

## Article

# Hydropolitical System Archetypes: Feedback Structures, Physical Environments, Unintended Behaviors, and a Diagnostic Checklist

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**Abstract:** Hydropolitics is defined as the systematic study of conflict and cooperation in transboundary water basins, affecting around 40% of the world's population. There has been great advancement in studies endeavoring to explore linkages between hydropolitical drivers and hydropolitical situations in transboundary basins. To add to this, we posit that hydropolitics would benefit from a system thinking approach that has remained less addressed in the literature. For this purpose, considering a transboundary basin as a system, this study is built on the main principle of system dynamics, which implies that a system's structure determines its behavior. Incorporating system archetypes into hydropolitics can provide a framework for assessing hydropolitical behavior according to the potential structure of archetypes. In this paper, we discuss five hydropolitical system archetypes and their feedback loop structures, the required physical environments, and potential unintended behavior over time. Finally, an example of a diagnostic checklist is presented that will help riparian states recognize patterns of behavior they may face in the future. This paper lays the groundwork for gaining insight into using system archetypes in projecting plausible hydropolitical behaviors and understanding past behaviors in transboundary basins.

**Keywords:** hydropolitical system archetype; transboundary basin; upstream state; downstream state



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## 1. Introduction

The cumulative influence of environmental and human factors, termed hydropolitical driver (HD) by Turton et al. [1], determines the hydropolitical situation of transboundary basins (TBs) with two broad outcomes: conflict or cooperation [2]. Discovering links between HDs and hydropolitical situations is central to predicting the future sustainability of TBs [1,2]. This issue becomes even more important when we recognize that more than 40% of the world's population lives in transboundary basins [3]. They will suffer from potential stresses as a result of water scarcity, exacerbated by anthropogenic factors [4], in the future.

The literature on monitoring the global hydropolitical situation began with the collection and collation of historical events worldwide at the transboundary basin level [5]. This idea was later pursued in a project titled "basin at risk", which brought together a series of events between the two extremes of conflict and cooperation versus potential HDs responsible for the events [6]. The attempt paved the way for using statistics to discover historical and future trends in the global hydropolitical situation [7–10]. In this context, more in-depth reflections focused on enriching this database in terms of quantity and quality of environmental or human variables [11–15] or developing a new database [16]. Based on such databases, there is a growing body of research aimed at speculating and mapping hydropolitical tensions in the future in relation to TBs [4,17–20]. This path has created a

very welcoming atmosphere for research that enhances this course through innovation or research into how future hydropolitical behavior in transboundary basins can be projected.

Treating each TB as a system, a small proportion of researchers have begun to adopt system dynamics (SD) to describe potential hydropolitical situations within TBs [21–23]. They employ SD's clear message that implies that the structure of the system determines its behavior [24] and use system archetypes (SA) [24] to infer hydropolitical behavior in TBs without relying on large amounts of data or complex correlation buildings. SA is defined in SD as a practical tool accounting for a pattern of a system's behavior consisting of circles of causality that have a similar structure [24]. It describes standard modes of action in a system [25] and is a helpful tool for answering the question "How can we prevent the same issues from recurring over time?" [26].

In different scholarly fields concerning system behavior, mapping SA has attracted as much attention as support thinking [27], global land system [28], spatial planning [29], construction safety [30], tourism planning [31], sustainable agriculture [32], capacity planning [33], healthcare [34], organic farming [35], rangeland management [36], fuel marketing [37], and watershed management [38].

Therefore, it will be interesting to study the application of SA in hydropolitics, representing the hydropolitical system archetype (HSA) concept. In this study, we argue that each TB maintains specific human–environmental HDs that contribute to generating potential HSAs. Furthermore, we hold that each TB's environmental HDs in terms of geography, morphology, hydrology, etc. may form human HDs, such as demand for development, dam construction, international relations, etc., and then give rise to activation of specific HSAs. This argument has remained unaddressed in previous studies using SA to deal with TBs [21–23]. This paper is a preliminary step to elucidating the application of SA in hydropolitics and to help riparian states provide a diagnostic checklist to recognize their potential HSA by monitoring human–environmental HDs to perceive potential risks in the future.

The rest of the paper is organized as follows. The second part explains the basic concepts of SA and its principles. In the third section, we discuss the mapping of five potential HSAs and their possible behaviors over time as a function of TB-specific environmental features. The fourth part presents a very brief diagnostic checklist for recognizing each HSA in TBs with its application in real case studies. Finally, the paper ends with a discussion of the way forward in the fifth section and a conclusion in the sixth section.

## 2. The Basics of a System Archetype Structure

In system dynamics (SD), the structure comes back to the feedback loops governing a system, namely, the causal loop diagram (CLD) [32]. Here, 10 general SAs are introduced [24], each consisting of CLDs as a powerful system dynamics tool to illustrate pictures of systemic perceptions or feedback structure patterns. CLDs include balancing or negative feedback loops (B), reinforcing or positive feedback loops (R), and a combination of both (Figure A1). According to system dynamics principles [39], the multiplication of total positive/negative signs drawn on the links of a loop by each other is crucial to determine the loop type. By this method, the loop is a reinforcing or a balancing loop depending on whether the given multiplication is positive or negative. A combination of simple reinforcing and balancing loops forms a dynamic structure.

Accordingly, based on SD principles mapped in Figure A1, reinforcing loops generate exponential growth and collapse, in which the growth or failure continues at an ever-increasing rate. In contrast, balancing loops are always bound to a target, a constraint, or a goal that is often implicitly set by the forces of the system [39]. A combination of balancing and reinforcing loops is responsible for the overall behavior of SA. Accordingly, to deal with the application of SA in hydropolitics, this paper follows the courses below:

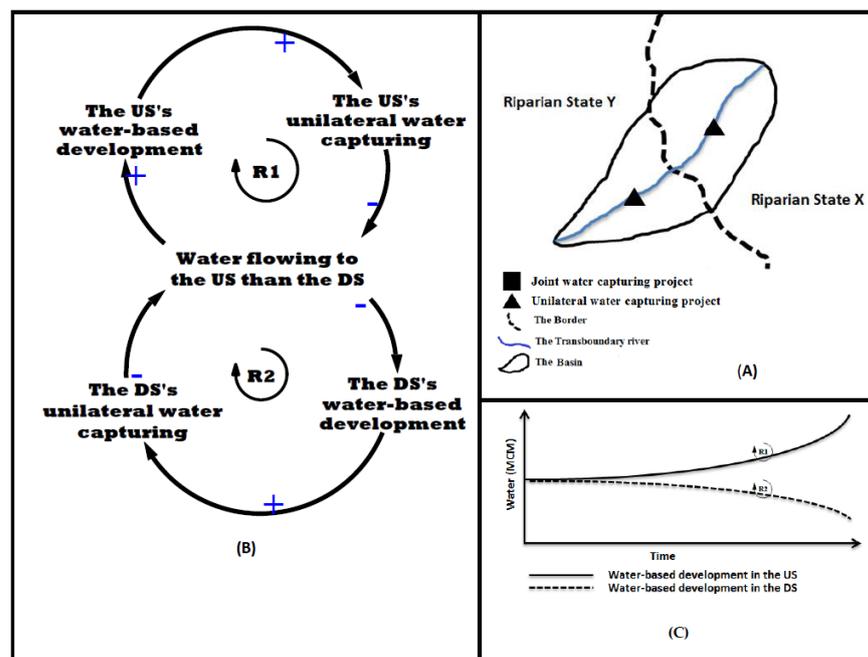
- To portray the schematic layout of borders and common water bodies in a TB;
- To speculate potential interactions between riparian states and with the common water bodies touched by the layout;

- To map the potential interactions via feedback loop structures by creating patterns from typical SAs or coming up with new ones out of the typical archetypes;
- To refer to the principles of the CLDs' performance to hypothesize potential behavior expected from mapped HSA over time;
- To analyze each HSA's feedback loop structure and discover its specific HDs;
- To enrich the diagnostic checklist by embedding HDs against corresponding HSA.

### 3. Mapping Hydropolitical System Archetypes (HSAs)

#### 3.1. HSA1: Bully and the Bullied

This HSA is patterned on a well-known SA titled “success to the successful” consisting of two reinforcing loops interacting against each other [24,40]. As more success for one brings more failure for the other, the result is rapidly skewed toward the more successful side. It fits a simple TB consisting of a transboundary river originating from an upstream state (US) and flowing toward a downstream state (DS) (Figure 1A). The US enjoys being dominant on the most natural water discharge, which typically occurs at the primary tributaries of each TB. Any water captured by it directly results in a decrease in the DS's water flow. This property is the primary hydrological and political feature that provides the environment embracing this HSA. In addition, both riparian states rely on the transboundary river's water, and they can catch the entire water streaming into their soils immediately or later (Appendix A, Table A1).



**Figure 1.** (A) The schematic of the physical environment that can embrace HSA1 (real cases in Appendix A, Table A1). (B) The “bully and the bullied” archetype. (C) The schematic of HSA1 behavior with its responsible loops.

Here, the HSA consists of two reinforcing loops: R1 and R2 (Figure 1B). R1 attempts to increase the US's water withdrawal and thus partially stimulates its highly water-dependent development, referred to in this paper as “water-based development”. Continuation of this action by the US leads to a decrease in water flow to the DS, and its development trend is downward.

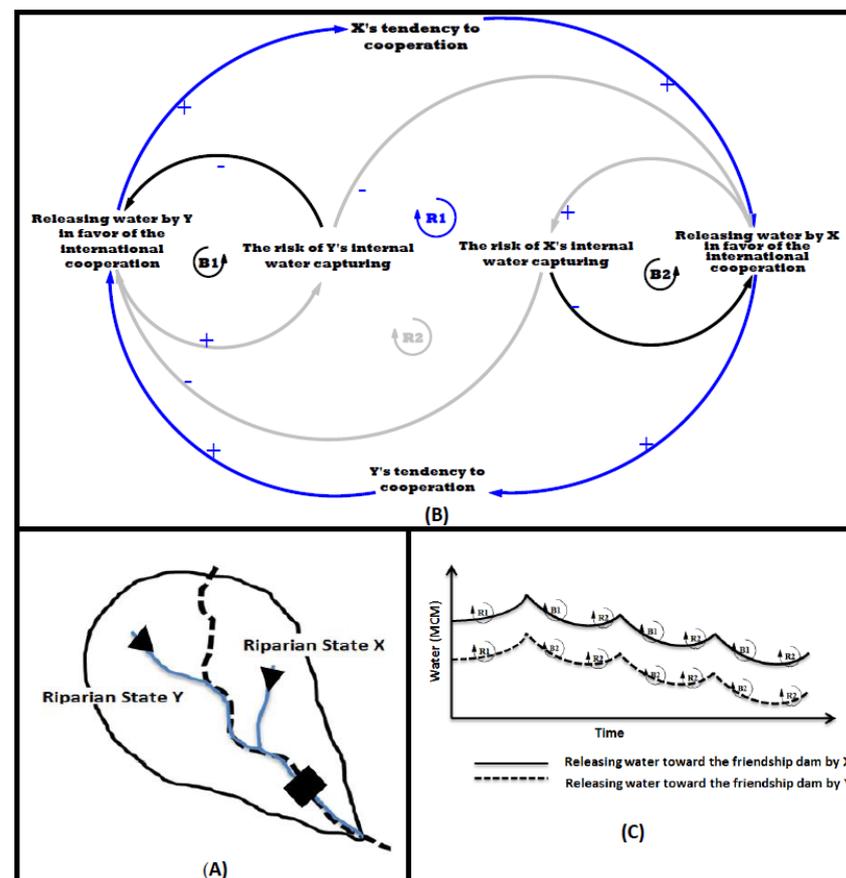
Based on loop performance in SD (Appendix A, Figure A1), the potential behaviors stemming from the mechanism are mapped in Figure 1C. Thus, we will probably witness incremental water withdrawal in the US as the ‘bully’ and decreasing water flows in the DS as the ‘bullied’ resulting from R1 and R2 activities, respectively.

### 3.2. HSA2: Small Players with the Big Game

This HSA follows the “accidental adversaries” archetype [41,42]. Correspondingly, it consists of two reinforcing loops and two balancing loops between two individuals seeking cooperation. Overall, system growth is driven by a global reinforcing structure implying collaboration between two sides. Notwithstanding, two local balancing loops stemming from each individual create a reinforcing loop limiting the overall cooperation.

HSA2 potentially emerges when the condition is suitable for cooperation between two riparian states in conducting a shared water withdrawal project at the international level as soon as their local activities in water withdrawal start harming the cooperation. Then, the HAS propels the situation toward the riparian states bearing their local activities rather than cooperating.

The appropriate environment to host this HSA represents the area where transboundary rivers form part of the borders between riparian states (Figure 2A). At the same time, they both dominate the river’s tributaries in terms of water capture and can control the same amount of natural flow. Furthermore, international borders may be a suitable place for a joint water-capturing project, such as a common dam, called the “friendship dam” in the literature [43–45], which serves various purposes, such as hydropower, agriculture, domestic water, and so on (Figure 2A).



**Figure 2.** (A) The schematic of the physical environment that can embrace HSA2 (real cases in Appendix A, Table A2). (B) The “small players with the big game” archetype. (C) The schematic of the potential behavior of HSA2 and responsible loops.

Once they begin constructing the friendship dam, the R1 loop is born, strengthening the stability of relations between the two riparian states (Figure 2B). Nonetheless, local areas in one or both riparian states that dominate the major tributaries of the transboundary rivers are likely to start increasing water-based development that affects the water supply certainty of the joint water-capturing project. Such measures might be taken autonomously

as part of the large-scale strategy of riparian states with respect to international water cooperation. Such a drawdown would establish balancing loops B1 and B2 in BT, which would advance the unilateral improvement goals of local regions, regardless of national interests. Although such activities sound fundamental for these local communities, they will impact the critical participation between riparian states at an international level, diminishing water due to flow to the big collaboration venture, such as a friendship dam. As a result, each state may feel that it has been betrayed and will correspondingly react to diminish the adverse effects of other states' actions by supporting its local development.

If this situation persists and the results worsen, the primary alliance between riparian states will face a breakdown. As a result, activation of the two balancing loops will be adverse to the constructive performance of the reinforcing loop (R1). It will reduce cooperation and increase instability in both riparian states. Thus, a vicious circle will be created, leading to the alliance's original purpose being forgotten. The actions of riparian states will now only focus on counteracting the hostile actions taken by the other state, supporting the local development in their soils unilaterally. They thus "accidentally" become adversaries.

Figure 2C shows the potential behavior over the long term. The responsible loops for each piece of the graph are also drawn. Friendship dams might initially arise from altruistic motives, and this model will assist riparian states in identifying one another's potential ways of acting by 'small players', which could overpower international participation as the 'big game'.

### 3.3. HSA3: Water and Fire

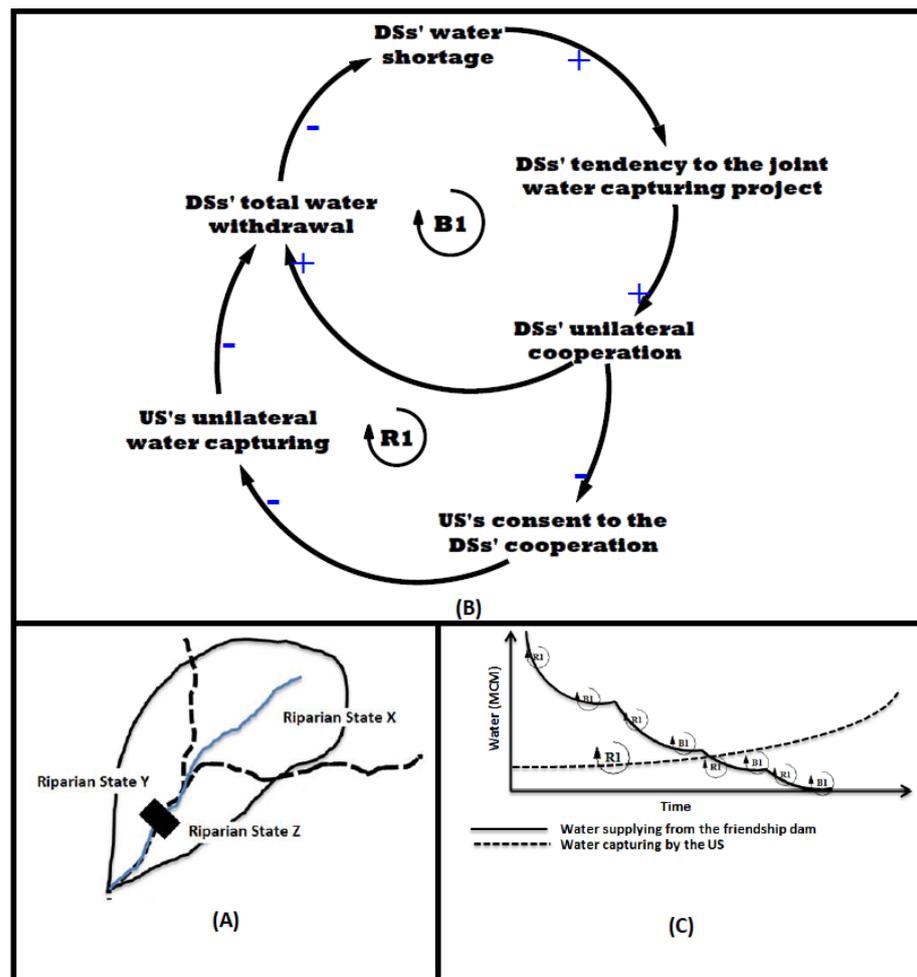
Modelled after the "fixes that fail" archetype [40], this archetype provides a basic system structure consisting of a reinforcing loop and a balancing loop. Reinforcing loops involve a short-term fix that creates long-term balancing loops and may result in the need for even more fixes. Such archetypes likely exist whenever we look for an immediate solution to an underlying problem.

Spatially, HSA3 is tailored to the environment of riparian states that have decided to initiate cooperation on transboundary rivers in the form of joint water abstraction projects. This is to meet their growing water demands. They do so at the expense of dissatisfying the US, which controls most of TB's natural water discharges. Consequently, they put themselves at greater risk of water supply uncertainty than before as they have now become more dependent on the project.

This archetype may be reflected in the location of major tributaries to transboundary rivers that originate from US soil and continue to form part of the international boundary between DSs (Figure 3A).

This archetype consists of a balancing and a reinforcing loop (Figure 3B). The balancing loop seeks to propel the situation toward the desired result while the other one foils the result later. The DSs have built up a dam of friendship based on cooperative relationships. Such a partnership will start with the B1 loop that works to supply water for DSs, but the HSA3 predicts changes in expectations in the long term. The archetype suggests that the quick-fix solution of DSs could bring about unintended consequences that will exacerbate the situation in the long run, causing dissatisfaction in the US. According to this hypothesis, DS's cooperation will activate the B1 loop, which will eliminate the water shortage problem temporarily. Nevertheless, the issue arises when R1 causes the situation to worsen over time, stimulating the US to capture water in its soil (Figure 3B).

This archetype suggests that the cooperation of DSs without considering the US may activate a mechanism that triggers water capture on US soil. The loop's results indicate that, although such a partnership between DSs for 'water' will alleviate their short-term water shortage problem, the long-term trend of the issue will only add fuel to the 'fire' of contention (Figure 3C).



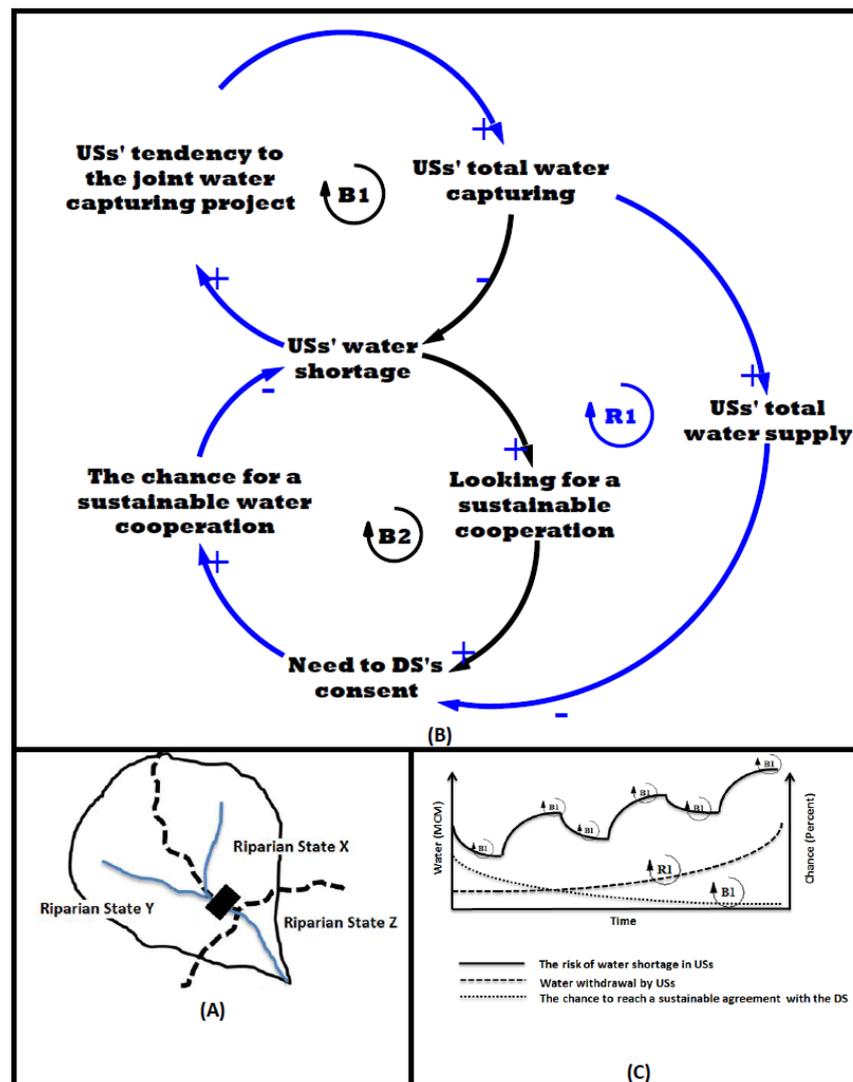
**Figure 3.** (A) The schematic of the physical environment that can embrace HSA3 (real cases in Appendix A, Table A3). (B) The “water and fire” archetype. (C) The schematic of the potential behavior of HSA4 with responsible loops.

### 3.4. HSA4: A Cooperation to Dry for

This HSA follows the “shifting the burden” archetype. It occurs when a system focuses on the symptom rather than the cause of a problem [46]. Accordingly, HSA4 is underpinned by two balancing loops and one reinforcing loop. One balancing loop leads the system to heal the symptoms immediately, and the other addresses the origin of the problem and solves it in the long term. Correspondingly, the reinforcing loop causes the system to overlook the problem’s primary source and delay activating the second balancing loop.

HSA4 allows USs to cooperate on constructing a friendship dam to meet their water demands. TBs will be exposed to HSA4 if they fail to consider DS in their interactions. The USs may be able to form a cooperative alliance in the short run, but HSA4 predicts that they will have different expectations in the long run.

One spatial feature that provides relevant areas for inclusion of this archetype is the transboundary river that forms part of the border between two USs and flows into a DS. USs dominate tributaries of the river and have the most amount of natural water discharge. In the same way, these spatial features tempt USs to construct a “friendship dam” at the international border (Figure 4A).



**Figure 4.** (A) The schematic of the physical environment that can embrace HSA4 (real cases in Appendix A, Table A4). (B) The “a cooperation to dry for” archetype. (C) The schematic of the potential behavior of HSA4 with responsible loops.

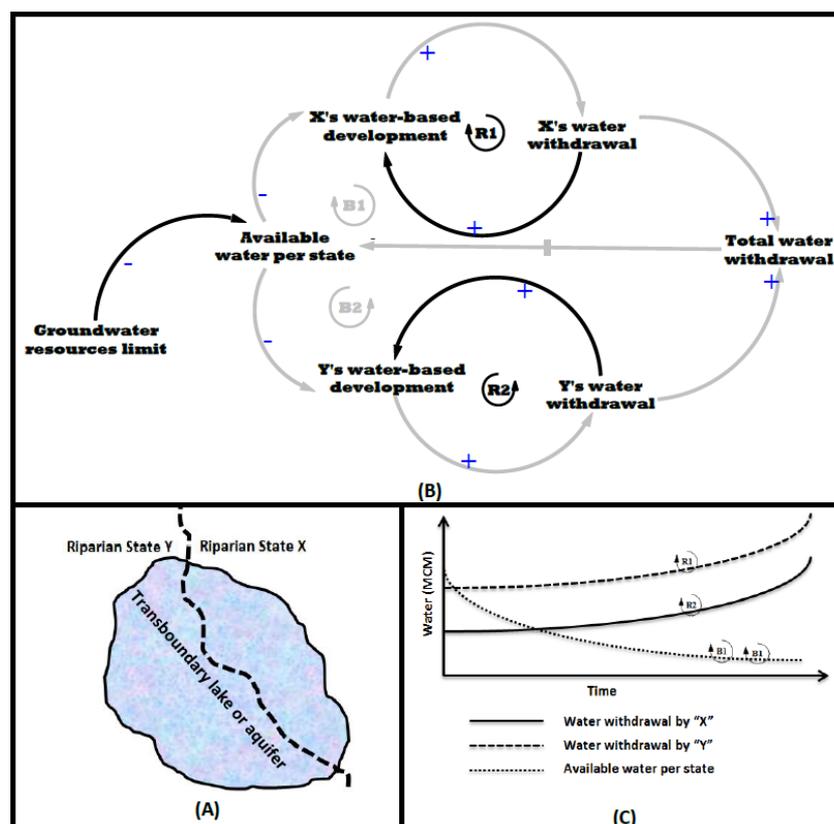
This system archetype consists of two possible balancing loops, B1 and B2, and one reinforcing loop, R1 (Figure 4B). Building the friendship dam without entering the DS into the deal, B1 balances the system by meeting USs’ water demands. On the other hand, B2, as a fundamental solution, has the potential to balance the system based on a sustained partnership while considering DS’s advantages. Therefore, B2 emphasizes the importance of collaborating with DS before building the friendship dam to increase the chances of long-term, sustainable cooperation.

The main problem arises when riparian states prefer to invest in B1 as a short-term solution instead of B2 as a long-term solution. Such a decision reduces the need for fundamental solutions and sustainable agreements with DS. As a result, temporary solutions that mask ‘cooperation’ inadvertently undermine B2’s activity and overall reduce the likelihood of achieving sustained collaboration, thereby activating the R1 loop that serves to ‘dry’ the flow of water to the DS. On a pessimistic note, if DS has enough power on other fronts, it could sabotage established partnerships.

Based on the description above, the corresponding behavior of the system archetype is shown in Figure 4C. The R1 loop is responsible for increasing water demand in the USs. The B1 loop drives a trend that increases the risk of water scarcity in the USs while reducing the chances of a sustainable agreement to zero.

### 3.5. HSA5: Covert Measures and Overt Effects

HSA5 comes from the “tragedy of the commons” theory dealing with a situation where two or more parties rely on a shared resource [47,48]. Their activities continue until the common resource runs out from overextraction. This archetype can be extended to all transboundary aquifers exposed to overextraction by their riparian states. Similarly, this archetype can also be applied to transboundary lakes that are at risk of drying up as a result of riparian states draining the rivers that replenish them. (Figure 5A).



**Figure 5.** (A) The schematic of the physical environment that can embrace HSA5 (real cases in Appendix A, Table A5). (B) The “covert measures and overt effects” archetype. (C) The schematic of the potential behavior of HSA5 with responsible loops.

The main characteristic of HSA5 is that each riparian state’s share in water withdrawal is immeasurable. Thus, even if they act in good faith, the unrestrained exploitation of a common water resource to meet their water demand would generate HSA5 [24]. Thus, each riparian state sees shared water resources as unlimited resources they can use to meet their water needs. However, the uncontrolled activities of riparian states regarding water withdrawal directly from common water sources, such as groundwater, or indirectly from recharge sources, such as lakes, will have irreversible effects on them.

The system structure consists of four causal loops, including two reinforcing (R1 and R2) and two balancing loops (B1 and B2) (Figure 5B). Both presumed states withdraw water from groundwater resources and engage with two reinforcing loops. The loops in the short term will reinforce water-based development in riparian states X and Y. On the other hand, their continuity enhances the process of increasing the withdrawal of groundwater aquifers. Then, the two balancing loops advance the situation toward reducing common resources to zero.

Based on the corresponding CLDs depicted in Figure 5B, it will therefore lead to a decrease in cooperation, creating an erosion in the goal of the riparian states. The rise in

tensions between countries as they blame each other for creating such a crisis is one of the potential unintended consequences of such an HSA.

The schematic of the potential behavior that may result from HSA5 and its responsible loops is plotted in Figure 5C. It assumes that if the total usage of transboundary common water resources as the ‘covert measure’ becomes too high for the system to support, the common water resources will become overloaded or depleted, and every state will experience ‘overt effects’.

One can further explore the idea by watching Video S1 in the Supplementary Materials, which includes animation associated with each HSA.

#### 4. Discussion

##### 4.1. Analogy of HSAs and a Diagnostic Checklist

To understand the potential hydropolitical situation, a cognitive map is sketched in Figure 6 to simplify the HSA analogy. The figure allows us to look at the hydropolitical situation by tracing the actions of riparian states back to potential HSAs. This simplified tool highlights the critical human HDs that underlie each HSA.

In addition, we analyzed the HDs of HSA causal loop structures and classified them into environmental and human in Table 1. Thus, the major HDs that help activate the introduced HSA are shown in Table 1. A diagnostic checklist is shown in Table 2 by marking the HDs contained within a particular HSA. As a result, the HDs of each TB can be compared against the checklist to identify a potential HSA.

**Table 1.** Human–environmental factors specific to each HSA.

Types of HDs	HD Number	Explanation of the HD
Environmental HDs	1	Common water resources, such as groundwater or lake, between riparian states
	2	Most of the transboundary river’s natural water discharge is generated in US/USs
	3	The transboundary river is considered part of a border between USs in its course
	4	The transboundary river is considered part of a border between DSs in its course
	5	The transboundary water body intersects a US–DS border in its course
	6	There is a potential for constructing a “friendship dam” on the US–DS border
Humanitarian HDs	7	Currently, the US/USs are dependent on the transboundary river or common water resources or will be in the future
	8	Currently, the DS/DSs are dependent on the transboundary river or common water resources or will be in the future
	9	Currently, the DSs can control the transboundary river or common water resources on their soils or can do so in the future
	10	Currently, the USs can control the transboundary river or common water resources on their soils or can do so in the future
	11	Low level of coordination between riparian states and their local region on water capture

**Table 2.** The diagnostic checklist to recognize the presented HSAs in TBs. ✓: Included in the HSA.

HSAs	HDs’ Number following Table 1										
	1	2	3	4	5	6	7	8	9	10	11
HSA1		✓			✓		✓	✓	✓	✓	
HSA2		✓	✓			✓		✓			✓
HSA3		✓	✓		✓		✓	✓	✓		
HSA4		✓	✓		✓	✓	✓		✓		
HSA5	✓						✓	✓	✓	✓	

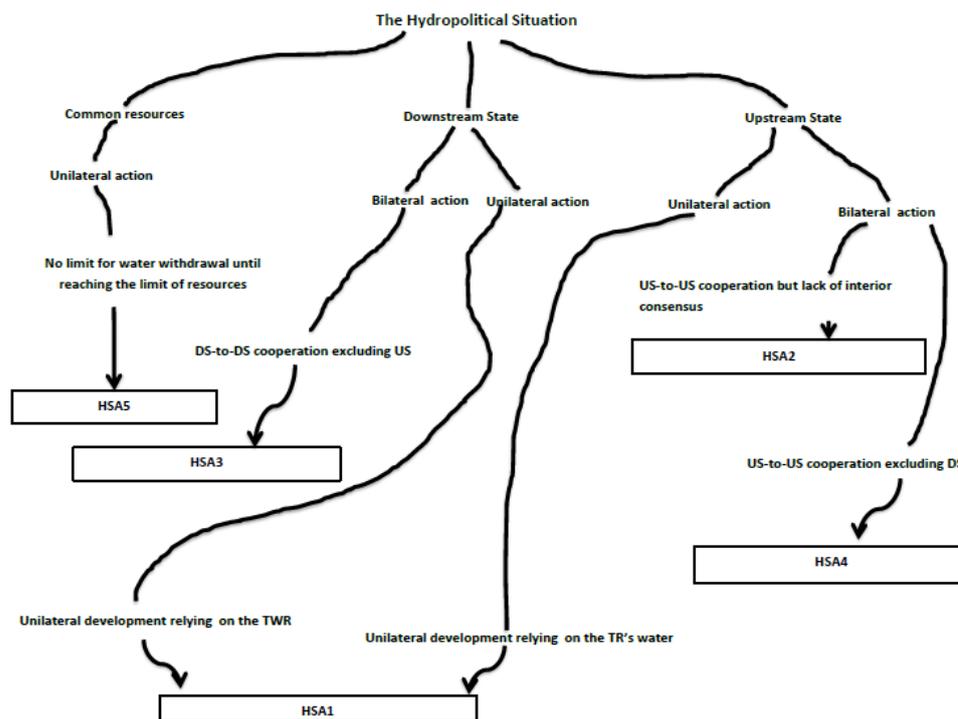


Figure 6. The cognitive map for studying the presented HSAs.

4.2. An Instance Implications

Drawing on Table 2, the authors worked through some TBs in terms of HDs to diagnose potential HSAs. Based on the results, Table 3 presents the potential HSAs for the surveyed TBs.

Table 3. Potential HSAs in some TBs diagnosed based on Table 2. ✓a: Included in the TB.

TBs	HDs Number Presented in Table 1											Potential Archetypes	
	1	2	3	4	5	6	7	8	9	10	11		
Mekong River		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	HSA1, HSA4, HSA3, HSA2
Helmand River	✓	✓			✓		✓	✓	✓	✓			HSA1, HSA5
Okavango River		✓		✓	✓	✓	✓	✓	✓	✓			HSA1, HSA4
Harirud River			✓	✓		✓		✓	✓	✓			HSA3
Amu Darya River		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		HSA1, HSA2, HSA4
Lake Victoria	✓						✓	✓	✓	✓			HSA5

The results provide information to riparian states of the Okavango, Mekong, and Harirud TBs about possible HSA4 and HSA3 where two riparian states are inclined to construct friendship dams on their water border while excluding one or more other riparian states [45,49]. The results suggest that the riparian states of Lake Victoria, Okavango, and Helmand TBs should be cautious about pursuing any water-based development [23,49,50] that will harm their own long-term development due to HSA5. The DSs in the Indus, Mekong, and Euphrates–Tigris TBs may be more inclined to substitute their water-based development with other patterns that will be less dependent on water as a result of potential HSA1 that accentuates water capture within their USs [51,52]. According to the results, riparian states along the Amu Darya and Mekong TBs should stop building friendship dams along their common borders [53,54] unless they guarantee high levels of internal coordination over water capture in their soils [55], otherwise HSA2 will reappear.

#### 4.3. Pros and Cons

Table 4 provides a comparison of critical criteria to assess whether the HSA approach can give insightful information and provide complementary contributions to the ongoing study path, which mainly relies on water conflict databases [4,19,20]. The points are as follows:

- Causal structures governing HDs contribute to explaining HSA and are more precise and transparent than previous studies (referring to criteria A).
- While recent efforts have focused on addressing hydropolitical situations in a quantity range between conflict and cooperation, the HSA approach focuses on discovering system structures that are responsible for future hydropolitical situations. (referring to criteria B).
- As the HSA approach does not rely on correlation building, it can barely interact with databases, including most of the variables (referring to criteria C).
- Applying this method allows HDs to be identified and added to related endeavors to enhance their databases. As an example, building a friendship dam is considered an indication of high level of cooperation between riparian states in TBs. The HSA approach suggests twice thinking about this mindset (referring to criteria D).
- Achieved HSAs have the potential to be utilized for simulation to manifest future hydropolitical situations resulting from any possible intervention in TBs (referring to criteria E).
- HSA provides an exemplary overview of the hydropolitical situation and helps scientists further substantiate their advanced research (referring to criteria F).

**Table 4.** A comparison between the system approach and recent works in assessing the hydropolitical situation.

Recent Approaches	Criteria					
	A	B	C	D	E	F
[4]	-	✓	✓	✓	-	-
[19]	-	✓	✓	-	-	-
[20]	-	✓	✓	✓	-	-
HSA	✓	-	-	✓	✓	✓

A: Transparency in mapping the causal relation between HDs and hydropolitical situations; B: Ordering and quantifying the hydropolitical tensions in TBs; C: Ability to interact with present databases and work with a vast amount of data; D: Help to promote the current databases; E: Simulation ability for assessing future interventions; F: Giving a quick holistic view of future hydropolitical tensions.

#### 4.4. Limitations and Ways Forward

- HSA mapping relies on juxtapositions of borders and transboundary water bodies. Even though these human–environmental features do not guarantee decisive behaviors of riparian states, they serve as physical environments that entice riparian states to engage in particular courses of action in the basins. Consequently, the typical juxtapositions are kinds of HDs that have not yet been taken into account in hydropolitical studies. We can demonstrate the significance of this HD in TBs by employing system archetype. However, only a small number of relevant issues are discussed in this paper. This human–environment HD should therefore be referred to as “hydropolitical morphology” as a new field of geographical studies dealing with hydropolitics.
- This paper looked at HSAs as dynamic hypotheses that call for more in-depth studies to be proven as a theory or practical principles. Therefore, condensed case studies that consider a wide range of variables, such as that carried out by Shahbazbegian et al. [23] for the Helmand transboundary basins, need to be used to enrich and shore up these HSAs. Hence, in order to broaden the diagnostic checklist’s applicability as well as its reliability, we recommend comparing some condensed case studies in this regard.

The HSA achieved does not reflect the full behavior and interactions in transboundary basins. Many factors contribute to mapping HSAs, such as power, trade, investment, the movement of people, and security arrangements. These factors affect the course of hydropolitics in a transboundary basin that this paper overlooked. This gap does not disprove the HSAs depicted here and will even contribute to their enrichment in further research. For example, according to the diagnostic checklist in Table 2, Euphrates–Tigris and Colorado TBs potentially bear HSA1 or the bully and bullied archetype (Table A1). However, evidence indicates that the Euphrates–Tigris basin complies with HSA1’s expected behavior over time, with the outstanding contribution of Turkey as a bully furthering its hydraulic mission in the TB at the expense of downstream states that are bullied [56–58]. On the other hand, compliance with HSA1 no longer pertains to the Colorado TB as historical evidence suggests successful water-based development in the USA and Mexico despite both states relying on the transboundary river [59,60]. This fact not only does not refute the application of HSA1 but also calls attention to uncovering other mechanisms or variables that have halted this archetype’s unintended outcomes in the Colorado TB. As a result, expanding on the bully and bullied archetype for the aforementioned case studies would be interesting because both of these cases bear this archetype. However, the riparian states of one have settled for it, while the others have succeeded in paralyzing it. Likewise, comparative studies, which may include HSAs in a variety of cases, may uncover novel HDs and system mechanisms that have the potential to sway the balance in favor of cooperation among TBs.

## 5. Conclusions

In this paper, it is argued that there is a high potential for employing SAs in order to obtain a holistic view of hydropolitical behavior. This involves complementing and extending the current approaches that rely on complex correlations. To this end, we investigated five dynamic hypotheses, each premised on a specific HSA, for five different TBs around the world. Hypotheses were formulated regarding the morphology of transboundary borders and transboundary rivers in TBs. In this regard, each HSA’s structure was mapped, and the schematic of expected behavior based on the principles of system dynamics was speculated over time. Next, an analogy of HSAs and HDs responsible for each HSA was developed to provide a typical diagnostic checklist for identifying HSA in some TBs worldwide. Overall, this article fundamentally shows how to employ SAs in hydropolitics and how to put the casual thinking approach into practice.

It must be mentioned that this study has many oversimplifying assumptions that we acknowledge as limitations of this work. For example, one of the main HDs that can influence HSA but was overlooked in this study, especially in HSA1, is power asymmetry between riparian states [61]. This HD dramatically affects the structure of the HSA system and can change the dominance of the loop, not to mention speculating on its behavior over time. However, this no longer changes the paper’s central message and can be considered an area for future research. This methodology is recommended for explicit TBs in order to eschew more top-down analytical approaches to identify the advantages and disadvantages of HSAs on the ground and track down ways to overcome their undesirable behavior.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/hydrology9120207/s1>. Video S1: animation associated with each Hydropolitical System Archetype (HSA).

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## Appendix A

**Table A1.** Objective cases that can environmentally embrace HSA1.

Name of the Basin	X	Y
Alsek basin	Canada	United States
Aysen basin	Chile	Argentina
Dasht basin	Iran	Pakistan
Euphrate–Tigris basin	Turkey	Iraq–Syria
Colorado basin	USA	Texas
Helmand basin	Afghanistan	Iran
Mmurghab basin	Afghanistan	Turkmenistan

**Table A2.** Objective cases that can environmentally embrace HSA2.

Name of the Basin	X	Y
Dragonja basin	Croatia	Slovenia
Chira basin	Ecuador	Peru
Atrak basin	Turkmenistan	Iran
Zarumilla basin	Ecuador	Peru
Foyle basin	Ireland	Great Britannia
Artibonite basin	Haiti	Dominica
Astara chay basin	Azerbaijan	Iran
Mana–Morro basin	Liberia	Sierra Leon
Zambezi basin	Zambia	Zimbabwe
Dra basin	Algeria	Morocco

**Table A3.** Objective cases that can environmentally embrace HSA3.

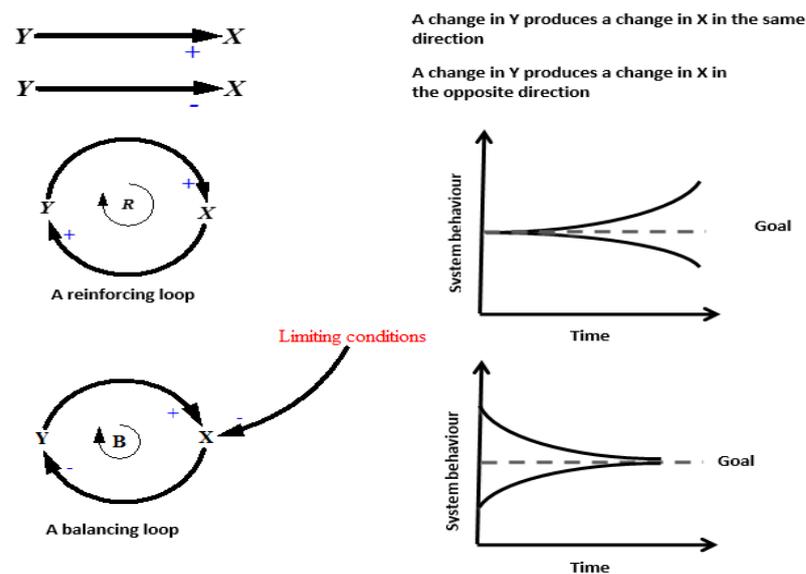
Name of the Basin	X	Y	Z
Aral sea basin	Turkmenistan	Tajikistan	Afghanistan
Jordan basin	Syria or Palestine	Israel	Jordan
Hondo basin	Guatemala	Belize	Mexico
Danube basin	Austria	Hungry	Slovakia
Danube basin	Serbia	Rom	Bulgaria
Mekong basin	Chile	Laos	Thailand
Orange basin	Batswana	Namibia	South Africa
Limpopo	Botswana	South Africa	Zimbabwe
Maritsa basin	Bulgaria	Turkey	Greece
La Plata basin	Brazil	Argentina	Paraguay
Maputo basin	South Africa	Mozambique	Swaziland

**Table A4.** Objective cases that can environmentally embrace HSA4.

Name of the Basin	X	Y	Z
Congo basin	Tanzania	Zambia	Congo
Dnieper basin	Russia	Belarus	Ukraine
Amur basin	China	Mongolia	Russia
Aral sea	Kazakhstan	Uzbekistan	Tajikistan–Kirgizstan
Gash basin	Ethiopia	Eritrea	Sudan
Asi/Drontes basin	Turkey	Syria	Lebanon
Kara–Arask	Russia	Georgia	Azerbaijan
Lempa	Guatemala	El Salvador	Honduras
Mekong	Laos	Thailand	Vietnam
Okavango	Angola	Namibia	Botswana
Volga basin	Russia	Kazakhstan	Volga lake

**Table A5.** Objective cases that can environmentally embrace HSA5.

Name of the Aquifer	X	Y
Vakhsh aquifer	Afghanistan	Tajikistan
Wasia–Biyadh aquifer	Saudi Arabia	Iraq
Ahangarqan aquifer	Uzbekistan	Tajikistan
Systema doiranis aquifer	The former Republic of Yugoslavia	Greece
Gedaref aquifer	Ethiopia	Sudan
Mountain aquifer	Israel	Palestine
Fleons–Simon aquifer	Italy	Austria
Geneves aquifer	Switzerland	France
Low Mino aquifer	Spain	Portugal
Agua Dulce aquifer	Bolivia	Paraguay



**Figure A1.** The features of simple “balancing” and “reinforcing” loops adopted from [39].

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