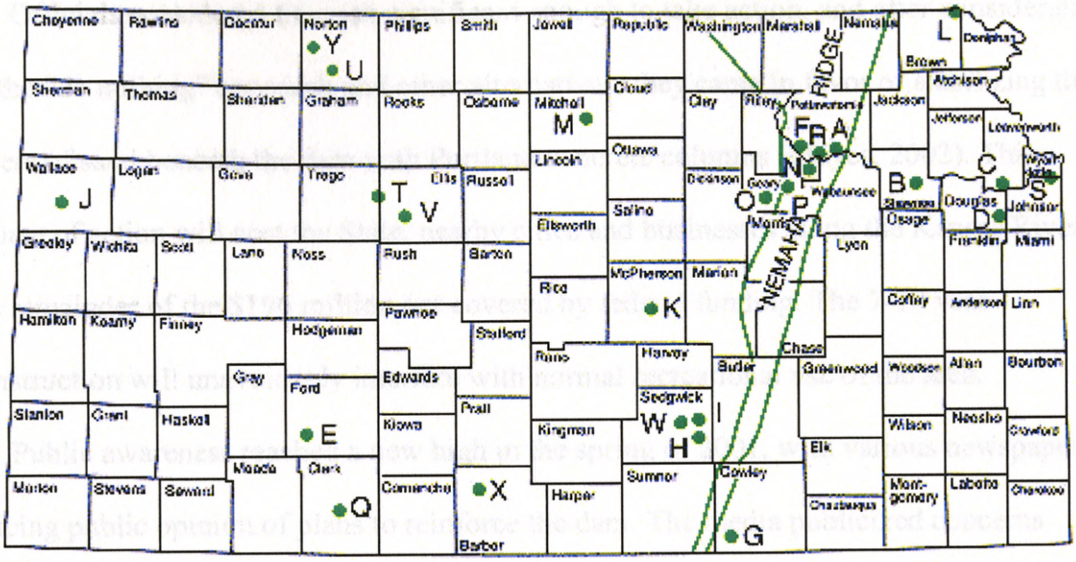
After a series of damaging floods in the 1930s, Congress sanctioned the creation of Tuttle Creek Dam, just outside of Manhattan, Kansas, in 1938 (USACE, 1976). The original investigation estimated a $6,121,233 annually recurring loss for land taken out of production (Meyer, 1962). But it wasn't until 6 years later, in 1944, that the Pick-Sloan Plan brought the proposal of Tuttle Creek to public forum. Local animosity towards the flooding of the Big Blue valley was focused on the loss of cherished, productive valley farmland and compounded by the consequent displacement of a 1500 people from 6 small towns for at least the next 90 years (Meyer, 1962). However, despite mounting opposition, the time that had passed since the project was sanctioned meant that only another act of Congress, or a lack of funds, could overturn the decision.

With losses in Manhattan totaling $13,394,000 after the flood of 1951, public pressure bowed out to the proponent perception of the potential for flood protection offered by the existence of a dam (Meyer, 1962). The USACE requested $5,000,000 to start construction and President Harry S. Truman sanctioned an emergency appropriation for construction to begin in 1952. Because of prolonged drought throughout the Midwest in the 1950's, the project quickly developed beyond the original dry dam proposal to include a permanent reservoir that began to fill in 1962, three years after the closure of the dam (USACE, 1976; USACE, 2001b).

From the outset of the scheme, the purpose of the dam has been flood control. However, such a large project has obviously impacted on the local area. Such a large expanse of water and increased access to the immediate site area has offered a multitude of uses for the local population, visitors and wildlife (USACE, 1976). The current uses are given by the USACE (2001c) as most importantly flood control, with additional uses including recreation, fish and wildlife conservation, water quality control and navigation supplementation. The multiple uses of the dam result in a necessarily complex decision process before any alterations and developments can be made. There are also a number of localized factors that have to be considered for the present and near future optimization of Tuttle Creek Dam and Reservoir.

There has been recent publicity of a seismic threat to Tuttle Creek Dam, as big earthquakes can liquefy the sands underneath (Petterson, 2001). In Kansas, earthquakes can occur along the Nemaha Ridge, a zone running from Omaha to Oklahoma City. Kansas Geological Survey data show a history of seismic activity throughout the area, most notably a cluster of events prior to 1977 on the southeastern tip of Riley County.

The closest earthquake to the location of the dam was in 1906 (letter F on Figure 4.3) with a magnitude of approximately 4.5 on the Richter scale, but in 1867 the largest earthquake in Kansas's history was recorded just twenty kilometers to the east, near Wamego (letter A on Figure 4.3); this quake was estimated to have had a magnitude between 5.1-5.5 (Steeples and Brosius, 1996; Petterson, 2001). This presence and proximity of a seismic threat has led to continuing exploration by the USACE.



A.	1867	VII	F.	1906	VII	K.	1927	V	P.	1929	V	U.	1933	V
B.	1875	V	G.	1907	IV	L.	1927	VI	Q.	1929	V	V.	1942	IV
C.	1881	III	H.	1919	IV	M.	1928	IV	R.	1929	V	W.	1948	IV
D.	1902	II	I.	1919	IV	N.	1929	V	S.	1931	VI	X.	1956	VI
E.	1904	IV	J.	1926	?	O.	1929	V	T.	1932	V	Y.	1961	V

<u>Figure 4.3: Historical Earthquakes in Kansas, Prior to 1977</u>. Roman numerals reflect Mercalli scale of earthquake intensity (Steeples and Brosius. 1996).

In 2001, engineers studied the earthquake risk, and came to the conclusion that there is a risk of dam failure through seismic activity. So much so, that the Director of the Kansas Geological Survey, M.Lee Allison, recommended that 'the dam should be seismically retrofitted, (or) removed, or the reservoir drained in order to reduce or eliminate the risk' (Petterson, 2001). USACE Project Safety Manager Bill Empson quantified that a risk of an earthquake large enough to significantly damage the dam would need to be of magnitude 5.7 on the Richter Scale, higher than the largest earthquake ever recorded in Kansas by 0.2 (Steeples and Brosius, 1996). Yet, there is a 3% risk of such an event occurring in the next 50 years (Petterson, 2001).

Officials considered this risk significant enough to take action, and after consideration of the "do nothing" approach and other alternatives, they came in favor of stabilizing the layers of sand beneath the dam with Portland concrete columns (Mayes, 2002). This course of action will cost the State, nearby cities and businesses along the Kansas River the remainder of the $196 million not covered by federal funding. The 7-10 year construction will unavoidably interfere with normal recreational use of the area.

Public awareness reached a new high in the spring of 2001, with various newspapers voicing public opinion of plans to reinforce the dam. The media publicized concerns about the impact of the construction on leisure activities and monetary cost to the state (Mayes, 2002; Watson, 2002). In the light of more recent concerns and from these findings, the USACE (2001a) make particular reference to their consultation with experts at every stage, from original design and construction in the 1950s, to the more recent "Dam Safety Assurance Program".

Tuttle Creek Dam was built to hold back a specific magnitude of floodwater, designed from conditions of flooding in 1903 and redesigned after the flood of 1951 (Meyer, 1962). Figure 4.4 shows the extent of floodwater that can be stored together with other storage allocations of Tuttle Creek Reservoir and Dam, as elevations above mean sea level (amsl). With similarly sized projects, the floodwater storage capacity is often calculated from knowledge of flooding with a 1% chance of occurring in a given year (a 100-year flood), recognizing that higher flood levels would have a smaller probability of taking place (USACE, 1976). The problem with this is that whilst the risk is low, floods have the potential to occur more often, and even to a greater magnitude, it is just less likely (Tobin and Montz, 1997). An incident of such greater magnitude did occur in

1993, when water had to be released down the spillway, and in fact, evidence suggests that the flood of 1951 would also have exceeded the storage capacity of the dam (USACE, 2001e; Meyer, 1962). Global climate change and the variability of precipitation and stream flow expected in the Great Plains over the next century will likely increase the frequency of these extreme events, posing doubt on the structural limits of the dam, as with many flood control structures (Mileti, 1999). The very idea of continuing to control flooding in the same manner as the present comes into question from the local impacts of a changing global climate.

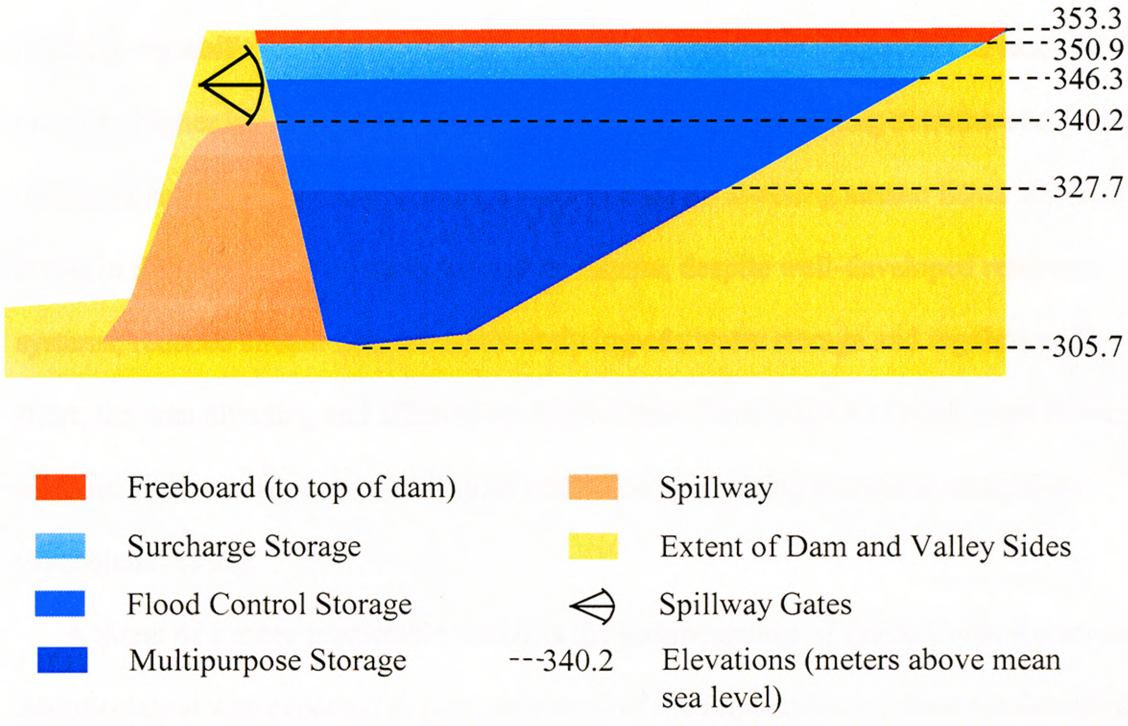


Figure 4.4: Elevations of Storage Allocations, Tuttle Creek Reservoir. (USACE, 2001f)

Projections for climate change in the Central Great Plains include increased temperatures, mainly minimum temperatures, and increased precipitation variability in many areas (Ojima and Lackett, 2002). The Hadley and CCC global climate models project minimum temperatures in northeast Kansas to increase by up to 7 degrees Celsius, maximum temperature by up to 9 degrees Celsius, and average annual precipitation to vary from 100mm less to 200mm more. This has significant bearing as current minimum temperatures in the Central Great Plains are around freezing point (0 degrees Celsius) and changes in precipitation have a direct relation to stream flow.

USEPA (1998) and Ojima and Lackett (2002) suggest implications of predicted moisture variability and a warmer climate in the Great Plains. The estimated result is based on higher late winter and early spring stream flows increasing extreme events, with increased summer evaporation under a warmer climate lowering stream flows and lake levels in the dry summer season. In eastern Kansas, despite well-developed reservoir systems, reduced stream flow could severely impede water storage and regulation. In short, the area affecting and affected by Tuttle Creek Dam could be facing more extreme seasonal and inter-annual variability of water flows, requiring additional mitigation (Wendland, 1993).

A threat of a more predictable nature is the sedimentation of Tuttle Creek Reservoir. Sedimentation was expected as part and parcel of the impoundment, since the damming of the river halts the flow of the water, its suspended load and bed load. Even though sediment deposition was expected, the effect of the advancing mudflats was not entirely understood (Combs, 2001). When the dam was built, it was perceived that much of the sediment would collect on the lakebed (USACE, 2001d). Instead, however, delta-like deposits have accumulated, with a variety of repercussions. The consequent mudflats offer wildlife habitat, but with marinas filled and water up to a kilometer away from dock facilities, use of recreation sites as proposed is inhibited.

An added complication to the situation concerns local wildlife. Migratory waterfowl, native shoreline birds and the fish stocks of the lake have helped reestablish the endangered Bald Eagle in the area (USDI, 1995; C.Anderson, pers. comm., 2003). This trend for wildlife additions to the area is enhanced by sedimentation of the reservoir's upper sections. The mud flats offer insects, waterfowl and mammals a habitat. Thus any decisions for the future of the Tuttle Creek project must include potential consequences to wildlife that are assisted by the mudflats and wetlands created by the sedimentation.

The establishment of parks and recreation areas around Tuttle Creek Reservoir has further increased the number and types users of this multi-resource facility. This year, Tuttle Creek Reservoir and State Park were declared fifth and seventh most visited of parks and lakes in Kansas, respectively boasting approximately 700,000 visitors (KDOCH, 2003). The loss of the reservoir and parks as a resource would not be well received, and would cost the city of Manhattan and surround area millions of dollars each year in lost revenue (D.Bayes, pers. comm., 2003).

Identification of Areas within the Dam Project

There are numerous facets to the Tuttle Creek project, different locations and different agencies managing them, all with various agendas. Most of the areas within the project lands are open to the public for recreational uses. Table 4.1 outlines the areas currently incorporated in the Tuttle Creek project, and who is responsible for managing them.

Location		**Controlling Organization**
Spillway		USACE (KCD)
Outlet works		USACE (KCD)
Dam		USACE (KCD)
Visitor's Center		USACE (TCP)
Reservoir		USACE (KCD)
Parks	River Pond SP	State/Co. (KDWP)
	Spillway SP	State/Co. (KDWP)
	Carnahan Creek	Pottawatomie Co.
	Randolph SP	State/Co. (KDWP)
	Fancy Creek SP	State/Co. (KDWP)
	Outlet	USACE (TCP)
	Tuttle Creek ORV	USACE (TCP)
	Stockdale	USACE (TCP)
	Tuttle Creek Cove	USACE (TCP)
	Observation point	USACE (TCP)
	Spillway Cycle Area	USACE (TCP)

*TCP = Tuttle Creek-based USACE *KCD = Kansas City district USACE

Table 4.1: The Constituent Parts of the Current Tuttle Creek Project, and Management Organizations.

The USACE manages the 4,998-hectare Tuttle Creek Reservoir and an additional 8,094 hectares of land around it. Six parks around the reservoir are managed and maintained by the USACE; these parks include paved access roads, utility systems, campsites, boat ramps and picnic grounds, with two of the parks devoted to off-road vehicle enthusiasts (USACE, 2002d). Some maintenance activities are contracted to the private sector. Mowing, trash collection and facility cleaning are a few of the activities that are performed by private contractors for the USACE.

A seven-member commission advises the KDWP on how to best oversee parkland management in Kansas (KDWP, 2003). The driving forces behind the Commission's actions are the goals and objectives of managing and promoting the wildlife and natural resources of our state. At Tuttle Creek, KDWP runs several of the state parks, but most specifically to the future of the project, River Pond Lake and State Park and the newly forming wetlands.

Management Organizations

The Tuttle Creek project is run almost entirely by the USACE, with KDWP overseeing the recreational use of some parks within the project and managing others (See Table 4.1 and Figure 4.5 for details). Because of this, the focus of the research paper's investigation into the organization for the future of this multi-resource facility will concentrate on the USACE and KDWP organizations. However, since this is a multi-resource facility, some mention and consideration will be made as to other stakeholders and interested parties.

Management of the project is handled by the USACE. They constructed and now run the dam, controlling the outflow of the reservoir from their Kansas City office (USACE, 1976). The organization of the USACE and how its structure fits into the management of the Tuttle Creek project can be seen in Figure 4.5. This Figure also shows how KDWP falls into the management system.

The USACE mission is to provide quality, responsive engineering services to the nation including:

- Planning, designing, building and operating water resources and other civil works projects (Navigation, Flood Control, Environmental Protection, Disaster Response, etc.).
- Designing and managing the construction of military facilities for the Army and Air Force. (Military Construction).
- Providing design and construction management support for other Defense and federal agencies. (Interagency and International Services)

The USACE is made up of approximately 34,600 civilian and 650 military men and women. Military and civilian engineers, scientists and other specialists work in both engineering and environmental matters. The diverse workforce of biologists, engineers, geologists, hydrologists, natural resource managers and other professionals attempt to meet the demands of changing times and requirements as a vital part of the US Army.

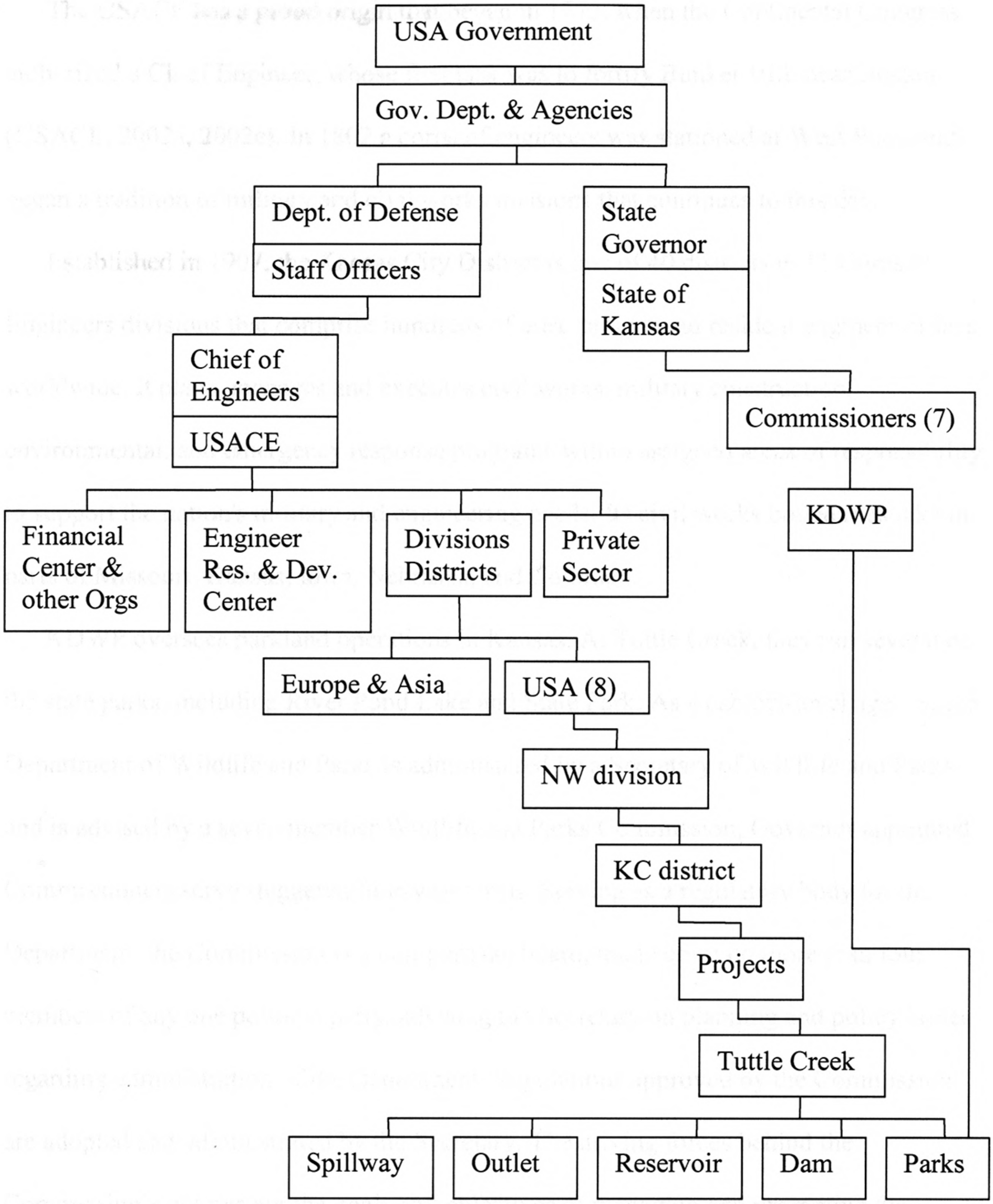


Figure 4.5: The Organizational Structure Between the Government of the USA and the Tuttle Creek Project.

The USACE has a proud origin that began in 1775, when the Continental Congress authorized a Chief Engineer, whose first task was to fortify Bunker Hill, near Boston (USACE, 2002a, 2002e). In 1802 a corps of engineers was stationed at West Point and began a tradition of military and civil works missions that continues to this day.

Established in 1907, the Kansas City District is one of 40 districts in 11 Corps of Engineers divisions that comprise hundreds of area, project and resident engineer offices worldwide. It plans, manages and executes civil works, military construction, environmental, and emergency response programs within assigned areas of responsibility to support the nation's military and engineering needs. Its civil works boundaries take in parts of Missouri, Kansas, Iowa, Nebraska, and Colorado.

KDWP oversees parkland operations in Kansas. At Tuttle Creek, they run several of the state parks, including River Pond Lake and State Park. As a cabinet-level agency, the Department of Wildlife and Parks is administered by a Secretary of Wildlife and Parks and is advised by a seven member Wildlife and Parks Commission, Governor appointed Commissioners serve staggered four-year terms. Serving as a regulatory body for the Department, the Commission is a non-partisan board, made up of no more than four members of any one political party, advising the Secretary on planning and policy issues regarding administration of the Department. Regulations approved by the Commission are adopted and administrated by the Secretary. The driving forces behind the Commission's actions are the goals and objectives of managing and promoting the wildlife and natural resources of the state (KDWP, 2003).

As a public steward of Kansas' natural resources, the mission of the Department of Wildlife and Parks is to:

- Conserve and enhance Kansas's natural heritage, its wildlife and its habitats, to assure future generations the benefits of the state's diverse, living resources.
- Provide the public with opportunities for the use and appreciation of the natural resources of Kansas, consistent with the conservation of those resources.
- Inform the public of the status of the natural resources of Kansas to promote understanding and gain assistance in achieving this mission.

The Department's mission statement reflects state law that KDWP is responsible for management of the state's living natural resources. This responsibility includes protecting and conserving fish and wildlife and their habitats, while providing for the sensible use of these resources with associated recreational opportunities for the public. The Department is also responsible for providing public outdoor recreation opportunities through the system of state parks, state fishing lakes, wildlife management areas, and recreational boating on all public waters of the state (KDWP, 2003).

There are some conflicting interests apparent from the mission statements of the two major management organizations. The USACE do consider environmental protection as part of their mission statement, but in that very same sentence building and designing is clearly included. This strongly suggests inclusion of structural components to their projects.

Also contrary to the KDWP, the USACE have distinct and obvious links to the USA Department of Defense. This primarily presents them management and constructional roles for military facilities, reducing the likelihood of their incorporating softer approaches.

Plainly evident in the KDWP mission statement are public and environmental conservation interests. This would seem to give them an air of accessibility to environmental consideration and answerability to the American public. This answerability does not seem apparent in any researched USACE material.

The two organizations are also organized quite differently. The USACE follows a top-down administration-style, whereby one figurehead leads and oversees all, with project planning and management stemming from successive branches from the leadership core. The KDWP stems from the same starting point as the USACE and also is supervised by a sole person, although this time it is the state governor answerable to the electorate. The KDWP also differs structurally as decisions are made from input given by a politically diverse group of short-term commissioners, with practices overshadowed by federal recommendations.

The difference in the organizational structure of the two is also suggestive of how policy changes may occur. The election of state positions and their limited term-life would suggest that publicly unpopular developments would have the potential to change more readily. Based solely on their mission statements, it is unfair to brand either organization as environmentally conscious and publicly aware, or to presume contrarily. As such, the various research materials encountered in this project have indicated significant levels of effort to make lands accessible to the public. Regardless of motive, both organizations do seem to want to make Tuttle Creek Reservoir and the surrounding parks available for community recreation, even if not for public scrutiny.

Chapter 5: Discussion of Hydrologic and Management Situation

Sedimentation

Construction of Tuttle Creek Dam by the USACE in the late 1950s flooded the Big Blue valley of Kansas. This alteration to the valley, creating a permanent multipurpose water storage pool, was to enable flood control and to provide sufficient flow for navigation downstream on the Missouri River (USACE, 2001c). Both of these original functions currently endure and uses have developed for the extensive waters and surrounding land; however, as with all lakes and reservoirs, Tuttle Creek Reservoir is only a temporary structure. Under such conditions, it was expected to eventually fill with sediment to a level where it could not be used for storing water for anything other than the purpose of flood control; that is it would no longer store water with which to release in order to provide regulated flows downstream, as it currently does (Scott, 2003), nor would it be useful for sailing or other recreational pursuits that involve the reservoir. According to the most recent projection, 75 years remained until sediment reached the dam in 2076, at 327.7m above mean sea level (amsl), the multipurpose storage level (USACE 2001d).

Sedimentation results from a drop in river velocity as the river deposits its sediment load to achieve a state that it can accommodate. The water gets from a to b, carrying its load, and depositing it to smooth the change in slope caused by the dam. The reservoir will keep capturing sediment until the sediment reaches the dam and spillway. At such time, the outflow station may become inundated with silt, rendering it unusable. This situation has been experienced already with many smaller dams (Goudie, 2000).

One viewpoint seemingly accepted by USACE officials is that reservoirs do eventually fill with sediment if they are not dredged. Moreover, the dominant perception fronted by the USACE in Tuttle Creek's case is that the scheme will have served its purpose for almost one century, a purposed deemed credible at the time under the principle of cost-benefit analysis. USACE officials give further credibility to this perception with the claim that flood protection will still be viable after the reservoir is full of silt. These comments reflect a perception that if the scheme lasts until 2076, then it is "mission accomplished". Publicly and privately the USACE is aware that something will have to be done with the scheme, but it is as if that would be a new problem to solve once this scheme has run its course through to the end. At such time, the loss of a habitat to wildlife, or of a recreational resource for local people, seems to be thought of as maybe just something that will unavoidably happen.

Engineering designs of the project allotted 0.23km³ for sediment storage (USACE, 2001f). After 38 years of having a reservoir full of water, the volume of sediment deposition in 2000 was an ahead of schedule 0.18km³ (USACE, 2001d). Whilst officials are aware that something must be done with the feature after the multipurpose storage pool is filled with sediment, they also admit to having no plan for such time (B.Empson, pers. comm., 2003). Astonishingly this status extends to there being no plan for the problem which is universally affecting hundreds of similarly aged dams across the country, and nobody seems in a rush to resolve this issue.

Should the lack of long-term planning not be problematic enough, the reservoir is not only filling with sediment slightly fast than the USACE projected, it is doing so in a delta formation rather than the expected lakebed accumulation (USACE, 2001d). Specifically, the USACE expected the sediment to settle mainly at the bottom of the reservoir over the decades, eventually filling it. Up to such time, the reservoir could still hold water and accommodate recreation on its waters and in the numerous lakeshore parks.

Conversely, the Big Blue, Little Blue and Black Vermillion Rivers each bring their suspended loads to the long, thin Tuttle Creek Reservoir, and the load is settling close to where the inflows meet the calm waters of the reservoir. The settling of sediment and consequent delta formation where each tributary enters the reservoir poses no present problem for the release of water for navigation on the Missouri River, nor does it alter the floodwater storage capacity any more than a bottom-up process would, but it does have a great impact on the local environment and recreational uses.

Tuttle Creek Reservoir has shrunk to less than half its original surface area, with its northernmost shore falling short of the Randolph bridge by approximately 1 kilometer, as can be seen in these two photos taken in September 2002 (Figures 5.1 and 5.2). The reservoir remains south of this mid point year-round (G.Wurst, pers. comm., 2003).

Figure 5.1: Photograph Showing the Sedimentation Under Randolph Bridge (September, 2002).

Figure 5.2: Photograph Showing the End of the Reservoir 1 km South of Randolph Bridge (September, 2002).

The inconsistency between expected and actual sedimentation patterns poses several problems for wildlife, recreation and planning. Fancy Creek State park was designed to be a camping ground and marina. It is now located over two kilometers from the lakeshore. No longer can boats moor there, or campers stay to swim near their RVs. The site also lost its drinking water supply in the flood of 1993; further reducing visitor numbers (G.Wurst, pers. comm., 2003).

There are positive consequences to the sedimentation pattern, though, largely for waterfowl. The mudflats provide an excellent place for migratory birds to settle and for native wetland species. The sediment conditions also present the possibility of observing wildlife and hunting. The altered landscape can similarly offer the potential for fish and fishing.

The wetlands to the north of Tuttle Creek Reservoir have been recently developed under management of the KDWP (C.Anderson, pers. comm., 2003). Although yet to be declared a wildlife refuge area, a small, but significant 145-hectares of wetland area has been enhanced to provide food and shelter for migrating shorebirds and waterfowl (USACE, 2002c). These areas provide excellent hunting and viewing opportunities.

The increasing value held for wetlands is a glimmer of hope for the message from President Carter in 1977, in which he heralded their worth and recognized the economic and environmental cost of the structural alternative, dams (White and Waterstone, 1977). Although the dam is still in place, consideration and value is being given to both human and to natural components of the situation at Tuttle Creek Reservoir (Midttømme *et al.* 2001).

The lack of plans for the future leave it unknown whether, when the reservoir is filled with sediment, the rivers can confluence and cut through the lakebed sediments, allowing the outflow tubes to continue releasing water. A decade ago, Engineers still held some confidence that the despite advance of sediment, the suction from the pressure of water leaving through the bottom-fed outflow tubes would leave a few square-kilometers of water behind the dam, although explanation of this cannot be found in the literature (G.Wurst, pers. comm., 2003).

If the tubes cannot continue to operate when the reservoir is filled with sediment, the flow will search out an alterative route, the spillway is engineered to be the next lowest exit for water from behind the dam, at an elevation of 340.2m (amsl), after the outflow tubes at 305.7m (amsl) it is the likely location for outflow. So, whilst the dam could still be useful for future flood control, it may well need to be reengineered in some way to enable water to keep flowing downstream to the Kansas River.

In its present configuration, the spillway would be a poor outflow channel. The damage of the flows of the 1993 floodwater to the spillway is well documented (Figure 5.3); continuous flow down Spillway Canyon could have the destructive force to create a knick point advancing headward into the polluted sediments. The sediment in Tuttle Creek Reservoir is polluted with arsenic, copper, other metals and trace elements that would only worsen the affect of such a rapid release of sediment on downstream areas (Juracek and Mau, 2002).

Figure 5.3: Damage to Tuttle Creek Spillway after the Flood of 1993. (USACE, 2002b).

Flooding

Flooding has been a problem to settlements throughout the Big Blue and Kansas River valleys before and since the construction of Tuttle Creek Dam. It is argued by the USACE (2001c) that the dam lessens the possibility and extent of flooding to cities and development in the flood plain immediately downstream. This may be correct on one level, as floods are less frequent than they might otherwise be, and during the 1993 flood the floodwater had the potential to have been higher than even the 1951 flood without the dam.

However, the sense of security embedded in these cities has encouraged development like the trailer parks created south of the dam 15 years ago, and the retail developments near the Big Blue River's confluence with Kansas River (G.Wurst, pers. comm., 2003). These areas of the flood plain might otherwise have intelligently been left undeveloped, or developed only for uses easily reestablished, or with limited loss, after a flood. And so the cost from floods like that of 1993 might actually have been significantly more because of damage to, and loss of, development that was encouraged by the construction of the dam. The losses in 1993 were also worsened by people being ill-prepared and not expecting a flood.

The flow of the Big Blue River is limited and regulated by the USACE to approximately 1000 cfs, under normal, current conditions. The mean flow of water prior to the construction of the dam was more in the range of 2000-3000 cfs (USGS, 2002). An unpublished study by Archer and Reker (2002) found that a return to a flow of 3000 cfs today would cause widespread problems, as there is significant development in areas with a high-risk of flooding. These same areas could actually suffer serious flooding with even a small increase above such flow rates. This is proof of a condition labeled by Cutter (1996) as social vulnerability, whereby a society suffers from a hazard because structural defenses remove their knowledge of its existence.

Conditions of flooding were experienced throughout the Midwest of the USA in 1993. Specifically in the Big Blue and Kansas River valleys, as the threat became apparent, rising floodwater from high precipitation rates was held back by Tuttle Creek and other dams in order to limit the already rising stream flows far downstream in St. Louis. This was to prove to be a fight against an inevitable occurrence as areas outside the city of St. Louis experienced major flooding. As water rose behind Tuttle Creek Dam it began to climb up the spillway gates. A decision was made to open the gates and controllably release the water, before it flowed uncontrollably over the gates. However, lady luck was not shining on the USACE that day, as the erosive power of a combined spillway and outflow tube release of maximum 60,000 cfs damaged the spillway gates, jamming them open as a result of the massive flow of water (Seaton, 1993). As the released water began to flood Manhattan and other cities downstream, it could not be stopped; the gates could not be closed. The question has to be asked as to whether the costs would have been as great if the flood was expected, or if the goal was not to focus the importance of the situation on such a far-off location as the Missouri River, rather than the local area.

Impact of Global Climate Change

A changing climate impacts the environment and creatures living in that environment. The greatest changes to the global climate that could affect the climate locally around Tuttle Creek Reservoir are changes in temperature and precipitation. According to Ojima and Lackett (2002) such changes might occur in the central Great Plains region.

It is suggested that maximum temperatures could rise by up to 9°C and minimum temperatures by up to 7°C. However, the seasonal changes in temperature may prove more worrisome should the researched possibilities become a reality, because whilst summer and fall temperatures may increase by a range of 3°C to 5°C, winter and spring temperatures may increase by a range of 2°C to 7°C. The greater increase and more variability of the winter and spring temperatures is suggestive of more extreme conditions

(Ojima and Lackett, 2002). This situation is exacerbated by predictions of greater spring precipitation increases of up to a 50mm, and made more complex by more extreme events also being anticipated.

The effect of increasing maximum temperatures will be most felt as a seasonal impact. The rise in maximum temperatures would increase summer evaporation, reducing stream flow rates. The increase of spring temperatures may bring about more storm events. With temperature changes affecting stream flow, conditions become even more variable when considering precipitation changes. The suggestions for average precipitation change range from increases to decreases, suggesting that a worsened situation of seasonal variability of flows may be experienced.

These changes have distinct application to consideration of water resource management (Wendland, 1993). The 1993 flows exceeded flood control structures; more irregular future flows and more extreme events would be harder to manage, especially behind a dam with less storage space for floodwater because of sedimentation. Even if control was attempted, there could always be that record-breaking flood to make current flood control attempts obsolete (Tobin and Montz, 1997).

Evaluation of Management Situation

Although the dam was intended to benefit human habitation, its existence poses potential threats to those in the immediate area. In addition to social vulnerability from flooding caused by large rains and upstream flows, there is the possibility of an uncontrolled breach of the dam. The seismic threat to the dam structure was evaluated prior to construction, but recent pressure and reevaluation have led to enhancement of the dam due to start later in 2003 (Mayes, 2002). The extent of construction is documented to be such that it will take 7-10 years and will cost up to $200 million (G.Wurst, pers. comm., 2003). $2 million has already been released for implementation of a downstream warning system, which will alert businesses and residents should the dam breach (G.Wurst, pers. comm., 2003). Whilst other options and a "do-nothing" alternative were considered, the USACE commitment to structural solutions offers significant suggestion for, so far undocumented, plans for the future of the project after its economic life ends in 2061.

There is evidence of the USACE considering potential nonstructural future uses of projects. USACE publications of the 1990s show explicit examples of collaborative resource management. As the twenty-first century dawned, the USACE put to print their plans for recreational use of all their water resource projects across the country, with emphasis on valuing four facets of natural resource recreational management: individuals, communities, the economy and the environment (USACE, 1999). This communicates advocating the connection of people and their environment, through collaboration with other government departments, community groups and the public at large.

The adoption of "grass-roots" development and collaborative resource management is exactly what is needed in the USACE water resource management projects. The USACE needs to now extend these principles to the principles of its structural endeavors. To clarify, rather than an imposing dam giving the distinct impression of an organization bent on control, what if a softer approach were taken, in which community-focused projects encouraged development away from the flood plain and out of danger, replacing them with recreational pursuits around the river. This is exactly the kind of practice visible at Grand Forks, North Dakota.

After crippling damage from local flooding in 1997, when enormous losses were incurred along the flood plain, a reevaluation took place (Parvey-Biby and Greendahl, 2002). With damages of $2 billion, amounting to $40,000 per person in the community, it was recognized that some major changes had to happen. The city of Grand Forks sits along a stretch of the Red River which flows north on a very gentle gradient; this makes the risk of flooding very high, especially when development straightens and narrow the channel, and cold winters give increased risk of ice-dams and high flows from spring thaws.

Addressing the problem of flooding at Grand Forks, the Mississippi valley division of the USACE implemented a system of acquiring land next to the river in order to put a riparian buffer "greenway" into practice. Riparian buffers are areas of vegetated land next to the river that slow the release of runoff into the river, and during floods, protect channel banks from erosion.

The Mississippi valley division, St. Paul district of the USACE, further reduced the risk of future flood and damage from them by limiting development in the flood plain, creating public recreational areas in this "greenway", removing some small dams, replacing them with intermittent rapids, and using levees outside of the "greenway" as an extra defense. The Management of the Grand Forks Greenway Project shows collaboration with different federal government departments, state government agencies, municipal administrations and people and businesses in the local community.

KDWP, as a state agency, has a natural interest in outdoor recreation across Kansas, managing many specific park locations. Five of the parks surrounding Tuttle Creek Reservoir are managed by KDWP, but they have little, if any, say in the future of the project. Local employees of KDWP at the Tuttle Creek project see their management role as projecting and enhancing wildlife, for its own good and for the public to enjoy (C.Anderson, pers. comm., 2003). The management of the project by KDWP has adjusted for the changes induced by sedimentation, and so they do not see why this situation should change.

However, the dam and reservoir caused the existence of the parks and created the newly developed wetlands on the north end of the reservoir, and should the USACE's future plans for the project persist with an emphasis on structural alteration, the management practices of KDWP could be disrupted, or the land being managed could entirely alter. Access to parks during the seismic retrofit is already going to be limited (Mayes, 2002).

KDWP does hold management responsibility to one feature that may prove vital to future development of the project: River Pond Lake and the accompanying state park. River Pond Lake and the surrounding area are an important transition between the dam and the Big Blue downstream, draining water below the dam and absorbing excessive outflows from the dam. Should the outflow station's function come into question after 2076 because of sedimentation, this area may prove even more vital as a transition between the downstream confluence with the Kansas River and the higher elevation of the river upstream of the dam.

Managing the parks themselves, KDWP seem to exult four key factors:

- Habitat
- Wildlife
- Recreation
- Economic interests

Ecocentrics, defined by Midttømme *et al.* (2001) as those with an approach supportive of the principles of bioethics, may like to see planning emphasize and implement the first three areas, or even the first two. Technocentrics, with an approach unrestrictive of consumption and being market driven (Midttømme *et al.*, 2001), would like to see only the last two, if not just the economic interests. However, in the name of reason and project sustainability, it is more sensible and will have a better chance of succeeding if all four are brought into balance. Utopia is a way off, but these four areas are an important guide when walking that path.

One important addition to this group of themes to be considered is awareness through communication. This means both educating business and people in communities about their local resources, and consulting with them. A two-way line of communication is being found to be increasingly pertinent for public works projects. Consultation with D.Bayes (pers. comm., 2003) of the Manhattan Conventions and Visitors Bureau, showed just how much value Tuttle Creek Reservoir has to the local community. With the reservoir and parks receiving approximately 700,000 visitors and generating millions of dollars in revenue each year, loss, or even interruption to the project, would be deeply felt in the local community (KDOCH, 2003; D.Bayes, pers. comm., 2003).

Referring back to the mission statements of the two main organizations involved in the Tuttle Creek project, successful future planning will call for less "structural" implementation from the responsive engineering of the USACE, and for more of KDWP's conservation and community involvement.

Engineering For the Future

This brings forth speculation of the alternative scenarios for the future of the dam structure, and subsequently a look at the options for the flow of the Big Blue River and for the surrounding area.

- **The do nothing alternative**

  The Big Blue River could run down the increasingly sediment filled valley, and the outflow station continue to release the water to River Pond Lake, and in turn on to the Kansas River. Additionally, the dam could remain, providing flood control.

- **The dam removal strategy**

  With the dam removed, the Big Blue River could return to an uninhibited flow downstream to Kansas River. Some Engineering will be necessary, at least initially, so as to accommodate the change in slope left after the dam has been removed and to accommodate the initial increase in sediment transfer downstream.

- **The reengineered dam structure**

  The Big Blue River could run through the newly deposited wetlands, but then through a reengineered spillway, continue on to River Pond Lake, and in turn on to the Kansas River. Alternatively, an Overholser-style diversion channel could be incorporated to the current system. With careful planning, the dam might still provide flood control for either system.

First, taking the “do-nothing” alternative, the sediment would build up and keep adding to the wetlands to the north until all that would remain would be a river winding through wetlands to the presently used outflow tubes. As sedimentation continued it would surely prove problematic to the outflow tubes; should the tubes become nonfunctional because of heavy siltation, the flow would then migrate to the exit with the lowest elevation, which would be the spillway. Whilst being a blessing to wetland plants and creatures, and perhaps to hunters and fishermen, this course of events would also have inherent problems.

During the flood of 1993 the spillway was tremendously damaged, and although the water flow would usually be a lot less, it would be for a much longer period. Erosion on the spillway occurs because of the extreme difference in elevation between the reservoir and the river below; as such, a knick point would likely develop and migrate headward, eventually reaching the spillway gates. Should the knick point erode headward into the sediment upstream of the spillway, such soft deposits would erode quickly, taking the wetland habitats and pollutanted sediment downstream.

Removal of the dam may be best in the long run for a utopian result, but removal would require structural alteration of hydrology downstream because of the elevational differences of the river levels. If the dam was removed and the Big Blue River was left to its own devices, the unregulated flow would inevitably waterlog downstream areas, even during periods of normal flow rates. What is more, during peak flow period, with no dam, there is no such assistance for flood prevention.

Dam removal would also increase the sediment load downstream. Although it was reduced by dam construction in the first place, the soft sediment deposits accumulated behind the dam structure would easily be eroded and transferred downstream if the dam were removed, along with the pollution attached to them. This increased sediment load would dramatically alter the river downstream, adversely impacting the water quality on the Kansas River, both directly and indirectly affecting the wildlife dependant on those habitats. Dredging such a large amount of sediment prior to dam removal would not be cost effective, and would result in a large amount of polluted sediment needing to be stored somewhere.

Removing Tuttle Creek Dam would remove the security felt by communities from its existence. Whilst this would remove the social vulnerability, there are problems with going "cold turkey" like this. For one, there has been development in areas of the floodplain that were previously threatened, but that had the threat of flooding dramatically reduced by the placement of the dam. Removal of these developments would both be costly and take time. Additionally, it took people time to adjust to the idea of constructing the dam, so it would seem logical that it will also take time to get people used to the idea of its destruction, so as to not face unreasonable local opposition towards it. Most of the dams in the USA that have already been removed were done so because they had become obsolete, in that their purposes were no longer applicable to current situations, or that their benefits did not outweigh their economic cost to maintain them or the ecologic damage they imposed (American Rivers, 2002).

In order to avoid some of the problems associated with the "do-nothing" strategy and with removing the dam, reengineering the area seems inevitable. But there are options as to the path to take with in the reengineered option, namely the adoption of soft or hard engineering methods.

The new structure could take the form of a permanent sluice or lock, equivalent, but on a smaller scale to the control structure on the much larger Mississippi River in Louisiana that stops the river from taking the lower elevation route via the Atchafalaya River (McPhee, 1998). On the Big Blue River, this might take the form of a permanent channel flowing from the reservoir area downstream to the confluence with the Kansas River. It could be engineered on, or to the east, of the current spillway. Because of the massive difference in elevation between the Kansas River and the Big Blue River upstream from the dam site, the channel would need to be controlled with a closeable, tapered exit, similar to the current outflow tubes but on the surface. However, with the Atchafalayan method, erosion is astonishing and so often the battle is almost lost in Louisiana during high water flows. This would prove costly in the case of the Mississippi or the Big Blue River.

Investigation of existing publications shows this tactic to be so far untried on dams facing terminal siltation, although there is a proposal to divert the flow around dams rather than remove them in the Pacific Northwest (Digital Studios, 2003). The Big Blue River alternative would be similar to, but permanently flowing form of, the diversion in operation beside the Overholser Dam and Reservoir in Oklahoma (Stout *et al.* 1985).

Another hard engineering method would be the prolonging of Tuttle Creek Reservoir's life by constructing a temporary bypass channel, similar to that used on the Overholser Reservoir, Oklahoma (Stout *et al.* 1985). This process uses stream channel sediment load monitoring upstream of the reservoir. In the event the river is deemed too loaded, the water is temporarily diverted away from the reservoir into lower sections of the basin, or into sediment traps like the example given for Melton Mowbray, England (Midttømme *et al.*, 2001). This would prolong the life of the reservoir, but not indefinitely, as the Overholser still receives sediment, but at a slower rate than without the system (Stout *et al.* 1985; Holden and Emmert, 1998). Additionally, the sediment sent downstream would alter the habitats there.

Softer engineering solutions could involve retaining the dam and sending water down the spillway, but implementing a system of rapids to bridge the elevational gap upstream and downstream of the dam, such as that successfully used in the Grand Forks, ND, Greenway project (Parvey-Biby and Greendahl, 2002). This would require modifying the spillway, and maybe lengthening its course upstream, downstream, or both to do it successfully. This method would have multiple positive results: with the dam in place, there would still be a possibility of flood protection by damming the rapids, should the situation be dire. However, most important would be retaining the current position of the sediment upstream of the dam. With the sediment upstream, the wetlands remain useable, and the pollution can, at worst, be released slowly to downstream reaches of the river.

Whilst a system of rapids would provide a fish-friendly transition between elevations, the possibility of new recreation like canoeing and maintain a relatively stable knick point, problems could occur during high water flows. Incorporation of River Pond Lake into the system could provide an additional transitional medium between the elevated Big Blue wetlands behind the current dam structure and the stream channel confluence with the Kansas River. The lake will also act as a natural sponge for small floodwaters (Schmid, 2000), and provide some continuation of some recreational uses enjoyed on Tuttle Creek Reservoir.

There will be social impacts to this soft engineering scheme, some similar to those for the previous alternatives, though lessened. Despite the continued existence of the dam, there will be a higher risk of flooding since the spillway area will always be in use. Because of this, there will be social vulnerability. Likewise, developments downstream on the flood plain will be under threat. To over come this, adoption of community involvement and awareness will assist. The soft engineering of a rapids system can be implemented before the 2061 or 2076 deadlines, and whilst the current system is in operation. With awareness of the pending change, but maintained safety of the dam, floodplain development can be stopped and requisitioned, levée construction can be completed, and the community will have time to adjust.

Evidence of Such Plans Being Made by Organizations

As previously mentioned, USACE officials say they are aware of the issue of the life of reservoirs across the country, but as yet offer no unilateral solution, or a solution specific to Tuttle Creek (B.Empson, pers. comm., 2003). The last "master plan" for the Tuttle Creek project was issued over two decades ago, in 1982, but it contained no plan for a post-2076 project (G.Wurst, pers. comm., 2003); a more up-to-date "master plan" is expected in the next couple of years, but there is no evidence in USACE literature to suggest that it will contain plans beyond 2061 either.

The recent reevaluation by the USACE of the seismic threat at Tuttle Creek Dam suggests at least some support for a structural solution to the filling of Tuttle Creek Reservoir. However, the inclusion of alternatives and outsider interest in the decision-making process, even if not having other stakeholders included as decision-makers, is encouraging. Similarly encouraging is the recognition of a high-level USACE Tuttle Creek Dam official that environmental considerations will be incorporated into future decisions (B.Empson, pers. comm., 2003).

KDWP recently took over the management responsibility of the developing wetlands to the north end of the reservoir, for the benefit of wildlife and public use (C.Anderson, pers. comm., 2003). This is a positive step towards acknowledging the importance of wetlands and the need to manage them for wildlife and recreation. However, the KDWP has only a coaching role in the natural resources of the state, with no decision-making capabilities, it does not portend to the continued existence of the wetlands. It seems, instead, just to be a continuing process that parks located where sedimentation is most severe are either turned over to the KDWP, as is the case of Fancy Creek State Park, or are considered obsolete by the USACE and abandoned, as the Garrison and Baldwin Areas were (see Figure 4.2).

It appears that there may be some contention between KDWP and the USACE. KDWP takes management responsibility for the wetland environments created by USACE alteration of the natural environment. However, USACE can potentially alter the environment again, without needing the agreement of KDWP. So, in effect, KDWP is spending time and sources to manage an ecosystem that is not only changing, but might not be there in a few decades. Although KDWP publicly wants to be seen as managing the ecosystem to the best of its ability (C.Anderson, pers. comm., 2003), the organization must be considering how much to invest and to what extent wildlife should be encouraged into an area that may not be sustained.

It would seem imperative that lines of communication between KDWP and the USACE are not only open, but also widened to include mutual discussion of what future is to be managed for. At this point it appears that the KDWP is just the natural steward protecting the wetlands, and entirely dependant on the decisions of the USACE as to how the wetlands will evolve in the future.

It would be beneficial if the USACE would adopt some of the management strategies used by the KDWP, such as the focus on conservation expressed in the KDWP mission statement, rather than the focus on construction apparent in the USACE mission. Some evidence of this is identifiable in the USACE non-structural management, for instance the inclusion of community and environment in the USACE (1999) view on national recreation. What needs to happen is adoption of these values instead of the USACE perception of structural responses being best. In short, the USACE needs to realize that sometimes nature is not controllable, but must be lived with. Alteration can be made to human action as well as to natural environments.

Chapter 6: Conclusion

Sedimentation of Tuttle Creek Reservoir renders it a temporary feature on the landscape. By 2076, when it is forecast to be filled with sediment, the reservoir will become devoid of its original primary purposes of flood control and water storage to enable release for sustained navigation downstream, likewise other important uses of the reservoir such as recreation will also be threatened.

Although the USACE maintain that the dam will continue to be useful for flood control after the demise of the project's economic life in 2061, global warming projections pose doubt as to how a structure unable to ultimately stop flooding in 1993 can do so for more extreme and variable stream flows in the future. Seismic threat to the integrity of the dam's substructure only adds imperative urgency to consideration of the future of the project.

In addition, multiple facilitators currently utilize Tuttle Creek Reservoir. Uses have diversified from the original USACE purposes to include numerous recreational pursuits, basic and applied research, sanctuary for wildlife and as a water sports facility. These uses face change or even eradication without considerate planning.

Aware that the future of the Tuttle Creek project requires a decision, the USACE admit that no such decision has been made. The lack of a decision is indicative of a mindset of the environment as a resource, usable as is reasonable and similarly sustained as required. The recent decision to reinforce the dam to reduce seismic hazard despite monetary cost, a finite lifespan of the reservoir because of sedimentation, and a decade-long interruption to recreational activities, only acts to further cement this perception.

A further problem to the conception of future planning stems from the amount of time left before the end of the useful life of the reservoir. With only 73 years remaining until the reservoir is filled with sediment, most people working on the project will have long since retired. There is, therefore, a lack of motivation to consider what might happen to the dam, reservoir and its wildlife and recreational users.

The perception of the USACE differs from that of other government organizations. KDWP is making attempts to manage the dynamic and dwindling project parks and wetlands for public and environmental gain, for instance acting as steward to the newly developing wetlands to the north end of the reservoir. This stance is even beginning to be adopted by other branches and divisions of the USACE, such as the Mississippi valley division and the Grand Forks greenway project, as they adopt softer approaches to flood control like riparian buffers to slow runoff into rivers and systems of rapids to bridge changes in river elevation.

The clock cannot be stopped on structural modifications to water resources, nor can it be turned back. But since the landscape has been altered, it requires dynamic management in order to reduce environmental damage and even to improve the condition.

This study has found that Tuttle Creek Dam and Reservoir have problems similar to those faced by other flood control structures across the nation and in different countries. The dam and reservoir were conceived in an era of technocratic responses to natural processes that threaten human habitation. Now, with its continued existence in question, a decision is required as to the project's future. Sedimentation of the reservoir limits the continued usefulness of Tuttle Creek Dam for water storage, and the geology specific to the area results in high sediment delivery to the reservoir. Additionally the geology causes seismic threat to the structural integrity of the dam. Additional problems mount as thoughts turn toward the future; global climate change alone is suggested to result in increasingly variable stream flows and more extreme events.

Based on informal interviews with USACE officials and reading of USACE documents, it appears that the USACE has no plan to deal with the future of the reservoir. The multiple uses of the dam, including the original uses of flood control and navigation downstream, have developed to include many recreational uses and wildlife habitats. The diversity of uses is tantamount to a diversity of stakeholders, all which should be considered and consulted for a truly holistic and sustainable future.

The pre-dam landscape has been altered irreparably and new landscapes and uses have developed. As such, the study found it to be most sensible for a sustained, but improved future. This is to include the continued existence of the dam, so as to maintain some potential for flood control and to contain the sediment deposits and pollution behind it. Reengineering of the project would take the form of a system of rapids to accommodate the difference in elevation either side of the dam; this would also allow a continued flow of water at a more natural rate. River Pond Lake, downstream of the dam, would become an important transition between the flow over the rapids and the Big Blue River's confluence with the Kansas River. River Pond Lake and would also take an essential role as a location for recreational uses previously enjoyed on the reservoir. This future would also permit continued use of current parks and the newly forming wetlands to the north end of the project area by humans and wildlife. The developments would be sustainable, as they stabilize the processes involved whilst allowing for their dynamic nature, benefiting present users without compromising the needs of future generations of humans, wildlife or the environment.

Collaborative resource management of the Tuttle Creek project is imperative for its continued use under dynamic conditions for all the stakeholders. This will require the management organizations of the USACE and KDWP to collaborate with one another and with other local authorities in planning for the future of the project. The planning should include all human users and the environment. A decision here may furthermore offer distinct possibilities and insight a decision for a plethora of dams similarly under threat of foreclosure in the nation, and give food for thought around the World.

References

Abler, R. *et al.* 1971. Spatial organization: the geographer's view of the World. New Jersey: Prentice-Hall

American Rivers, 2002. "63 dams in 16 states to be removed." (http://www.amrivers.org/pressrelease/damremoval071802.htm) July 2002

American Rivers, 2003. "Wildlife restoration act: Pittman-Robertson." (http://www.amrivers.org/tableofcontents/wra.htm) February 2003

Anderson, C. 2003. Tuttle Creek Wildlife Biologist, KDWP. Personal communication, April 2003

Archer, J. and Reker, R. 2002 Unpublished. Manhattan area flood risk post Tuttle Creek Dam removal. Kansas State University, Department of Geography

Atkins, P. *et al.*, 1998. People, land and time. New York: John Wiley & Sons

Bai, X. and Imura, H. 2001. Towards sustainable urban water resource management: a case study in Tianjin, China. *Sustainable Development* 9(1): 24-35

Baish, S.K. *et al.*, 2002. The complex decisionmaking process for removing dams. *Environment* 44(4): 21-31

Bankoff, G. 2001. Rendering the World unsafe: 'vulnerability' as western discourse. *Disasters* 25(1): 19-35

Barbour, G.B. 1937. The Tennessee valley project. *Geographical Journal* 89(5): 393-405

Barrows, H.H. 1923. Geography as human ecology. *Annals of the Association of American Geographers* 13(1): 1-14

Bayes, D. 2003. Tourism Sales Manager, Manhattan Conventions & Visitors Bureau. Personal communication, April 2003

Chelikowsky, J.R. 1972. Structural geology of the Manhattan, Kansas, area. *Kansas Geological Survey* 204(4)

Collier, M.P. *et al.* 1997. Experimental flooding in Grand Canyon. *Scientific America* 276(1): 82-89

Combs, K. 2001. What lies beneath. *The Manhattan Mercury*, Flint Hills supplement: C1, 05/20/01

Cutter, S.L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20(4): 529-539

Dale, A. and Robinson, J.B. 1996. Achieving sustainable development. Vancouver: University of British Columbia Press

Dane, S.C. and Steinhacker, W. (*eds.*) 2003. Washington update: Congress passes inland flood warning bill. *Natural Hazards Observer* 37(3): 8

Digital Studios, 2003. "Salmon conflict issues" (http://www.cyberlearn.com/remove.htm) March 2003

Empson, B. 2003. Tuttle Creek Dam Safety Study Manager, Kansas City District USACE. Personal communication, February 2003

Ferrell, J. 1993. Big dam era: a legislative and institutional history of the Pick-Sloan Missouri Basin program. Omaha: Missouri River Division USACE

Freudenthal, L.E. 1933. Flood and erosion control as possible employment relief measures. *Science* 78(2029): 445-449

Gober, P. 2000. Presidential address: in search of synthesis. *Annals of the Association of American Geographers* 90(1): 1-11

Gore, J.A. and Petts, G.E. (ed.) 1989. Alternatives in regulated river management. Boca Raton: CRC Press

Goudie, A. 2000. The human impact on the natural environment, 5th ed. Cambridge, MA: The MIT Press

Graf, W. 1999. Dam nation: a geographic census of American dams and their hydrologic impacts. *Water Resources Research* 35(4): 1305-1311

Graf, W. 2001. Presidential address: damage control: restoring the physical integrity of America's rivers. *Annals of the Association of American Geographers* 91(1): 1-27

Handmer, J. (ed.) 1987. Flood hazard management: British and international perspectives. Norwich: Geo Books

Hedgpeth, J.W. 1944. The passing of the salmon. *Scientific Monthly* 59(5): 370-378

Higgs, S. *et al.* 2002. The ecology of dam removal: a summary of benefits & impacts. Washington D.C.: American Rivers

Holden, G.I. and Emmert, B.A. 1998. Spatial variability of sediment storage in Tuttle Creek Reservoir, Kansas. *Papers and Proceedings of the Applied Geography Conferences* 21: 42-47

International Rivers Network, 2003 "Three Gorges campaign." (http://www.irn.org/programs/threeg/) January 2003

Jamieson, D.G. 1980. Planning, design and operation of water-resource systems. In Operations research in agriculture and water resources: proceedings of the ORAGWA international conference held in Jerusalem, November 25-29, 1979. Yaron, D. and Tapiero, C. (ed.): 381-391. New York: North-Holland Pub. Co.

Jobin, W. 1998. Sustainable development for dams and waters. Boca Raton: Lewis Publishers

Jones, S. 1984. Glen Canyon Dam: and steel-arch bridge. Page: Sun Country Publications

Jun, X. *et al.* 2001. Enlightenment on sustainable management of water resources from past practices in the Bositeng Lake Basin, Xinjiang, China. Wallingford: Regional Management of Water Resources: Proceedings of a Symposium (Symposium S2) held during the Sixth Scientific Assembly at Maastricht

Juracek, K.E. and Mau, D.P. 2002. Sediment deposition & occurrence of selected nutrients and other chemical constituents in bottom sediment, Tuttle Creek Lake, northeast Kansas, 1962-1999. USGS Water-resource Investigations, Report 02-4048

K.D. of Commerce and Housing. 2003. "Top tourist attractions in Kansas." (http://kdoch.state.ks.us/NewsApp/news_single_release.jsp) April 2003

K.D.W.P. 2003. "About KDWP." (http://www.kdwp.state.ks.us/about/about.html) March 2003

Lindeborg, K. 1973. Evaluation of regional multipurpose economic benefits resulting from a water and related land resource development. Washington D.C.: Office of Water, US Department of the Interior

Los Angeles Department of Water and Power. 2003. "Water services." (http://www.ladwp.com/water) February 2003

Mann, C.C. and Plummer, M.L. 2000. Can science rescue salmon? *Science* 289: 716-719

Marsalek, J. *et al.*(ed.). 2000. Flood issues in contemporary water management. Dordrecht: Kluwer Academic Publishers

Marts, M.E. and Sewell, W.R.D., 1960. The conflict between fish and power resources in the Pacific Northwest. *Association of American Geographers* 50(1): 42-50

Mayes, K. 2002. Stabilize, but don't drain. *The Manhattan Mercury*, front page, 16/04/2002

McPhee, J. 1998. The control of nature. New York: Noonday Press

Meyer, P. 1962. Tuttle Creek Dam: a case study in local opposition. University of N. Carolina: Thesis (M.A.)

Midttømme, G.H. *et al.*(ed.). 2001. Dams in a European context. Lisse: A.A.Balkema Publishers

Mileti, D.S. 1999. Disasters by design: a reassessment of natural hazards in the United States. Washington D.C.: Joseph Henry Press

Mitchell, G. 1999. Demand forecasting as a tool for sustainable water resource management. *International Journal of Sustainable Development and World Ecology* 6(4): 231-241

Moore, J. and Moore, D. 1989. The Army Corps of Engineers and the evolution of federal flood plain management policy. University of Colorado: the Institute of Behavioral Science.

National Research Council (US) Rediscovering Geography Committee. 1997. Rediscovering geography: new relevance for science and society. Washington D.C.: National Academic Press.

Ojima, D.S. and Lackett, J.M. 2002. Preparing for a changing climate: the potential consequences of climate variability and change: central Great Plains. Fort Collins: Colorado State University

Parvey-Biby, M. and Greendahl, K. 2002. "Grand Forks greenway" (http://www.grandforksgov.com/Greenway/index.html) April, 2002

Pattison, W.D. 1990. The four traditions of geography. *Journal of Geography* 89(5): 202-206

Petterson, J.L. 2001. Engineers study earthquake risk at Tuttle Creek Dam. *The Kansas City Star*, 09/07/01

Petts, G.E. 1979. Complex response of river channel morphology subsequent to reservoir construction. *Progress in Physical Geography* 3(3): 329-362

Petts, G.E. 1984. Impounded rivers: perspectives for ecological management. Chichester: John Wiley & Sons Ltd.

Probe International, 2003. "Three Gorges probe." (http://www.probeinternational.org/pi/3g/index.cfm) February 2003

Proven Engineering Products Ltd. 2001. "Proven Energy: FAQ" (http://www.almac.co.uk/proven/) April 2001

Rasid, H. and Mallik, A. 1995. Flood adaptations in Bangladesh: is the compartmentalization scheme compatible with indigenous adjustments of rice cropping to flood regimes? *Applied Geography* 15(1): 3-17.

Rees, J. 1990 Natural resources: allocation, economics and policy. 2nd ed. London: Routledge

Reisner, M. 1987. Cadillac desert: the American West and its disappearing water. New York: Penguin

Reynard, E. 2001. Aménagement du territoire et gestion de l'eau dans les stations touristiques alpines. Le cas de Crans-Montana-Aminona (Valais, Suisse). *Revue de Géographie Alpine* 89(3): 7-19

Ring, I. *et al.* 1999. Regional sustainability: applied ecological economics bridging the gap between natural and social sciences. New York: Physica-Verlag

Saha, S. and Barrow, C. (eds.) 1981. River basin planning: theory and practice. Chichester: John Wiley & Sons.

Savory, A. 1999. Holistic management. 2nd ed. Washington D.C.: Island Press

Schmid, J.A. 2000. Wetlands as conserved landscapes in the United States. Ch..6 in Murphy, A.B. and Johnson, D.L. (ed.). 2000. Cultural encounters with the environment: enduring and evolving geographic themes. Lanham: Rowman & Littlefield Publishers, Inc. pp.133-156

Scott, M. 2003. Mizzou to get More Tuttle water. *The Manhattan Mercury*, 04/25/03

Seaton, E. (ed.), 1993. The flood of '93. *The Manhattan Mercury*, Supplement. 08/08/93

Steeples, D. and Brosius, L. 1996. "Kansas Geological Survey, public information circular (PIC) 3." (http://www.kgs.ukans.edu/Publications/pic3/pic3_4.html) March 2002

Stout, L.A. *et al.* 1985. Bathemetric changes in Overholser Reservoir. *Proceedings of the Oklahoma Academy of Science* 65: 69-72

Tellegen, E. and Wolsink, M. 1998. Society and its environment: an introduction. Amsterdam: Gordon and Breach Science Publishers

Tobin, G.A., and Montz, B.E. 1997. Natural hazards: explanation and integration. New York: The Guilford Press.

Thomas, D.H.L. and Adams, W. 1997. Space, time and sustainability in the Hadejia-Jama'are wetlands and the Komodugu Yobe Basin, Nigeria. *Transactions of the Institute of British Geographers* 22(4): 430-449

Trush, W.J. *et al.* 2000. Attributes of an alluvial river and their relation to water policy and management. *Proceedings of the National Academy of Sciences of the United States of America* 97(22): 11858-11863

U.S.A.C.E. 1976. Final environmental statement: operation & maintenance, Tuttle Creek Lake, Kansas. Kansas City, M.O.: USACE

U.S.A.C.E. 1999. Recreation: value to the nation. USACE

U.S.A.C.E. 2001a. Tuttle Creek Dam fact sheet: expert consultation on Tuttle Creek Dam. USACE

U.S.A.C.E. 2001b. Tuttle Creek Dam fact sheet: original project construction. USACE

U.S.A.C.E. 2001c. Tuttle Creek Dam fact sheet: project purposes and economics. USACE

U.S.A.C.E. 2001d. Tuttle Creek Dam fact sheet: sedimentation. USACE

U.S.A.C.E. 2001e. Tuttle Creek Dam fact sheet: spillway. USACE

U.S.A.C.E. 2001f. Tuttle Creek Dam fact sheet: the lake. USACE

U.S.A.C.E. 2002a. "Mission statement." (http://www.nwk.usace.army.mil/msn.html) February 2002

U.S.A.C.E. 2002b. "Tuttle Creek Lake's Spillway Canyon." (http://www.nwk.usace.army.mil/tuttlecreek/spillway.htm) March 2002

U.S.A.C.E. 2002c. “Wetlands.” (http://www.nwk.usace.army.mil/tuttlecreek/wetland.htm) March 2002

U.S.A.C.E. 2002d. “What we do.” (http://www.nwk.usace.army.mil/tuttlecreek/whatwedo.htm) March 2002

U.S.A.C.E. 2002e. “Who we are.” (http://www.usace.army.mil/Organized) August 2002

U.S.A.C.E. 2003. “Dam and river basin.” (http://www.nwk.usace.army.mil/tuttlecreek/dam.htm) March 2002

U.S.D.A. Forest Service. 2003. “Grey Towers national historic landmark: Gifford Pinchot.” (http://www.pinchot.org/gt/gp.html) January 2003

U.S.D.A. Natural Resources Conservation Service. 2003. “A story of land and people.” (http://www.nrcs.usda.gov/about/history/story.html) February 2003

U.S. Department of Energy. 2002. “Energy efficiency and renewable resources network.” (http://www.eren.doe.gov/) March 2002

U.S. Department of the Interior. 1995. Biologue series: Bald Eagle. U.S. department of the Interior: U.S. Fish and Wildlife Service.

U.S. Department of the Interior, Bureau of Reclamation. 2001. “Hoover Dam: how it all works.” (http://www.usbc.gov/lc/hooverdam/workings/main.htm) September 2001

U.S. Environmental Protection Agency. 1998. Climate change in Kansas. EPA 236-F-98-007i

U.S. Environmental Protection Agency. 2002. “The guardian: origins of the EPA.” (http://www.epa.gov/history/publications/origins.htm) June 2002

U.S. Environmental Protection Agency. 2003. “National environmental policy act.” (http://www.epa.gov/compliance/nepa/index.html) January 2003

U.S. Geological Survey. 2002. “Surface-water data for Kansas” (http://ks.waterdata.usgs.gov/nwis/sw) November 2002

U.S. National Park Service. 2000. “Crater Lake nation park administrative history.” (http://www.nps.gov/crla/adhi/adhi3a.htm) July 2000

Varis, O. and Vakkilainen, P. 2001. China’s 8 challenges to water resource management in the first quarter of the 21st century. *Geomorphology* 41(2): 93-104

Viladas, J.M. 1973. The American people and their environment – 1973: a study of national opinion and attitudes about environmental problems and their solutions. Washington D.C.: USEPA

Walmsley, J. *et al.* 2001. Indicators of sustainable development for catchment management in South Africa: review of indicators from around the World. *Water S. A.* 27(4): 239-550

Watson, M. 2002. 10-year construction project could stabilize dam. *Kansas State Collegian*, front page, 24/04/2002

W.C.D. 2000. Dams and development: a framework for decision-making: a report of the World Commission on Dams. London: Earthscan Publications

W.C.E.D. 1987. Energy 2000 : a global strategy for sustainable development : a report for the World Commission on Environment and Development. London: Atlantic Highlands

Weiss, D. 1999. "John Muir & I: the man, the trail, and the wilderness ideal." (http://www.ecotopia.org/about/JMI/ch05.html) June 1999

Wendland, W. 1993. Kansas climate with global warming: agricultural and other economic impacts. *Transactions of the Kansas Academy of Science* 96(3-4)

White, A. and Waterstone, P. (eds.) 1977. The President's environmental message. *Natural Hazard Observer* 1(4): 8

Winpenny, J.T. 1991. Values for the environment: a guide to economic appraisal. London: HMSO

Wurst, G. 2003. Tuttle Creek Dam Office, USACE. Personal communication, April 2003

Appendix I: Glossary

CRM: Collaborative Resource Management is the more inclusive method used by organizations for water resource projects in recent decades, to consult and include all stakeholders.

EIA: Also known as Environmental Impact Statements, Environmental Impact Assessments were developed from the National Environmental Policy Act of 1969 in order to incorporate environmental sensitivity into new developments, ensuring that all necessary steps are taken to protect the natural environment.

Holism: The theory that whole entities have an existence other than as a sum of their parts, used in this research paper as interpreted from Savory (1999) to mean that management of a multi-resource facility is better undertaken in collusion with each member part as well as considering what is best for the facility's purpose.

KDWP: Kansas Department of Wildlife and Parks is a cabinet-level agency administered by the Secretary of Wildlife and Parks. As a public steward of Kansas's natural resources, KDWP mission is to conserve habitats and involve the public, in the best interests of the State.

Multi-Resource Facility: Used in this paper in reference to water resource facilities, and their multiple uses, be they recreational, in the interests of humans or as habitats for wildlife.

Sustainable Development: Often used to describe methods of continuing a process indefinitely, the term is used in this paper more as pertaining to more sensible use of a resource, uses as dynamic as the facility and resource themselves, as determined by Jobin (1998). More specifically, since it is established in the paper that reservoirs are temporary, the uses of it should be in acknowledgement of this, as should the management of them.

Tuttle Creek Dam Project/the Project/the Scheme: refers to the area defined in the study area. This includes the dam, reservoir and adjoining parks.

USACE: the United States Army Corps of Engineers, a branch of the Department of Defense, developed from fortification constructors to provide quality, responsive engineering services to the nation including, and most known for, flood defenses.

Water Resource: refers to a feature providing water used for consumption, agriculture, recreation, wildlife and any combination of these and other uses. Features such as aquifers, rivers, lakes and coasts, although in this paper the resource refers to either reservoirs or rivers.

Water Resource Management: because of their multiple purposes and uses, water resources require very careful management. In the case of Tuttle Creek reservoir, management comes from the USACE, and so reference to water resource management refers to how they do so, or a comparison of an alternative.