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Institutional Assessment of Transboundary Water Resources Management

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1 Introduction

1.1 Transboundary water resources management

Water management first occurred 4500 years ago with the introduction of water infrastructure. Public works were organized in ancient Egypt to clean clogged mostly natural, irrigation canals. The system was simple. Every Egyptian's duty was to move 30 cubic meters of soil a year, and local governors managed the works.[1] Moslem civilization introduced sophisticated water courts as a conflict resolution mechanism. The water Court in Valencia still functions today.[2] Roman aquaducts, Persian Quanats and 16th century French waterways would not have been be possible without adequate institutions for planning, construction and maintenance.

People were always very creative in overcoming problems concerning water management and effective water management spurred the development of human civilization. The emergence of national states and the modern system of international relations produced a challenging new agenda – navigation on international rivers. International water treaties were signed to manage navigation on international rivers such as the Danube and Rhine. Water law was a successful problem-solving tool at that stage of civilization's development, but new problems were already on the horizon.

Twentieth-century water policies relied on the construction of massive infrastructure in the form of dams, aqueducts, pipelines, and complex centralized treatment plants to meet human demands. These facilities brought tremendous benefits to billions of people, but they also had serious and often unanticipated social, economical, and ecological costs. Many unsolved water problems remain, and past approaches no longer seem sufficient. (Gleick P. 2003)[3]

Every substantial shift in human civilization was followed by adaptation in the water management sector. Water management was introduced at the dawn of the agricultural revolution, when people began to live sedentary lives. It became international after the emergence of national states and finally it became global in the previous century. There is no doubt the water sector will go through substantial changes in the 21st century and the question is, whether transboundary water management schemes will be resilient enough to cope with that changes, or become vulnerable to them and fail to help humanity solve its water related problems.

1.2 Complexity, uncertainty and sustainable water management

International watersheds are systems of interactions and competing interests. *Water management is, by definition, conflict management. All water management is multi-*

1 The world's oldest large dam was the Sadd-el-kafara dam built in Egypt between 2950 and 2690 B.C in:Butzer, K. W.(1976) *Early Hydraulic Civilization in Egypt*, University of Chicago Press, Chicago.

2 Cosgrove1, William J.(2003) Water Security and Peace - A synthesis of studies prepared under the PCCP–Water for Peace process (An UNESCO–Green Cross International Initiative)

3 Gleick Peter H. (2003): *Global Freshwater Resources: Soft-Path Solutions for the 21st Century.* Science Vol. 302

objective and based on navigating competing interests. The chances of finding mutually acceptable solutions drop exponentially as more stakeholders are involved. Add international boundaries, and the chances decrease exponentially yet again. (Wolf 2006)

Fortunately sustainable international water management can be achieved through resilient water institutions. This paper focuses on transboundary water institutions in particular. They can be defined as persistent and predictable arrangements such as treaties, laws, or organizational structures dealing with transboundary water resources. Sometimes they posses an institutional body, like a river basin organization and sometimes they are merely a code or set of rules. A set of rules of water institution can be viewed as an analog to a genotype of a living organism and the effects of the rules or actions of joint institutions could be seen as an analog to a phenotype in nature.

It is a great advantage for institutional analysis of international watersheds, to have a finite and comprehensive dataset of treaties as a well as an equally finite dataset of 263 international river basins. This will allow high-precision analyses, once we reach at least a crude understanding of institutional and ecosystem linkages.

Water institutions are among other things responsible for **sustainable** use of a shared transboundary resource. Sustainability (box 1) refers to the *persistence and structure of any system; the concept is thus of central interest to both eclogists and policy analysts who study resource use.*(Constanza, Low, Ostrom, Wilson 2001)[4] Even though sustainability is a widely used term, it is rather difficult to define. It always takes time to determine, whether the pattern of use of transboundary water is sustainable or not, but we have a stake in biasing the outcome.[5]

Assessment of sustainability always faces **uncertainty**. Discussion about of global climate change is the most obvious example. Policy makers are demanding certain answers from the scientific community to form their policies, but there are no certain answers; there is "ocean of uncertainty".

Institutional resiliency in transboundary water resources management means that institutions and their ecosystems remain *resilient* to *uncertainties* and consequently are environmentally, politically and economically viable, while the others become vulnerable to uncertainties, and thus not effective in the face of change.

To find the difference between resilient and vulnerable water institution we need a theoretical framework to understand the subject, solid definitions to categorize the variables and case studies to see the explanatory scheme in action.

1.3 Theoretical framework

There are three main reasons for choosing Complex Adaptive System (CAS) theory as a theoretical framework for institutional assessment of transboundary water resources management models.

The first reason is the complexity of relations in each watershed. Transboundary water management depends on relations between riparians or stakeholders. Inter-

4 *Institutions, Ecosystems and Sustainability.* (2001): edited by: Constanza R. et al. CRC Press LLC Lewis publishers.
5 Ibid.

connections between riparians and other relevant agents are not simple or linear and we cannot understand the watershed as a sum of its components.[6]

To understand the behavior of a complex system we must understand not only the behavior of the parts but how they act together to form the whole.[7]

States are still the most important pieces on the world chess board. *The relevance of national governments is declining somewhat, even though the power to take action is still concentrated largely at that level.*[8] The states themselves are very complex systems and their attitude toward transboundary issues is a result of intricate political processes. States are not capable of solving transboundary issues without cooperation and therefore they may surrender part of their sovereignty in favor of transboundary water institutions. These institutions may become active agents in the system if they posses an institutional body – for example a river basin organization. Institutions without "institutional bodies", like international treaties or mechanisms of international law, do not have an ability to express their will, so they cannot become system agents.

The Mekong river basin is a good case of complex relations between states, and rivalry among water institutions.[9] The Mekong has six riparians grouped into three different water institutions or programs including the Mekong River Commission, Greater Mekong Sub-region and Quadruple Economic Cooperation. MRC has four lower Mekong countries and QEC includes four upper Mekong countries, while Thailand and Laos are members of all three organizations at the same time. All six riparians are members of GMS. The Mekong River Commission has the longest history of cooperation and has the support of various international organizations including UNDP, but has failed to attract China and Myanmar as members. The greater Mekong Sub-region program founded by ADB, has the advantage of all six riparians being members allowing to it proceed with the implementation of large scale water infrastructures such as the Nam Theung 2 hydroelectric project in Lao. China is the greatest supporter of QEC and of the Agreement on Commercial Navigation on Lancang-Mekong River. This treaty was signed to improve navigability of the Mekong and to allow Chinese ships to reach sea-ports in Thailand. Rapids and shoals were blasted to remove obstacles for the large ships. This has not been good news for the Mekong River Commision which could have used navigability of the Mekong to improve its bargaining position in negotiating Chinese participation in its structures.

Are the relations on Mekong truly complex or just complicated? The answer lies in the emergence of the number of rival institutions in the region. Emergent structures may rise from the watershed as a result of the patterns of relationships between the agents. Water institutions are always a result of interactions between riparian states. *System is complex in the sense that a great many independent agents are interacting with each other in a great many ways.*(Waldrop 1993)[10]

6 Waltz, Kenneth: (1979): *Theory of International Politics.*
7 Bar-Yam, Yaneer (1997): Dynamics of Complex Systems.
8 Murray Gell-Mann (1996): The Simple and the Complex.
9 Battle for relevance between MRC and GMS in: RATNER, BLAKE D.(2003):"The Politics of Regional Governance in the Mekong River Basin", Global Change, Volume 1
10 Waldrop, M. Mitchell (1993) Complexity: The Emerging Science at the Edge of Order and Chaos

It was not intended or planned to have overlapping institutions on the Mekong. They emerged from negotiations between states and they are not an outcome of rational planning. If it were otherwise, we would probably not have an incoherent institutional framework with several rival institutions.

The second reason is the non-linear relation between causes and effects. Simple cause and effect relationships between inputs and outcomes are in fact very rare. A small change in a watershed may cause a large effect or no effect at all. Dam construction in China can influence biodiversity in Tonle-Sap Lake and take away the livelihood of Cambodian fisherman. Water diversion in the Khong Chi Moon project in Thailand can result in salinization of the Mekong delta which threatens the rice production in Vietnam. The decision to intensify cotton production in USSR caused desiccation of Aral Sea. It is interesting, that the magnitude of these effects is extremely difficult to predict. They could be large, small or have no impact at all. This is not something particular to international watersheds. In history many "inputs" created non-proportional "outputs": the opening of a tunnel started the second intifada, the assassination of the successor to the Habsburg Throne started the First World War and many more.

The third reason is prevailing uncertainty. Institutions *are susceptible to an array of uncertainties in the environmental, political, and economic arenas, threatening their long-term longevity and viability* (Fishhanler, Wolf 2005).[11] Geopolitical, socioeconomic and biophysical uncertainties are also pools of perturbations or stressors; they can threaten long term sustainability on one hand, but provide the only proof that institutional or ecosystem resilience exists.

When the uncertainty level is high the academic and policy-making communities are vulnerable to searching for panaceas. (Rosenau J. 1997).[12] Complex adaptive system theory is focused on complexity, uncertainty and ambiguity itself and does not offer a panacea of its own. CAS can only tell us that complex systems are ultimately comprehensible. CAS is a tool to enhance understanding, not a "cure for all" theory.

Complex adaptive system theory offers an inspiring conceptual and theoretical framework in which we will examine various watersheds and their institutional arrangements, to identify resilient and vulnerable models of transboundary water management.

11 Fischhendler I., Wolf Aaron T. (2005) *Institutional adaptation to uncertainties: a study of transboundary resources*.

12 Rosenau James N.(1996) *Many Damn Things Simultaneously:Complexity Theory and World Affair.* paper presented at the Conference on Complexity, Global Politics, and National Security.

1.4 Definitions

Description of the institutional resilience would not be possible without clear definitions.(Box 1)

BOX 1

Transboundary Water Institutions are persistent and predictable arrangements like treaties, laws, or organizational structures dealing with transboundary water resources.

The system of all institutions connected to transboundary water issues in the basin constitutes an **institutional framework**.

Resilience is the ability to return to the steady state following a perturbation. (Pimm, 1984; O'Neill *et al.*, 1986; Tilman and Downing, 1994; Tilman, 1996)[13]

1) A transboundary water institution is in **steady state**, when it performs according to a given set of rules. Every international water institution has a set of rules, which governs its institutional life and defines goals for transboundary water management. For example, if the main purpose of the Indus Waters Treaty (India and Pakistan, 1960) is water allocation, the *steady state* would be the situation, when all waters from the Indus would be allocated according to the treaty provisions.

2) Steady state for **institutional framework** is a state of **sustainable** water management.

A sustainable system is a renewable system that survives for some specified (non-infinite) time. (Contanza and Patten 1995)

Perturbation is an external stimulus, which has impact on the water institution. In this paper *perturbations* are called stressors, in compliance with proposed terminology of long term research project in this field.[14] In case of the Indus waters treaty 1960 the stressor would be two Indo-Pakistani wars in 1965 and 1971.

Emergence is the production of global patterns of behaviour by agents in a complex system interacting according to their own local rules of behaviour, without intending the global patterns of behaviour that come about. In emergence, global patterns cannot be predicted from the local rules of behaviour that produce them. To put it another way, global patterns cannot be reduced to individual behaviour. (Stacey 1996)[15]

Embedded systems are components

2 Stressors and transboundary water institutions

Water institutions are embedded systems in a complex and rapidly changing world. Uncertainties are continually threatening the sustainability of transboundary water institutions and institutional frameworks. Stresses or perturbations can significantly vary in length and intensity. They do not have to indicate abrupt changes in future conditions. For example, water dependency and significant power asymmetry appeared a relatively long time before the development of a system of international relations. Perturbations or stresses are not only obscured by future uncertainties, they are also the heritage of our

13 Gunderson, Lance; Holling, C. S.; Pritchard, L. Peterson G. D.: Resilience. Volume 2, The Earth system: biological and ecological dimensions of global environmental change, pp 530–531 in: Encyclopedia of Global Environmental Change 2002

14 Fischhendler I., Wolf Aaron T. (2005) *Institutional adaptation to uncertainties: a study of transboundary resources*.

15 Stacey, Ralph (1996): "*Complexity and Creativity in Organizations"*

turbulent past. Institutional resilience is needed to face biophysical, socioeconomic and geopolitical stresses.

According to post-Rio[16] sustainability discourse, stresses can be divided into three categories. Geopolitical, socioeconomic and biophysical stressors will be identified in international watersheds.

2.1 Geopolitical stressors

Geopolitical stressors can be seen as a result of longstanding interaction between space and politics. Watersheds as hydrological units are divided among states as political units in a process of fragmentation which creates transboundary watersheds.[17] Building viable joint water institutions is a contrasting process, which creates linkages or joint mechanisms to share transboundary resources. The system of international relations is the most important source of geopolitical stressors. The concrete stressors might include, but cannot be restricted to: significant power asymmetry, absence of diplomatic relation between riparian countries, significant dependence on transboundary water resource, generally hostile relations, no incentives for cooperation, ideological conflicts, internationalization of river basin, international integration that goes across the basins, disintegration of riparian states, major political shift including change of government, under representation in RBO, public participations of NGO groups and dissent within the states, change of riverbed border, unresolved territory claims, etc.

2.2 Socio-economical stressors

Watershed dynamics in demography, industrial development and local or global economic changes are among the foremost sources of socioeconomic stress. Some of them are more predictable than others. It is highly probable that post-Taliban Afghanistan will go through a phase of economic development and thus water withdrawals from Syr-Darya tributaries will increase. A similar situation also applies to Cambodia on the Mekong. Stressors from changes in the global economy are much harder to forecast and could have devastating impacts: Argentina's performance in the Paraná-La Plata institutional framework after its economic collapse should be researched. Privatization and the introduction of market mechanisms in the post-communist countries might have an impact on the on joint water management structures as they take control of the agricultural sector from state. Other examples of socioeconomic stressors could be: rapid change in population growth rate (increase/decrease), unreliable and unavailable water basin data, deterioration of an economic situation and market changes, privatization, changes in development capital policy, changes in water consumption following industrial development, expansion of irrigated land area, neglected water needs of riparians in periods of instability, increased hydropower demands, etc.

2.3 Biophysical stressor

Biophysical stressors have a direct impact on river basin ecosystems, and an indirect impact on water institutions. Resilience is needed in both cases, but ecosystem resilience is different than institutional resilience. Ecosystems have developed through a process of evolution and can flip to another regime of behavior. Ecosystem *resilience is measured*

16 UN Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in June 1992

17 Parker, Geoffrey: (1999) "Globalisation and the Status of the Territorial State." Paper presented at the International Roundtable on the Challenges of Globalization

by the magnitude of perturbation that can be absorbed before the system redefines its structure by changing the variables and processes that control behavior[18]

Institutions have been created through the process of political negotiation and use treaties consisting of rules to govern their institutional life. They are designed to have only one *steady state* or equilibrium.

A water institution is in a steady state when the riparian and stakeholders in the watershed are sharing water according to the rules incorporated within the institutional arrangement. In short if the institutional genotype is in compliance with the institutional phenotype.

Transboundary water institutions are not very likely to change state to another equilibrium system. Ecosystems are mostly multiple-equilibrium systems and many different steady states can develop over time.

Someone might argue that even a single institution can reorganize and find a different equilibrium; take the Interim Mekong Committee (1979-1995) as an example. After the Vietnamese invasion and installation of a pro-Vietnamese government in Cambodia, the Cambodian government was no longer independent and the Mekong Committee could no longer accept Cambodian representation. An interim Mekong Committee (IMC) was established in 1979. IMC was nothing like its predecessor, it had only three members and projects on the main stream were paralyzed.[19] After long and difficult negotiations, Cambodia was readmitted in 1995. (Box 5)

Single institutions are mostly single equilibrium systems, but basin wide institutional frameworks can probably reorganize and find a new equilibrium through emergent behavior.

The fact that biophysical stressors affect both ecosystem and institutional resilience make them more intricate than other stressors. Their effect on institutions may be delayed as it needs to overcome ecosystem resilience first. The Aral Sea is a good example of the delayed effect of biophysical stress, as its institutional framework seems to be resilient to geopolitical changes, but the process of environmental degradation is most likely irreversible and harm to the ecosystem permanent.

The river basin population depends on the ecosystems, and the institutional framework is responsible for the population and the ecosystem. In other words, perfect international cooperation over transboundary water, that fails to protect ecosystem or population is not resilient.

The list of biophysical stressors may include: drought, flood, erosion, change of ecosystem, sedimentation, unstable amplitude of seasonal flow, biophysical changes resulting in decease of water in watershed, unsustainable withdrawal in aquifers , salinization caused by improper water management, and deterioration of water quality due to industry/sanitation/fertilizing.

18 Gunderson, Lance; Holling, C. S.; Pritchard, L. Peterson G. D.: Resilience. Volume 2, The Earth system: biological and ecological dimensions of global environmental change, pp 530–531 in: Encyclopedia of Global Environmental Change 2002

19 Nakayama, Mikiyasu (2004): China as Basin Country of International Rivers

2.4 How to measure institutional resilience

Resilience occurs only if the institutional framework is impacted by a geopolitical, socioeconomic or biophysical stressor. The higher the level of present stress, the more institutional resiliency is needed to return to the steady state. Considering the mathematical limits of this hypothesis and the possible metrics for measuring institutional resilience, we can gauge institutional resilience as inversely proportional to stress.(Figure 1) This means that the number of resilient water institutions will decrease with the growth of stressor intensity.

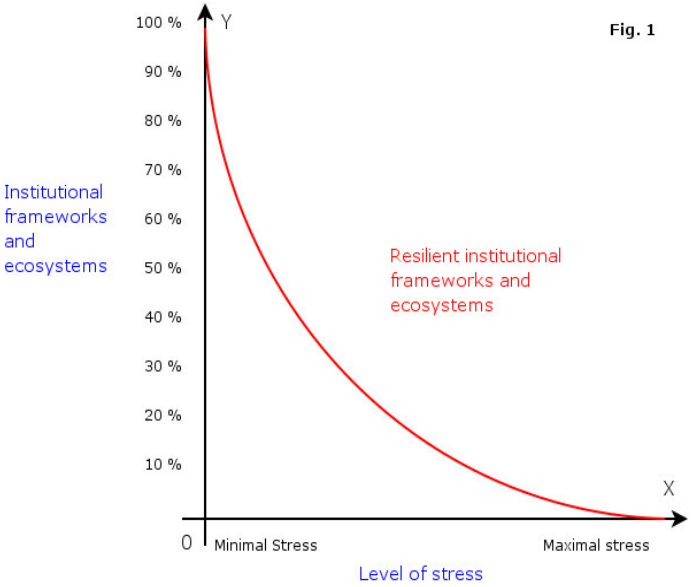

Fig. 1

Despite the simplicity and linearity of the proposed measuring method, there is one important implication. No institution could be resilient at the maximal intensity of a stressor and reorganization of the institutional framework would become inevitable. The search for an ideal institution is the search for a panacea that can not be found. The study of institutions and stressors in the context of CAS can help improve components of the institutional framework, as well as gain more resilience and facilitate reorganization on institutional framework level where emergent behavior and self-organization are possible through interaction between independent agents – states and other relevant international actors.

2.5 Insufficient resilience, adaptation and role of institutional framework

What happens if the stressors are too intense or last for a long period of time and there is not enough resilience to return to a steady state? It depends on whether we are talking about water institution, or about the whole framework. Possible scenarios for a single institution are: incompliance with the institutional mechanism by agents, termination of an institution, or change of rules and institutional reform.

The institutional framework as a system of all institutions in one watershed offers a more interesting perspective. If the institutional framework is not resilient enough to return to the steady state after a geopolitical, socioeconomic or biophysical perturbation, various negative events may occur. Geopolitical stressors may induce water conflicts, and

socioeconomic and biophysical stressors can result in ecosystem degradation, acute water scarcity, poverty and other negative impacts of insufficient or unsustainable water management.

Fortunately the institutional framework as system is more resilient, because it has more properties of a complex adaptive system and emergent behavior and self-organization do play an important role on this level.

In the case studies we will attempt to reveal the most important stresses threatening the institutional and ecosystem resilience as well as roughly estimate their impact in the examined basins.

3 Aral Sea Basin

The disappearing Aral Sea, once the 4th largest body of water in the world, is fed primarily by two rivers: the Amu Darya and the Syr Darya. The Aral Sea basin is shared by the five post-Soviet countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan and three other countries: China, Afghanistan and Iran.

3.1 Biophysical stressors

This transboundary basin is very often taken as an example of environmental degradation and it is abundant with examples of biophysical stressors. Decrease of flow and subsequent soil degradation due to the Soviet-era irrigation schemes for immense cotton industries from the 1960s is probably the most well known case.[20] Chemical, nuclear[21] and biological weapon[22] pollution is disturbing the fragile ecosystem resilience of the region. Uncertainties of climate change led to the world's most persistent and severe drought in Central and Southeast Asia. The drought has had devastating socioeconomic and environmental consequences and has been exacerbated by the rapid disappearance of glaciers in the Pamir Mountains. Glaciers feeding the flow of the Amu-Darya have been reduced by 40 % in recent decades.[23] Climatologists predict that rapid melting of the Pamir's glaciers will increase flow of the Amu-Darya in winter and reduce flow in summer. Such flow reallocation will have a severe impact on the availability of water for irigation.[24] It is not an overstatement to say that the *whole region is an environmental disaster.*[25]

3.2 Geopolitical stressors

The largest geopolitical change in the recent history of the Central Asia region was the disintegration of the Soviet Union, which it created a huge stress on the institutional framework of the Aral Sea basin. In the Soviet Union every important decision had been made by the water ministry - Minvodkhoz. This method of authoritative resources management is primarily responsible for the present biophysical and socioeconomic stressors. Central Asia has always been located between world powers which has resulted

20 Dukhovny, V and Sokolov, V (2005) "Challenges and Actions for integrated Approaches: position for the 4 World Water Forum Central Asia" Scientific-Information Center ICWC

21 Carius, Alexander and Feil, Moira (2003): "The case of Central Asia and South Easatern Europe: Environment and Security Transforming risks into cooperation" UNEP (ROE), UNDP and OSCE

22 Brashko, Vasilina (2002): "Anthrax on Vozrozhdenie Island", Interstate Coordination Water Commission of Central Asia (ICWC) bulletin No 1 (29)

23 Dukhovnyi, Viktor and Shuter U., (2003): " Southern PriAralie-new prospects, Science for Peace" Tashkent

24. Dukhovny, Viktor A (2002): "Dialogue on Water and Cimate" Aral Sea Basin Case Study

25 Sievers, Eric W. (2002): "Water, Conflict, and Regional Secourity in Central Asia." N.Y.U Evirnonmental Law Journal.

in political fragmentation and ethnic diversity. Central Asia is not clearly dominated by any of the world power. Russia, Turkey, Iran, China, Pakistan, India and the United States all have strategic interests in this region. Central Asia may become geopolitically unstable, which might deteriorate the relations between riparians and disrupt the water cooperation framework.

3.3 Socioeconomic stressors

An important, but sometimes overlooked stress factor is the delayed development of post-Taliban Afghanistan, which stood apart from the building of joint water institutions in the 1990s. Future Afghan water needs were not accounted for by existing institutions and a substantial increase in water usage is expected due too increased economic development.

3.4 Complex concurrent stressors with a feedback loop

Socioeconomic and biophysical stressors in the Aral Sea basin are intertwined and create an amplifying feedback loop. It is impossible to deal with them without a coordinated approach. Significant (though varying in extent) decreases in GDP per capita in all riparian countries have led to a sharp reduction in subsidies and support of agriculture and the water sector.[26] Estimated costs of nation-wide installation of a highly effective *drip irrigation system* in Uzbekistan are USD $100 billion.[27] Uzbekistan is the second largest cotton exporter and its agricultural sector creates 38% of the nation's GDP. A significant factor affecting the regional water sector is the sharp fall of world prices for cotton (from $1,760 to $800 per tone). The introduction of market mechanisms in agriculture, and privatization have caused the break up of large state and collective farms into hundreds and thousands of small farms. This change was not combined with the establishment of effective infrastructures and institutions for water distribution and allocation.[28]

BOX 2

Toktogul dispute

The impact of concurrent stressors on the politics of riparian countries in an internationalized river basin can be illustrated by a dispute between Kyrgyzstan and downstream riparian countries. Toktogul dam reservoir and its 1200 MW hydropower plant were built in the former the Soviet Republic. Kyrgyz SSR was entitled to a free supply of fossil fuels principally from Uzbekistan, in exchange for timely water releases according to the agricultural needs of its downstream neighbors. This barter trade however ended with the break up of the USSR. Uzbekistan began asking for market prices for its fossil fuels and demanded that the water releases remain at the same rate in summer for the sake of its cotton fields. Kyrgyzstan was releasing water in winter to produce electricity for heating and reciprocally asked downstream states to contribute to the operation and maintenance of the Toktogul water infrastructure. Kyrgyzstan estimated costs as high as USD 25 million a year.(Siviers 2002, McCaffrey 2003) It may seem from the first glimpse of this situation that the dispute is caused by geopolitical stress (disintegration of the USSR), but this stress occurred after the introduction of a free market to the region.

26 Dukhovny, Viktor and Sokolov, Vadim (2003): "Lessons on Cooperation Building to Manage Water Conflicts in the Aral Sea Basin" PCCP series n°11

27 Sievers, Eric W. (2002): "Water, Conflict, and Regional Secourity in Central Asia." N.Y.U Evirnonmental Law Journal.

28 Dukhovny, Viktor and Sokolov, Vadim (2003): "Lessons on Cooperation Building to Manage Water Conflicts in the Aral Sea Basin" PCCP series n°11

3.5 Resilience of institutional framework and its ecosystem

The institutional framework of the Aral can be divided into two groups. The first group subsumes soft law basin-wide water institutions incorporated into a multilateral declaration and joint institutions as the 1992 Agreement on Cooperation and Interstate Commission on Water Coordination (ICWC 1993), which was later integrated with International Fund for the Aral Sea (IFAS 1997). This soft law institutional arrangement has two purposes:

1) Coordinate the state's water policies
2) Create a platform for distribution of funds contributed by international donors (World Bank, GEF, European Union, UNDP, UNESCO, USAID, SIDA etc.)

The first group of institutions may be resilient to potential geopolitical stress to a certain degree as its primary purpose is likely fundraising from the international donor community. This matter will need a further detailed survey.

The second group consists of more specific "hard law" instruments like the 1997 Treaty on *Use of the Syr Darya Water Resources* and the 1996 Treaty on the *Use of Water and Energy Resources of the Syr Darya River basin.* These treaties were aimed at finding the solution to the water issue and energy sharing in the Syr Darya River basin. (BOX 2) *Nevertheless, like in previous cases, the two treaties failed by and large because of the non-compliance problem.*[29]

Despite the fact the Aral Sea basin is a very volatile region; its framework does not seem to be significantly affected by geopolitical stress - however that does not mean that it is resilient to it either. Review of riparian countries attitudes on transboundary water issues can be assessed from their adherence to international law. They accede to various conventions on environmental protection[30] just for the sake of acceding, avoiding the implications of such treaties. Reform of state policies and adoption of sustainable water use patterns will be necessary to confront the enormous biophysical stressors in Central Asia.

BOX 3

Development of the Aral basin Institutional framework:

The need to integrate water resources management was recognized before the internalization of the Aral Sea Basin. In the climate of the Perestroika proposal for an institutional framework, approved in 1986, two River Basin Organizations were created: RBO "Amu-Darya" with headquarter in Urgench, and BWO "Syr-Darya" in Tashkent.[31] In the period of independence, the Interstate Commission for Water Coordination (ICWC) was founded in accordance with the "Agreement on collaboration in the sphere of joint water resources management within interstate water sources" approved in 1993. Later (in 1993), two new organizations were established. Those were: the Interstate Council for the Aral Sea (ICAS), set up for program coordination; and the International Fund for Saving the Aral Sea (IFAS), which had the purpose of raising and controlling funds. Later these two bodies were merged into the new IFAS. This institutional framework comprises post-soviet republics. Other riparian states such as China are connected to the framework via a bilateral treaty.

29 Shalpykova, Gulnara (2002) Water Disputes in Central Asia: The Syr Darya River Basin

30 Sievers, Eric W. (2002): "Water, Conflict, and Regional Secourity in Central Asia." N.Y.U Evirnonmental Law Journal

4 Ganges-Brahmaputra-Mengha

4.1 Geopolitical stress

The Ganges River is a part of larger Ganges-Brahmaputra-Mengha watershed shared by five riparian countries: Nepal, Bhutan, China, India and Bangladesh.[32]

Among the main geopolitical stressors are: significant power asymmetry, complete water dependence, and undisputed territory claims. Without active China's involvement, India is by far the strongest riparian country in the basin. *Significant power asymmetry* between India and its upstream neighbors (Nepal, Bhutan) and downstream neighbor (Bangladesh) might be the reason for the strictly bilateral institutional framework.[33]

Bilateral links between India and its neighbors sustain stressors like unresolved territory claims, sudden political shifts or political assassinations of Prime Ministers of India and Bangladesh.[34]

In addition to the most apparent geopolitical stressors presented above, more subtle stressors are present in the Ganghes-Brahmaputra-Meghna watershed. For example Indo-Nepal water relations have always been worse than relations between India and Bhutan. Explanation of the difference might be in different perceptions of national identity by Bhutan and Nepal.

The Kingdom of Nepal is economically and politically dependent on India and shares the same Hindu culture. Predominantly Nepalese leaders use nationalism and anti-Indian feelings to justify the existence of their monarchy. India was also involved in both Nepalese revolutions in 1951 and 1990 and the process of democratization in the 90s was supported by India. The question of Indo-Nepalese relations became a controversial theme on the political scene in Nepal once it was established in 1990s.

In contrast, isolated Bhutan is a Buddhist kingdom, and is very different from India in terms of religion and ethnicity. Bhutan does not see an urgent need to its national identity against their powerful neighbor. India is planning and financing water infrastructure in Bhutan and buys the electricity at advantageous rate.

This is a good example how complexities of national politics can influence relatively simple bilateral water institutions. Embedded institutional systems like states can be even more complex, then the system of relations on the international level. The effect perturbations within the state on the institutional framework were significant and *in the years to come quickly Bhutan will over take Nepal's hydroelectric capacity.*[35]

4.2 Socio-economical stressors

Rapid population growth and expansion of irrigated areas, data sharing problems, pollution combined with increased water demand and hydroelectricity demand in India

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31 Dukhovny, Viktor and Sokolov, Vadim (2003): "Lessons on Cooperation Building to Manage Water Conflicts in the Aral Sea Basin" PCCP series n°11

32 TFDD: The sixth is Myanmar, which is sharing only negligible 80 km2 of the Ganges-Brahmaputra-Mengha basin.

33 Aline Baillat: Hydropolitics in Small Mountainous States. Two Cases of Cross-Asymmetries: The Kingdom of Lesotho and the Republic of South Africa, the Kingdom of Nepal and the Republic of India, 2004 Graduate Institute of International Studies, Geneva

34 Swain Ashok: (2004) "Managing Water Conflict: Asia, Africa and the Middle East" Routledge London and New York

35 Aline Baillat: Hydropolitics in Small Mountainous States. Two Cases of Cross-Asymmetries: The Kingdom of Lesotho and the Republic of South Africa, the Kingdom of Nepal and the Republic of India, 2004 Graduate Institute of International Studies, Geneva

are the most obvious socio-economical stressors in the basin. An interesting modality of data-sharing problems tested resilience of the 1996 Treaty between India and Bangladesh.[36] Political representatives of the countries used inflated water flow data to create an unrealistic water budget for the allocation in the treaty. The reason behind the data manipulation was to please the constituency and blanket opposition.[37]

4.3 Biophysical stress

There is a great seasonal variability in the total amount of rainfall and its spatial distribution within the basin: three quarters of the yearly precipitation occurs only during the three monsoon months, June, July and August. As a consequence, the basin suffers from severe droughts in the dry months and floods inundate large areas during the monsoon season.[38]Bangladesh experiences yearly flooding on up to two-thirds of its territory during the monsoon season.[39]

4.4 Institutional framework

The main pillars of the contemporary institutional framework are on three bilateral transboundary water cooperation sets of institutions. The dyads are not interconnected and can be examined discretely. Institutional framework could be likened to wheel and then India would be a hub and bilateral links would be a spokes. The "Dharma Chakra" wheel is also incidentally on the Indian flag.

Institutions working between Bhutan and India is seems to be very resilient. There are no major biophysical stressors and cooperation is profitable for both sides. Bhutan does not have capacity and financial resources to build water infrastructure to utilize its immense hydroelectric potential and India is the only reasonable buyer for the produced electricity. There are no identity problems and a special treaty relationship with India is helps to protecting Bhutan against Chinese agression. Memorandum of understanding was signed in September 2003 with regards the 870 MW Punatsangchu hydroelectric power project.[40]

Relations between India and Nepal improved as evidenced by the Mahakali Agreement signed in 1996. Mahakali River forms the boundary between the India and Nepal; the treaty gives the right to both countries to the *equal entitlement of the utilization of the waters* and specifies implementation of the joint Pancheshwar Multipurpose Project. This relationship is different then the case of Bhutan. Nepal is trying to be as independent as possible and seeks investors for Hydroelectric project between international donors or private companies. For example Kali - Gandak power plant inaugurated in January 2004 is the largest hydroelectricity project in Nepal, and it was financed by the Nepalese government and Nepal Electric Authority with loans of the Asian Development Bank (ADB) and Japan Bank for International Cooperation (JBIC).[41]

36 Treaty Between the government of the Republic of India and the government of the People's Republic of Bangladesh on Sharing of the Ganga/Ganges Waters at Farakka
37 McCaffrey, S.C. (2002): Water Disputes Defined: Characteristics and Trends for resolving them. in: Resolution of International Water Disputes. Kluwer Law International November 2002
38 Elhance, Arun (2000): „Hydropolitics in the Third World"
39 Herb Wiebe (2000)"Flood Action Plan in Bangladesh"
40 Aline Baillat: Hydropolitics in Small Mountainous States. Two Cases of Cross-Asymmetries: The Kingdom of Lesotho and the Republic of South Africa, the Kingdom of Nepal and the Republic of India, 2004 Graduate Institute of International Studies, Geneva
41 Ibid.

The dispute over the Farakka barrage (see Box 4) had been deteriorating the **relations between India and Bangladesh** for many years before agreement was signed in the year 1996.[42] This agreement valid for 30 years has been concluded after more then 20 years of negotiations resulting provisional solutions because of seasonal fluctuation of water flow and climatic uncertainty. Both sides agreed to use overestimated water budget for the unrealistic 1996 Treaty allocation mechanism to make the treaty politically feasible. This did not pay of as the severe drought impacted Bangladesh and mass protest were pressing Bangladeshi government to find a solution. Bangladesh requested immediate consultation with India *on emergency basis* as permitted by Article 2 of the 1996 Treaty, but then unexpected rain eased the tensions.[43]

Perturbation may vary in length and in this case, the whole framework would probably not have been able to return to steady state if the drought had lasted much longer. Therefore 1996 Treaty could be vulnerable to drought in the future.

The change from bilateral institutions to multilateral institutions is widely discussed in scientific community, because it broadens the "basket of benefits" and creates a better platform for determination of win-win scenario (Wolf 2002, Rahaman 2003).[44] A multilateral framework will most certainly bring more possibilities for cooperation, but is not necessary a step towards resilience to geopolitical stressors for two reasons: firstly, bilateral institutions developed through time according to the power configuration in the basin; secondly, if one of the bilateral links breaks up, the other connections remain intact.

In this case the system works differently than in the Mekong, where unilateral development in China can disrupt the existing cooperation of lower Mekong countries with increased uncertainty of available water quantity and possible modification downstream ecosystems.

Box 4
Diversion at Farakka:
The Farakka barrage water diversion was disturbed the relationship between India and Bangladesh for more then 20 years. India began operation of Ganges water diversion project in West Bengal in the year 1975 to improve navigation in the port of Culcatta and Hooghly channel by reducing sludge sedimentation and salinity. This diversion threatened historic uses of Bangladesh. Eighty percent of Bangladeshi's annual water budget depends on water flowing from India (Nishat, Faisal, 2000). In 1975-76 several geopolitical and biophysical stressors including drought, a military coup and the assassination of the Bangladeshi Prime Minister Mujibur Rahman, destroyed the positive momentum in mutual relations. Bangladesh tried to improve its weak bargaining position through official protests in the UN General Assembly, Summit of Non-aligned Movement and the Islamic foreign ministers conference (Swain 2004). After an unsuccessful pursuit of change from bilateral to multilateral negotiations, Bangladesh returned to bilateral talks with India and finally signed a water treaty in 1977. Unfortunately this treaty failed to address the key biophysical stressor – seasonal fluctuation of flow. It was not planned as a long term solution. It failed to guarantee minimal flow to Bangladesh in the time of drought and had to be renewed every 5 years.
Long term (30 year) institutional arrangement was signed in 1996 [45] but the ability of the institution to perform under biophysical stress of seasonal fluctuation of flow is still questionable.

42 Treaty Between the government of the Republic of India and the government of the People's Republic of Bangladesh on Sharing of the Ganga/Ganges Waters at Farakka.
43 McCaffrey, S.C. (2002): Water Disputes Defined: Characteristics and Trends for resolving them. in: Resolution of International Water Disputes. Kluwer Law International November 2002
44 Rahaman Muhammad M.:(2003) "Water versus power: Role of dams in geopolitics of Ganges basin." Riversymposium 2003 Papers.
45 1996 treaty on Sharing of the Ganges Waters at Farakka

5 MEKONG

The Mekong River flows from Qing Hai province in western China and through the provinces of Xizang (Tibet) and Yunnan. In southern Yunnan, it leaves China to form the border of Myanmar and Lao PDR, crosses the territories of Thailand, Cambodia, and Vietnam and finally discharges into South China Sea. Development of the water institutions on the Mekong River can be divided into three distinct periods. (see Box 5)

5.1 Biophysical stressors

The Thai Khong Chi Mun[46] diversion plan and similar activities held the potential for worsening environmental problems already present in the highly productive Mekong delta. Around 25% of the Mekong's flow feeds Vietnam's Mekong delta and 1.6 million ha of the delta suffers from salt-water intrusion from the South China Sea.[47] Geologic surveys have confirmed the presence of large areas of underground salt deposits in many provinces in the northeastern region.[48] Two million hectares in the Korat plateau are influenced by underlying geologic salt deposits.[49] Additional stressors include: seasonal fluctuation of flow and floods; change of ecosystems impacting local populations (fishermen on Tonle Sap in Cambodia), etc.

5.2 Geopolitical Stressors

Among the main geopolitical stressors in the Mekong basin we find significant power asymmetry between states on different levels; lack of interest on the Chinese side in entering a broader cooperation framework; ideological conflict between communist and non-communist countries have played a significant role in the past; Thailand and Cambodia dispute sections of their boundaries because of missing boundary markers; Cambodia claims Thai encroachments into Cambodian territory and obstructing access to Preah Vihear temple ruins[50]; environmentalists in Myanmar and Thailand remain concerned about China's construction of hydroelectric dams upstream on the Salween River in Yunnan Province.

5.3 Socio-economical Stressors

Uneven economic development created a gap between Thailand and post communist lower Mekong Riparian countries. Thailand was able to find financing for the Kong Chi Moon Project from regional sources through ADB and consequently lost some of its incentives for cooperation with other lower Mekong counties.[51]

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46 Lerdsak Kamkongsak and Margie Law: Laying waste to the land: Thailand's Khong-Chi-Mun Irrigation Project; Watershed Vol. 6 No. 3, 2001

47 (Hiebert, 1991a, 28; 1991b,24) HIEBERT, M. 1991a "Muddy Waters." Far Eastern Economic Review (21 February): 28, 1991b . "The Common Stream" Far Eastern Economic Review (21 February): 24.

48 Fedra, K., Winkelbauer, L. and Pantulu. V.R. (1991): RR-91-19. International Institute for Applied Systems Analysis. A-236l Laxenburg, Austria

49 HIEBERT, M. (1991): "Muddy Waters"; " The Common Stream" Far Eastern Economic Review

50 CIA World Factbook

51 Joint Declaration of Principles (1975) articles 10 and 20

5.4 Institutional framework

The institutional framework on the Mekong was formed through the second half of the 20th century and has gone through many changes. The last reorganization was started by the ending of the cold war.

Box 5

From Mekong Committee to Mekong River Commision

The first period of the Mekong Committee (1950s – 1975) was characterized by significant US economic, and later military, presence in the region. The second period (1975 – 1995) was started by the spread of communist regimes in the region leading into a stall of the Interim Mekong Committee. Cambodia was not considered a fully independent country after the Vietnamese invasion in 1978 and thus the IMC had only three members. The institution withstood the geopolitical stress, but no major mainstream project was feasible in the times of IMC.

Cooperation with Cambodia was possible again after of the Paris peace accord in 1991. Despite of favorable conditions on both the regional and the international levels the negotiation process was far from simple. Thailand continued with the implementation of Khong-Chi-Mun project, in order *to direct water from the mainstream of the Mekong River into its underdeveloped Northeastern region.*[52] Thus Thailand was reluctant to return to the 1975 Joint Declaration,[53] as its Article 20 demands "unanimous consent" of all members – practically a veto power – for any mainstream extra-basin diversion. Thailand did not want to submit its unilateral project for revision. The MRC Executive Agent, Chuck Lancaster, was advocating submission of the Khong Chi Moon irrigation scheme and Thailand declared him persona non grata.[54] UNDP career employee was recalled back to UNDP headquarters and the existence of the long standing cooperation on Lower Mekong was at risk. The Deputy Foreign Minister of Thailand said: *if joining the committee means the loss of our sovereignty, we prefer to go it alone.*[55] UNDP mobilized its powers to bring the countries to negotiations. Some cooperation mechanisms had to be removed to reach a compromise. "Veto power" was neutralized by Thailand's non-compromising stance and the former position of Executive Agent was redefined as a position called CEO albeit with fewer powers. Finally Cambodia was readmitted to the Mekong River commission and the Agreement on cooperation was signed in 1995.[56]

The period from 1995 onward is characterized by a plurality of overlapping institutions, the increasing role of China in regional politics and rapid economic development and implementation of water development plans. Beside the most prominent Mekong River Commission that has existed through the whole second half of 20th century and is an outstanding example of institutional resilience, there are at lest two other regional institutions that are gaining momentum.

The Greater Mekong Sub-region (GMS) program of the Asian Development Bank (ADB) began operation in 1992. GMS has the clear advantage of having all six Mekong countries as members and recently moved to implementation of water infrastructure projects like the 1,070 megawatt Nam Theung 2 dam in Laos.

The Quadripartite Economic Cooperation (QEC) is an initiative of China, Thailand, Laos and Myanmar. QEC is proceeding with the blasting of rapids on the Mekong, to improve

52NAKAYAMA, Mikiyasu: TRANSITION FROM MEKONG COMMITTEE TO MEKONG RIVER COMMISSION.http://www.wrrc.dpri.kyoto-u.ac.jp/~aphw/APHW2004/proceedings/APHW-Others/56-OTH-A695/56-OTH-A695.pdf

53 Joint Declaration of Principles (1975) Article 20

54 Makim, Abigail(2002): The Changing Face of Mekong Resource Politics in the Post-Cold War Era: re-negotiating arrangements for water resource management in the Lower Mekong River Basin (1991-1995)

55 Kanwerayotin, S. (1992): The Mekong - More of a liability than an asset?, Bangkok Post, 21 March 1992

56 Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin 1995

the Mekong's navigability. This will allow 100 ton ships to navigate from Thai sea-ports to the Chinese province of Yunnan.[57] China is main the benefactor of this agreement, but blasting of the rapids may have a negative environmental impact on both Vietnam and Cambodia.

Establishment of the QEC and especially the signing of the Lancang-Mekong Navigation Agreement has been a wasted opportunity for the MRC to attract China, which is still very reluctant to enter to MRC. Navigation could have been a part of larger "basket of benefits", that would have brought China into a basin wide cooperative framework. Yunnan province of PR China does not benefit from foreign investments like coastal provinces, but if Yunnan goods could reach Thai ports, it would be a large boost for Yunnan's economy.

China's ambition is to get access to the sea for goods from Yunnan and continue with unrestricted dam construction on the Upper Mekong. QEC is a good platform to achieve this goals and the Commercial Navigation agreement (2002 – China, Myanmar, Laos, Thailand) is very profitable for China.

The absence of China renders the Mekong River Commission vulnerable to biophysical and socioeconomic stress as it cannot estimate the amount and quality of water in the Mekong due to the development of Chinese hydroelectric and water infrastructure projects in Yunnan. China plans to build seven cascade hydropower dams in the Upper Mekong Basin. Manwan dam, was officially completed in 1996, but its reservoir was filled earlier in the 1992-1993 dry season.[58] Construction of the second dam Dachaoshan dam was completed in December 2002.[59]Construction on the third dam, Xiaowan Dam, began in 2001 and is expected to complete by 2013.[60] Hydropower development in Yunnan Province in the PRC is likely to have a great impact on hydrology of the Mekong Basin - with a potential installed capacity of 15,600 MW and active storage of 23,200 mil. m^3 by 2025.[61]

Laos also has plans for development in the hydropower sector, that are likely to have significant downstream impacts. However Laos will have to consult with the MRC on its schemes for development. Consultation with downstream riparian nations can improve the systems resilience against biophysical and socioeconomic stress and keep the Mekong development sustainable. It is absolutely vital to bring China into the broader institutional framework; It could be done in various ways. Cooperation between Mekong River Commission and Greater Mekong Sub-region seems to be very promising and seems promising and is likely an effective way to improve the resilience of Mekong institutional framework.

57 Free navigation is stipulated in (2000) Lancang-Mekong Navigation Agreement
58 International Rivers Network. October 2002. "China's Upper Mekong Dams Endanger illions Downstream." Briefing Paper 3. Berkeley, California
59 Khanh , Tran Tien (2003): „ Death of A River :The Mekong River and the Chinese Development Projects UpstreamVietnamese" Bulletin Vietnamien, Vol. 19, No.1
60 Richardson, Michael. 2002. "Sharing the Mekong: an Asian challenge." The International Herald Tribune
61 (2004) Cumulative Impact Analysis and Nam Theung 2 Contributions Final Report

6 Concluding remarks

Building viable transboundary water institutions for sustainable water management and strengthening of existing cooperation in international basins is one of mankind's great challenges. Water resource management requires an interdisciplinary approach and scientists from different fields often have difficulties understanding each other, although the gap between social sciences and "hard" sciences is narrowing and new theories are being developed invented to explain the complex interrelationships between social and natural systems.

Cooperation over international water is a process depending on the complex relations between relevant actors, ranging from international organizations to individual stakeholders. The power to take action is still concentrated at the state level, but solving transboundary water issues requires international institutions.

This paper proposes the use of Complex Adaptive System theory to bridge the gap between social systems and ecosystems, and find the attributes of resilient water management models. It proposes a simplified tool to measure both institutional and ecosystem resilience. Resilience is perceived as an ability of a system to recover after a perturbation. If a system is represented by a pond of water, the perturbation a stone thrown in to the pond, then system resilience is the ability to restore a smooth surface; a steady state of the water in the pond. Resilience depends on the structure of the molecules in the fluid, initial conditions and vigor power energy of the tossed stone. Water institutions and ecosystems face stressors like those described in this paper and their steady state is, in the broad sense, their sustainability.

Case studies of three international river basins were presented to show examples of stressors, and examination of other watersheds will bring more examples to list. Once the crude understanding of responses of human systems and ecosystems to stressors is refined, we can design more resilient water institutions or facilitate the emergent behavior of such institutions on the level of institutional frameworks.

Fig. 2

Stresses		Watersheds					
		Mekong	Ganges Brahmaputra Meghna	Aral Sea	Jordan	Nile	Danube
Geopolitical	Significant power asymmetry	■	■		■	■	
	Absence of diplomatic relation between riparian countries	■			■		
	Significant dependence on transboundary water resource		■	■	■	■	
	Generally hostile relations		■		■		
	No incentives for cooperation	■	■				
	Ideological conflicts	■			■		
	Internationalization of river basin		■	■			
	International Integration across the basins	■					
	Disintegration of riparian states		■				■
	Major political shift - Change of government	■	■		■		
	Under representation in RBO	■	■		■		
	NGO and public participations groups dissent	■	■	■		■	
	Change of riverbed border				■		
	Unresolved territory claims	■	■		■		
Socioeconomic	Rapid change in population growth rate increase/decrease	■	■		■	■	
	Unreliable, unavailable water basin data	■	■			■	
	Deterioration of an Economic situation and market changes			■			
	Privatization			■			■
	Future development of countries	■		■	■	■	
	Expansion of irrigated land area	■		■		■	
	Neglected water needs of riparian in/after a period of instability	■		■		■	
	Increase of water demand for industry			■	■		
	Increase of water energy demand			■		■	
Biophysical	Draught		■	■	■	■	
	Flood	■	■	■			■
	Erosion			■			
	Change of ecosystem affecting population in the basin	■		■		■	■
	Sedimentation	■	■				
	Unstable amplitude of seasonal flow	■	■				
	Biophysical changes resulting in decease of water in watershed			■			
	Unsustainable withdrawal in aquifers			■	■		
	Salinization caused by improper water management	■		■	■	■	
	Deterioration of water quality due to industry/sanitation/fertilizing		■	■			■

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