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Water Bankruptcy: The Formal Definition

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Abstract

"Water crisis" has become the default label for almost any episode of water stress, from short-lived droughts to decades-long overuse of rivers and aquifers. Yet in many regions of the world, water problems no longer resemble a crisis in the conventional sense. They represent a post-crisis failure state in which human–water systems have exceeded their hydrological carrying capacities, and societies have spent beyond their sustainable hydrological budgets for so long that critical water assets are depleted, some ecosystem damages are irreversible on human time scales, and a return to "normal" is infeasible even with prohibitive economic, social, and environmental costs. This paper proposes *Water Bankruptcy* as a more meaningful and useful term for this condition and provides the first formal, scientific definition of this concept grounded in hydrology, ecology, and socio-economics. Water bankruptcy is presented not only as a metaphor to communicate the severity of the problem and the urgency of a transformative fresh start, but also as a diagnostic label for human–water systems whose water use persistently exceeds hydrological carrying capacity (insolvency), eroding the water and natural capital to the extent that some damages are irreparable (irreversibility). Drawing on a bank-account analogy that likens surface water to a checking account and groundwater to a savings account, the paper explains why language matters for policy outreach and public discourse and discusses why bankruptcy framing calls for not only protecting water but also the natural capital and hydrological cycle that produce it. It also outlines the misleading policy implications of terms such as stress, crisis, or emergency in reference to the state of systems that can no longer restore their baseline conditions. While the focus of the paper is on water, the underlying discussions and framing are applicable to other natural systems facing insolvency and irreversibility under human pressure, including the climate system.

Keywords Water bankruptcy · Water crisis · Water stress · Water governance · Integrated water resources management (IWRM) · Human-water systems

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1 Introduction: When the Crisis Never Ends

Policymakers, journalists, and scientists continue to speak of "water crisis" in different parts of the world with increasing urgency. The term is used for everything from a failed monsoon season in a single year to the multi-decadal depletion of aquifers and the drying of lakes and wetlands. Despite the differences in their type, scale, significance, and root causes, the ongoing water scarcity, water access, and drought problems worldwide are all labeled as a "water crisis". The phrase is powerful, but conceptually loose when used insensitively and continuously for perpetual problems without triggering any action.

In the risk, disaster, and crisis-management literatures, a *crisis* is not just any undesirable state. It is typically defined as a situation that: (1) poses a severe threat to core values or life-sustaining systems; (2) generates a high level of uncertainty and frustration; and (3) demands urgent decisions under time pressure. Crucially, a crisis is usually understood as a *temporary departure* from normal conditions, triggered by an acute shock (such as a drought, flood, storm, hurricane, wildfire, or contamination event) and followed by some form of resolution, either a return to a prior equilibrium or a transition to a new, more stable state. Crisis management is therefore *episodic* and *restorative*. Extraordinary measures are mobilized for a limited period with the goal of "getting through" the shock and restoring functionality.

Viewed through this lens, the phrase "water crisis" fits many short-lived, shock-driven events: a multi-year drought that stresses a reservoir system and pushes a city toward Day Zero, a sudden contamination that forces a city to shut down its supply, or a conflict over water triggered by an intervention of an upstream riparian state to block the downstream flows. In such cases, the onset is relatively clear, the deviation from normal conditions is evident, and the goal of policy is to mitigate the problem, survive the event, and return to something resembling the pre-crisis baseline, hopefully with some improvements in preparedness to avoid similar events.

However, what is unfolding in many regions of the world does not resemble this episodic pattern. Globally, many lakes, rivers, and wetlands have shrunk or dried up, groundwater levels have fallen, land has subsided, and sinkholes have appeared as aggressive overextraction continues, and desertification, biodiversity loss, wildfires, and sand and dust storms have intensified. On one hand, the media and some environmental activists have the tendency to "climatize" these disastrous trends to seek attention to the important global threat of climate change, with the hope of triggering policy action, and on the other hand, many decision makers blame these issues on climate change to evade responsibility and accountability. Nonetheless, the similar patterns of chronic overuse and degradation across the world are not temporary deviations caused solely by climatic anomalies; they are the cumulative result of decades of systematic overspending of surface and groundwater, pushing systems toward their boundaries and into a failure mode.

From a systems perspective, these conditions are better understood as a long-term, path-dependent transformation of the coupled human–water system than as a water crisis in the classic sense. The system is no longer oscillating around a stable baseline temporarily disrupted by shocks; instead, the baseline itself has shifted because critical natural capital—perennial river flows, groundwater storage, lakes, wetlands, snowpacks, glaciers, forests, and other water sources and water-related ecosystems—has been consumed or degraded.

In many basins, even a sequence of many wet years cannot restore the lost functions within any reasonable human time frame.

The bitter reality for many water systems worldwide is that they are facing both *insolvency* and *irreversibility*. Accordingly, the author has been using the term *water bankruptcy* to capture it: a state in which a human-water system has spent beyond its hydrological means for so long that it can no longer satisfy the claims upon it without inflicting unacceptable or irreversible damage to nature (Madani 2017). The metaphor resonates because it mirrors the logic of financial bankruptcy: income, assets, creditors, and default. Yet, as discussed in this paper, what distinguishes water bankruptcy (and bankruptcy of other human-nature systems) from financial bankruptcy is that the latter concerns insolvency only, whereas the former is the manifestation of both insolvency and irreversibility.

This paper offers the first formal definition of *water bankruptcy in human-water systems*, drawing on the author's work in the scientific, policy, and advocacy worlds, as well as his public communication experiences over the last two decades, to move the water bankruptcy concept beyond a metaphor. It argues that recognizing water bankruptcy as a distinct *post-crisis state*, rather than an endlessly prolonged crisis, is essential for water governance in the Anthropocene, because not only does it facilitate communication to the public and policy circles and transform the discourse, but also it fundamentally changes both the questions that are asked and the strategies that are pursued.

2 The Misleading Implications of the "Water Crisis" Discourse

The objections of the author to using the term *water crisis* to describe the contemporary water problems in different parts of the world are not merely semantic; they are strategic and philosophical. As crisis theory emphasizes, crises are typically acute, time-bounded events that demand urgent but temporary deviations from normal governance and business-as-usual. In many over-exploited basins, by contrast, water stress is chronic and structurally embedded. Several features of these systems make the crisis label misleading (Madani 2017):

I. **Crisis implies temporariness and reversibility.**
A crisis has a beginning and an end. If it persists for decades, then by definition, the system has failed to exit the crisis, and the appropriate terminology is *defeat*, not ongoing emergency. Repeatedly labeling a chronic water condition as a water crisis or water emergency obscures the reality that the system has failed and the pre-crisis baseline is no longer attainable.

II. **Crisis has a psychological function that has been exhausted.**
The main utility of declaring a crisis is to mobilize stakeholders in response to a significant threat. But the term has been applied so often and across so many sectors that it has lost its power to galvanize action. In many contexts, talk of "water crisis" has become background noise, creating fatigue rather than urgency.

III. **Crisis management focuses on restoration, not transformation.**
In genuine crises, the management goal is to mitigate the problem and restore the system to its previous state. For the natural systems that have already exceeded their safe limits of human pressure and healthy thresholds (Rockström et al. 2009; Steffen et al.

2015; Bunsen et al. 2021) due to persistent excessive water use, restoration of dried wetlands, drained aquifers, subsided lands, and extinct flora and fauna is unrealistic within any reasonable time frame. Clinging to a restoration narrative encourages costly attempts to resurrect the past rather than investing in adaptation to new realities. Crisis management focuses on mitigation only, but bankruptcy management is about a transformative, fresh start—mitigation plus adaptation to a new, bitter reality in which, while some damages remain irreversible, new damages can be effectively prevented.

IV. **Crisis talk keeps systems in denial and delays the admission of defeat.**
When managers and politicians are in denial and refuse to acknowledge that the system is already in a post-crisis failure state, they continue to make promises implying that the problem is only temporary and can be mitigated. In such conditions, decision makers mainly rely on technological supply-oriented solutions. These decisions, which seek to address the water deficit (symptom of the problem) through increased water supply, without considering the main social-ecological dynamics that cause the chronic water shortages, normally backfire, further degrading the resource base. The longer the denial persists, the larger the irreversible losses and the higher the cost of eventual adaptation.

In summary, when water bankruptcy is still described as a crisis, public discourse promises mitigation and recovery instead of managing decline and re-negotiation of expectations. This is a strategic mistake as the mislabeling actively hinders effective response. Figure 1 reflects the fundamental differences between the three states of concern in human-water systems.

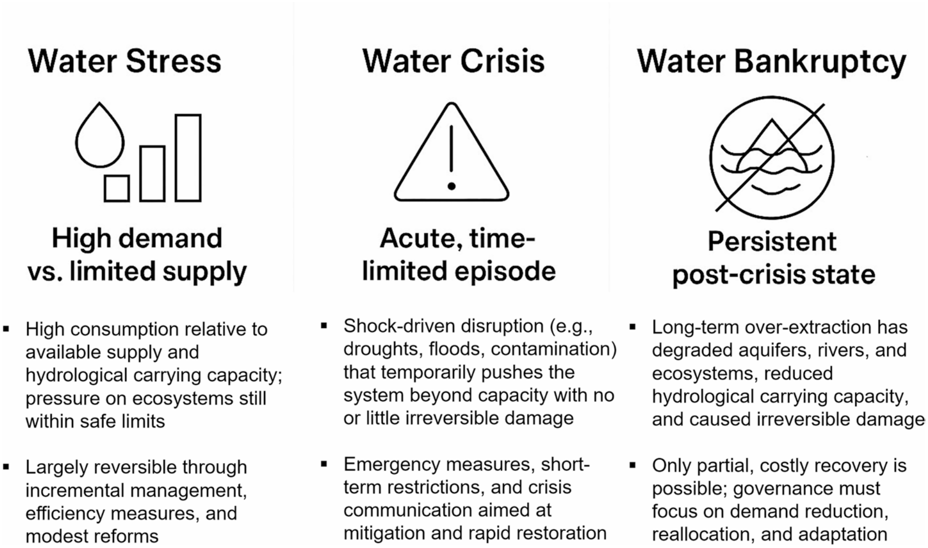

Fig. 1 The three states of concern in human–water systems: (i) water stress, where high demand relative to supply is still largely reversible; (ii) water crisis, an acute, shock-driven episode that temporarily exceeds capacity; and (iii) water bankruptcy, a persistent post-crisis state marked by degraded natural capital, reduced hydrological carrying capacity, and the need for demand reduction, reallocation, and adaptation

3 From Metaphor to Allocation Tool to System Diagnosis

Over the last decade, the term *water bankruptcy* has become a prevalent choice to describe the worsening water situation in the author's home country, Iran (Madani et al. 2016). Although developing a new discourse on Iran's water mismanagement (Mahoozi 2025a) was very costly from the security and political standpoints (Stone 2018; Kamali Dehghan 2018; Tamman 2021), this term has been established as a popular choice in the Persian community worldwide and international media to better communicate the severity of Iran's long-running chronic water problem (Collins 2017; Ketabchy 2021; Yee and Nikounazar 2023; International Crisis Group 2023; Goldstein and Bar-Sef 2025; Sharifi 2025). But the concept is not geographically limited. Similar patterns of water over-allocation, aquifer mining, and ecological collapse are observed in various parts of the world. In the Middle East and North Africa region, high water stress, climate vulnerability, low agricultural productivity, energy-intensive desalination, and sand and dust storms intersect with complex political economies; in parts of South Asia, groundwater-dependent agriculture and urbanization have produced chronic declines in water tables and land subsidence; and in the American Southwest, Colorado River and its reservoirs have become symbols of over-promised water under development and climate change. Across these contexts, water bankruptcy is increasingly invoked in media, policy analysis, and academic work to capture a shared intuition: that systems are not merely under stress, but have been structurally overspent.

While the use of this term for Iran and other parts of the world has more than a metaphorical meaning, as will be described in this article, the combination of the words 'water' and 'bankruptcy' to convey a severe state of water shortage is not new. Table 1 summarizes the various development phases of the water bankruptcy concept, which are described below.

3.1 Water Bankruptcy as a Metaphor

The term "water bankruptcy" has been used as a means to draw attention to looming water shortages at least since the late nineteenth century (Middleton 1898). These early appearances, and most of those throughout the twentieth century (Black 1966; Ramdial 1971; Coates 1985; Famisa 1977), were sporadic and purely rhetorical to dramatize a perceived mismatch between available water and current or projected demands.

In the early twenty-first century, similar metaphorical uses appeared sporadically in media commentary, environmental advocacy, academic publications, and some policy reports (Barlow and Clarke 2001; Williams et al. 2009; Shaofeng et al. 2010; World Economic Forum 2009; Madani et al. 2016). In this strand of usage, 'water bankruptcy' functioned mainly as a vivid label for 'running out of water' and the risk of a mismatch between water availability and water demands.

3.2 Water Bankruptcy as a Normative Reallocation Tool

Water bankruptcy has also been used as a legal–economic framing to describe and prescribe solutions for insolvency situations when there is not enough resource to satisfy all rights and expectations, and some form of triage and reallocation is unavoidable, whether or not the law acknowledges it explicitly. Under this type of framing, bankruptcy rules and resolution methods (O'Neill 1982; Aumann and Maschler 1985; Curiel et al. 1987) are applied in the

Table 1 Genealogy of the 'water bankruptcy' concept

Framing	Phase	Use
Metaphoric	Late 1800 s – present	Used as a metaphor in media, public discourse, policy documents, and occasionally in scientific publications, to warn of extreme water scarcity, without any formal definition or analytical content.
	2016 – present	Used without a formal definition, as a popular metaphor in media, public discourse, policy documents, and scientific publications, especially to describe the chronic water shortage issues in Iran, following the advocacy efforts of the author and the publication of Madani et al. (2016)
Normative Regulatory Reallocation	2008 – present	Used in scientific literature in operations research, economics, and water resources management as an analytical tool to resolve overallocation problems using bankruptcy methods, following Sheikhmohammady and Madani (2008) and Ansink (2009)
	2011 – present	Used in scientific literature in economics and law as a legal/institutional mechanism to resolve insolvency problems, following Madani and Dinar (2011) and Klein (2012)
Diagnostic	2017-present	Reframed and used in public and policy discourse to describe chronic water overuse, ecological degradation, and mismanagement in the case of Iran to highlight governance failure in crisis management, crossed thresholds, and non-restorability of past conditions, following Madani (2017)
	Post-2026	Formal definition of water bankruptcy in human-water systems established in the scientific literature by this paper for diagnosis of systemic failure, not a temporary shortage, and a persistent post-crisis state of basins and nations where long-term water use and claims have exceeded renewable availability and safe depletion limits, causing irreversible or effectively irreversible degradation of natural capital, extending the use to the global scale as a diagnostic lens to transform water governance agenda for mitigation, adaptation, reallocation, and justice

case of water bankruptcy, where the available water stock must be divided among claimants whose total demands exceed the available quantity. This is done using various axioms, transparent principles, and regulations that can facilitate a fresh start and 'fairly' distribute the losses.

In 2008, Sheikhmohammady and Madani proposed using the conventional rules of practice rooted in religion and tradition, as well as economic methods used to address bankruptcy problems, to resolve allocation conflicts over transboundary water systems. The financial bankruptcy resolution methods also inspired their early applications to water allocation in transboundary river systems (Ansink 2009; Ansink and Weikard 2012; Madani et al. 2014), leading to a growing body of literature on solving water insolvency problems using bankruptcy allocation principles (Madani et al. 2014; Mianabadi et al. 2015; Degefu and He 2016a, b; Oftadeh et al. 2016; Janjua and Hassan 2020; Rightnar and Dinar 2020; Yazdian et al. 2021; Zheng et al. 2022; Virani et al. 2025; Janjua et al. 2025).

Another line of work on the use of bankruptcy principles in water resources bankruptcy problems sought to establish regulatory procedures. In 2011, Madani and Dinar proposed using the bankruptcy rule to build a regulatory institutional framework for dealing with groundwater bankruptcy and overallocation of other common-pool natural resources (Madani and Zarezadeh 2012; Madani and Dinar 2013). A year later, Klein (2012) used an analogy between the reallocation of water rights and Chap. 9 municipal bankruptcy in the United States, proposing a structured approach to reconcile rigid legal priorities with the practical need to reallocate water under scarcity conditions (Larson and Kennedy 2015; Zarin-Rosenfeld 2023).

In this category of water bankruptcy literature and framing, a shared water system, river basin, aquifer, or municipality is not physically out of water; rather, existing legal entitlements or justified claims cannot all be honored simultaneously, and a quasi-bankruptcy proceeding is needed to reset them. In other words, in this line of work, water bankruptcy is only a *normative* device: given insufficient water to fulfill demands, how should the shortfall be shared? The focus is on addressing insolvency through rules of division and legal procedures of reallocation, not on whether the underlying hydrological system is managed poorly and being mined unsustainably, or whether the situation is reversible.

3.3 Water Bankruptcy as a Post-crisis State of Failure

A subsequent step in the development trajectory of the water bankruptcy concept took it beyond a *metaphor* to highlight the water availability-demand gap and a *normative tool* for water reallocation, thereby transforming it into a *diagnostic label*: to highlight the condition of a coupled human–water system that has maximized withdrawals for short-term economic and political gains at the cost of eroding long-term resilience.

While the first application of this framing was in the case of Iran (Madani 2017), the concept is globally applicable to describe similar conditions in other basins and regions, signaling a shift from viewing water shortage as a purely exogenous (natural, climatic, and physical) phenomenon to recognizing the major socio-economic drivers of chronic overuse and its irreparable consequences.

To explain water bankruptcy to non-specialist audiences, a simple analogy was used by the author that has since been widely quoted in media and policy discussions (Mahoozi 2025b; Setiadi 2025; International Crisis Group 2025; Oliphant and Makoii 2025; Doran and Thorne 2025; Paddison 2025):

I. **Surface water is the checking account.**
Rivers, wetlands, and reservoirs are mostly replenished on annual to decadal time scales. This is the account, recharged by the income societies receive from nature, from which they are meant to pay recurring expenses. Yet, the income level is not constant, and the checking account recharge can be more or less than the long-term average in wet and dry conditions.

II. **Groundwater is the savings account.**
While soil moisture, shallow groundwater, and some aquifers recharge quickly and can be considered a component of a checking account, many aquifers recharge slowly, accumulating water over decades to millennia. Some hold fossil groundwater that is effectively non-renewable on human time scales. Water savings that societies inherited from their ancestors give them resilience in times of drought and water shortages. The savings account must be kept healthy and recharged during the high-income (wet) years. This account is meant for emergencies and strategic investments, not for covering chronic overspending.

III. **Water expenditure exceeds the renewable water budget for a long time.**
If the system's expenditure exceeds its income for an extended period, the system goes bankrupt. When a society routinely withdraws from both checking and savings to

maintain an artificially high level of consumption that is beyond the water replenishment rate, while climate change and land-use change reduce inflows, the combined balance of these accounts becomes negative. In financial terms, the system is insolvent: income plus safely withdrawable assets can no longer cover recurring obligations. In water terms, the system is *water-insolvent*: it has promised more water than climate, hydrology, and ecosystems can sustainably deliver, even if all remaining reserves are mobilized.

IV. **The rights of water creditors can no longer be fulfilled.**
Water rights holders, cities, farmers, industries, and ecosystems are creditors that hold implicit or explicit claims on the water system. When bankruptcy hits, not all claims can be honored. Some users must accept losses and adapt to the new levels of water availability. The central question is whether this renegotiation occurs in a planned, transparent manner or through chaotic conflict and collapse. One should note the importance of recognizing ecosystems as one of the creditors—a voiceless water right holder whose rights are frequently violated in favor of other water right holders.

V. **The business model requires urgent transformation.**
When expenses consistently exceed income, the business model is flawed, and one cannot solely blame the failure on exogenous forces such as drought, climate change, sanctions, and economic recession. The worst strategic mistake in this case is taking on more debt from nature through the implementation of additional water supply infrastructure, such as new dams, deeper wells, inter-basin water transfers, and desalination plants, which increases income without controlling expenditure by fixing the business model. Admitting bankruptcy and failure is bitter and requires courage, but it can save the system from bigger losses and more irreversible damages. Effective management of a water-bankrupt system requires transforming the development model, not just an increase in water supply. It calls for addressing the root causes (development model) rather than the symptoms (water deficit).

VI. **The system will not bounce back.**
Financial bankruptcy assumes *elasticity*, meaning that the system has the chance to bounce back, while water bankruptcy insists on *plasticity*, i.e., baseline conditions can never be achieved again. When various components of the ecosystem are pressured beyond their thresholds for an extended period, they reach their tipping points or points of no return. This means that even with a fresh new start and transformation of the business model, the baseline conditions of a water system can never be restored, as some damages to the natural capital are irreversible, e.g., subsided lands, compacted aquifers, melted glaciers, dried wetlands, and extinct species.

In this line of framing, the persistent water deficit and degradation of lakes, rivers, wetlands, and aquifers are attributed to the cumulative consequences of decades of mismanagement, exacerbated by droughts and climate change, rather than being framed as an episodic water crisis or drought. Thus, water bankruptcy is used as a notion to explain the state of failure of a water system resulting from the complex and interrelated dynamics of natural and human-induced changes.

Unlike the previous two types of framing of water bankruptcy, diagnostic framing does not concern itself solely with *insolvency*, making water bankruptcy (or bankruptcy of any component of human-nature systems) fundamentally distinct from financial bankruptcy by including *irreversibility* as another essential characteristic of the bankrupt system. While a financially bankrupt system can recover or improve beyond the pre-bankruptcy baseline conditions, water-bankrupt systems cannot practically restore the baseline conditions due to the irreversible damage to different components of the natural system.

This thinking framework has encouraged a new discourse that identifies water bankruptcy as the end state (product) of the 'Anthropogenic drought' (human-nature process)—a chronic water shortage that is continuously growing due to the compounding impacts of poor water management, climate change, and global environmental degradation (AghaKouchak et al. 2021). Despite this proliferation, an explicit definition of water bankruptcy under the diagnostic framing is still missing in the scientific literature. The remainder of this article aims to provide one. Offering a formal definition rooted in hydrological carrying capacity, long-term deficits, and irreversible damage can help turn this intuition into an operational concept that can be monitored, debated, and used to guide decisions at the local and global scales.

4 The Formal Definition of Water Bankruptcy

Building on this conceptual foundation, water bankruptcy in the Anthropocene is defined as follows:

Water bankruptcy is the persistent post-crisis condition or the state of failure in a human-water system in which:

1. *Long-term average human withdrawals from surface and groundwater—the checking and savings accounts of the system—exceed the system's renewable freshwater inflows and the safe limits of depletion of strategic water reserves and pressure on water-dependent ecosystems; and.*
2. *The resulting depletion and degradation of water-related natural capital cause partially irreversible damages on societally relevant time scales*, *such that historical levels of water supply and ecosystem function cannot be restored without disproportionate social*, *economic*, *or environmental costs.*

Several elements of this definition are critical:

a) **Persistent post-crisis condition**: Water bankruptcy is not a transient shock. It describes a structural disequilibrium that has persisted beyond an acute "crisis" phase and has already reshaped the system.
b) **Combined checking-and-savings balance**: The definition explicitly aggregates surface water and groundwater. A country that appears balanced in terms of annual renewable flows may still be bankrupt if it has long relied on unsustainable mining of aquifers or fossil groundwater.
c) **Hydrological carrying capacity**: The "safe limits of depletion of strategic water reserves and pressure on water-dependent ecosystems" corresponds to the system's *hydrological carrying capacity*: the maximum level of consumptive water use that can be sustained while maintaining critical ecological functions and avoiding significant

water quality degradation and irreversible damages such as land subsidence, permanent loss of wetlands, widespread salinization, and biodiversity loss.

d) **Irreversibility and cost**: Irreversibility is not absolute. Some damages to a system that has been pushed beyond its boundaries into bankruptcy may be technically reversible, but only at economic and political costs so high that no realistic government or society will bear them. In practice, this means that historical baselines of water systems and ecological functions are no longer meaningful planning targets.

e) **Anthropocene and role of humans**: Water bankruptcy is a property of human–water systems, not of purely natural systems. Without human intervention and over-use, natural systems adjust to droughts or water crises through internal processes, sometimes at the cost of some natural creditors without institutional insolvency.

This framing distinguishes water bankruptcy (insolvency combined with irreversibility) from financial bankruptcy (insolvency) and the previous framings of water bankruptcy in the scientific literature (Table 1). Unlike financial bankruptcy, water bankruptcy is not limited to the arithmetic of inflows and outflows. The definition explicitly links withdrawals to the condition of the hydrological processes and ecosystems that regenerate water. Water bankruptcy is reached not only when "too much" water has been taken (insolvency), but when the way it is taken and degraded undermines the very cycle that could have replenished it (irreversibility), calling for better management of both water and the natural capital that produces it.

This is one important distinction of the diagnostic framing from the normative reallocation framing of water bankruptcy problems. The latter treats water as a *good* to be captured, stored, allocated, and delivered—measured in cubic meters in canals, pipes, reservoirs, and rights registers. Accordingly, the proposed targets, legal instruments, and institutions under the normative reallocation framing have largely focused on allocating water as a good, while the hydrological processes and natural capital that generate and sustain it have remained in the background. The diagnostic water bankruptcy framing brings those processes to the center. It invites us to look not only at the "balance" in the checking and savings accounts (i.e., product), but also at the health of the natural and water capital—soils, vegetation, wetlands, rivers, aquifers, snowpacks and glaciers—and the hydrological cycle that produce that balance in the first place. In this sense, water bankruptcy shifts attention from managing only the product to managing both the product and the process that underpins it.

Recognizing water bankruptcy and irreversibility under the diagnostic framing has another significant policy implication. When failure and irreversibility are formally recognized, adaptation is no longer a choice but a necessity. Governing bankruptcy, therefore, combines *mitigation* efforts to transform the management model, restore the restorable elements, and prevent further degradation of the baselines, with *adaptation* efforts that are designed for achieving the best achievable goals and realistic targets under the new normal.

5 Diagnosing Water Bankruptcy

The formal definition of water bankruptcy in the Anthropocene is intentionally agnostic about specific numeric thresholds, which will vary by basin and ecosystem. However, it invites the development of location-specific indicators and monitoring schemes to classify systems along a continuum from water stress to water crisis to water bankruptcy. Table 2 presents a typology of these three states of concern in human-water systems.

Operationalizing the water bankruptcy definition will require a combination of quantitative indicators and qualitative judgment. Crucially, diagnosis must therefore track not only the volumes of water being used, but also the state of the hydrological cycle and natural capital that make those volumes possible. Potential indicators include, but are not limited to:

a) **Chronic water deficit:** Multi-decadal averages of total withdrawals exceeding renewable water availability (surface water and shallow groundwater) at an acceptable quality, after accounting for environmental flow requirements
b) **Groundwater mining beyond recharge:** Persistent declines in groundwater storage, particularly where pumping rates exceed natural recharge and subsidence is observed
c) **Manifested irreversible impacts:** Documented drying of lakes and wetlands, loss of perennial rivers, widespread land subsidence and aquifer compaction, salinization of soils and aquifers, desertification, and loss of biodiversity—signaling that natural capital has been consumed, not just temporarily stressed
d) **Structural over-commitment of water rights:** Legal and customary entitlements that, if honored, would require water volumes significantly greater than hydrologically available even in normal or wet years

Table 2 The typology of the three states of concern in human-water systems

	Water Stress	Water Crisis	Water Bankruptcy
Basic Definition	Demand for water is high relative to available supply, but most obligations can still be met and ecological buffers remain.	An acute episode in which water demand and/or supply disruption temporarily exceed the system's ability to cope, creating severe impacts and urgency.	A persistent post-crisis state in which long-term withdrawals from surface and groundwater exceed renewable inflows and safe depletion of strategic reserves, causing irreversible or prohibitively costly damage.
Time Scale & Dynamics	Chronic or seasonal condition; the system still oscillates around a relatively stable baseline.	Short to medium term (e.g., drought years, contamination event); clear onset and eventual resolution.	Long-term, path-dependent condition; the baseline itself has shifted because critical natural capital (aquifers, wetlands, perennial flows) has been consumed or degraded.
Main Drivers	Growing demand, moderate over-allocation, and climatic variability relative to hydrological carrying capacity.	Extreme shocks (droughts, floods, infrastructure or quality failures) interacting with pre-existing stress and over-allocation.	Decades of structural over-allocation and over-extraction of surface water and groundwater relative to hydrological carrying capacity, often amplified by climate change.
Reversibility	Largely reversible if pressures are reduced and management improves.	Potentially reversible; aim is to restore pre-crisis conditions or a similar level of service.	Only partially reversible; historical conditions cannot be restored without disproportionate social, economic, or environmental cost.
Typical Management Focus	Efficiency improvements, incremental reforms, supply expansion, and demand reduction.	Emergency measures, short-term restrictions, crisis communication, temporary infrastructure or transfers, focused on restoration and mitigation.	Admission of insolvency, permanent demand reduction, reallocation of rights and expectations, protection of remaining natural capital, and long-term adaptation in addition to restoration and mitigation efforts.

e) **Valid narratives of permanent scarcity:** Official or implicit evidence-based recognition that even with new infrastructure, governance systems cannot guarantee previous levels of water deliveries to all sectors, leading to conflicts, migration, or enforced rationing.

6 Water Bankruptcy in a Changing Climate

Climate change does not, by itself, "cause" water bankruptcy, but it interacts with and amplifies it. In other words, water bankruptcy is the outcome of past unsustainable choices and climate change is a *risk multiplier* that catalyzes water bankruptcy through various impacts such as:

a) **Shrinking income to the water account**: Changing precipitation patterns and volumes, higher temperatures, and altered snowpack reduce renewable inflows, increase evaporation in many regions, and degrade water quality (Tsakiris and Loucks 2023). This lowers the hydrological carrying capacity and the total available water assets to be allocated.
b) **Expanding the total expenditure**: Increasing temperatures result in higher evapotranspiration, increasing the water demand of crops, plants, and trees. Warmer temperatures also increase the electricity demand for cooling, increasing the water demand of the energy sector. Changing precipitation patterns and reduced soil moisture lead to a decrease in rainfed agriculture yields, thereby increasing the need for irrigation. As the climate warms, water demand increases, placing additional pressure on already stressed water systems.
c) **Rising variability and risk**: Greater year-to-year variability encourages risk-averse actors to hold larger safety margins, yet in bankrupt systems, safety margins have already been consumed. When a multi-year drought hits a water-bankrupt basin, the impacts are far more severe than in a basin that has preserved its natural and human-made (infrastructure) buffers.
d) **Lock-in of maladaptive infrastructure**: Many countries respond to perceived or real crises by building more dams and desalination plants, drilling deeper wells, or diverting rivers—options that can temporarily mask scarcity but deepen long-term insolvency. Climate change then exposes the fragility of these engineered solutions, as reservoirs and conveyance systems designed for past hydrological regimes struggle under new extremes and non-stationary climate conditions.

7 Governing Water Bankruptcy: From Resistance to Resilience

Water bankruptcy is not about how much water a system has to begin with but about how it manages it. Thus, water bankruptcy can happen in any human-water system that does not maintain a healthy balance between its water consumption and renewable water budget regardless of how water-rich or water-poor they are naturally.

Accepting that certain basins, cities, countries, and human-water systems are already water-bankrupt has profound implications for policy. Governing water bankruptcy requires pragmatism, honesty, sense of urgency, transformative management, and commitment to transparency, justice, and inclusion through the following actions:

I. **Admit defeat—honestly and early.**
The biggest strategic mistake in bankruptcy, whether financial or hydrological, is refusing to acknowledge insolvency. In water-bankrupt systems, continued promises to restore full historical deliveries are both unrealistic and unethical. Public trust is better served by transparent acknowledgment of limits and losses.

II. **Shift from supply expansion to demand reduction and reallocation.**
Once checking and savings accounts are overdrawn, new supply options (desalination, wells, inter-basin transfers, wastewater reuse) can help, but they are expensive and often energy-intensive. They cannot, by themselves, erase decades of overcommitment. A central task of governance becomes redesigning allocation through pricing, regulation, and negotiated settlements to prioritize essential uses and protect critical ecosystems.

III. **Protect remaining natural capital as the core asset.**
What remains of wetlands, aquifers, perennial rivers, soil, pastures, forests, glaciers, flora, and fauna becomes a strategic reserve that must not be sacrificed for marginal gains. Each additional centimeter of subsidence or square meter of dried wetland represents a loss of resilience that no engineering project can fully replace.

IV. **Re-imagine development goals.**
National narratives built on notions of "self-sufficiency" in water-intensive crops, industries, or urban forms must be revisited. This is particularly important as the world enters a new era in global politics, in which trade and international cooperation are being weakened. Countries trapped in *resistance* mode, treating nature as something to be conquered rather than a set of limits to be respected, remain locked into cycles that deepen water bankruptcy. A shift to *resilience* mode accepts hydrological constraints and designs economies around them, through strategic trade, diversification, and managed retreat from unsustainable activities. A fresh start and transforming the development model are essential to the successful management of water bankruptcy.

V. **Make bankruptcy management and reallocation just and inclusive.**
An official recognition of the necessity and urgency of bankruptcy allocation can encourage the design of transparent, principled rules for sharing scarcity. However, these rules are not value-neutral; choices about which rule to apply embed judgments about fairness and power. Combining them with participatory processes and strong social safety nets is crucial to prevent bankruptcy management from becoming a technocratic justification for dispossession.

8 Conclusions: Naming Failure to Enable Change

Language shapes policy, and public discourse shapes expectations. Calling a chronic, self-inflicted condition a "crisis" implies that societies can and should return to a pre-crisis normal. In many water-stressed regions, that normal no longer exists. Checking accounts have been drained, savings accounts overdrawn, and natural assets sold off to pay short-term bills. This article proposed *water bankruptcy* as a formal name for this post-crisis state, defined by: (1) persistent over-withdrawal relative to renewable inflows and safe levels of depletion; and (2) the resulting irreversible or prohibitively costly loss of water-related natural capital.

Just like a crisis and disaster, bankruptcy involves severe threats and losses, but it is not a temporary episode. It is a *structural condition* in which obligations systematically exceed the system's capacity to meet them. Water bankruptcy occurs when natural income and liquid assets, even if fully mobilized, can no longer cover existing claims without unacceptable sacrifice of essential functions and damaging the natural capital. Water bankruptcy management is therefore *structural* and *transformative*. Instead of promising a return to the previous pattern of spending, it focuses on acknowledging both insolvency and irreversibility, recognizing claims, reallocating burdens, and designing a sustainable path forward under tighter constraints in a new reality.

The proposed definition and framing of water bankruptcy in this paper redirects attention from protecting and reallocating a fixed stock of water as a good or product to also safeguarding the processes that produce it. In doing so, it encourages policymakers to treat the hydrological cycle and water and natural capital as core objects of governance, rather than as externalities or background conditions, and to design reforms that stabilize both the balance sheet and the machinery that fills it. While the focus of this paper was on water, the arguments and general framing are applicable to other components of the human-natural systems that are suffering from both insolvency and irreversibility due to human impacts. These include, but are not limited to, the world's climate, as well as many forests, glaciers, oceans, and various ecosystems that are already bankrupt and in the post-crisis failure state. Using terms such as crisis and emergency to refer to their conditions, as is done in climate advocacy, is scientifically flawed and has misleading policy implications for the reasons outlined in this paper.

Recognizing water bankruptcy does not mean giving up. On the contrary, it is a precondition for honest, science-based adaptation to a new reality that has emerged as the result of past decisions and the global environmental changes in the Anthropocene. Once it is acknowledged that the old baseline is gone, attention can shift to three urgent tasks: protecting what remains of natural capital, designing fair and transparent rules for sharing a smaller pie, and reshaping economies and expectations to live within the planet's hydrological budget. This shift is also essential for climate policy. Climate change is shrinking and destabilizing water accounts, as many growing societies discover that their savings have already been spent. Continuing to describe this situation as a "crisis" that will be solved by a few good rainy years or another infrastructure project deepens the bankruptcy. Naming it accurately and designing governance and justice mechanisms accordingly offers a more realistic path to avoiding the worst social and ecological consequences of past overspending and short-sighted policy-making. Unlike crisis management, which focuses on mitigation, bankruptcy management requires a combination of mitigation and adaptation to new norms based on more realistic targets.

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Declarations

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