Chapter 6

From Water Services to Water Governance: Risk-Based Transformation in Water Security

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Abstract

This chapter examines the transformation of water security from a technical service-oriented framework to a governance-based paradigm grounded in risk management under conditions of uncertainty. Traditionally defined through infrastructure capacity, service continuity, and compliance with quality standards, water security has increasingly become insufficient in addressing contemporary challenges such as climate change, hydrological variability, water stress, and institutional fragmentation. Drawing on the international literature on risk governance, adaptive governance, resilience, precautionary approaches, and anticipatory governance, the study argues that risk-based water security approaches extend beyond technical safety tools and function as governance instruments. These approaches reshape decision-making logics, redefine institutional roles, and transform policy instruments by prioritising uncertainty management, institutional coordination, and long-term resilience. Methodologically, the study is based on a theoretical review of international policy frameworks and academic literature. It demonstrates that the evolution of water security constitutes a structural transformation across three dimensions: decision-making processes, institutional arrangements, and governance instruments. The study concludes that water security should be conceptualised not as an infrastructure performance outcome, but as a governance capacity defined by the ability to anticipate, prioritise, and manage risks under uncertainty. In doing so, it contributes to repositioning risk-based approaches from technical management tools to a comprehensive governance transformation framework in water management.

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1. Introduction

Water management has long been framed within technical and operational objectives such as expanding service coverage, renewing infrastructure, improving operational efficiency, and ensuring compliance with quality standards. Within this perspective, it has largely been conceptualised as a service delivery function. Success has typically been measured through indicators such as uninterrupted supply, expansion of physical capacity, and improvements in technical performance.

However, global and local dynamics -including rapid urbanisation, the climate crisis, rising water demand, declining resource quality, and ageing infrastructure- have increasingly exposed the limitations of this service-oriented approach in the face of uncertainty and systemic risk (Brown et al., 2009; Cosgrove & Loucks, 2015).

These developments signal a paradigm shift in which the sustainability of water services can no longer be understood solely in terms of technical competence. Instead, it must be situated within the broader domain of public policy, where governance dimensions -such as inter-agency coordination, the quality of decision-making processes, transparency, and accountability- play a defining role.

(Service Delivery - Infrastructure Expansion - Technical Performance)

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Systemic Pressures

(Climate Change, Urbanization- Water Stress- Infrastructure Aging- Institutional Fragmentation)

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Water Security Conceptualisation

(Sustainable and Equitable Access - Ecosystem Integrity - Risk Awareness)

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Risk-Based Water Security

(Uncertainty Management - Precaution - Resilience - Adaptive Capacity)

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Water Governance

(Inter-institutional Coordination - Accountability - Transparency - Multi-level and multi-stakeholder decision-making)

Figure 1. Logical Flow of Conceptual Transformation in Water Management

Water Services Approach

Referance: Prepared by the researcher.

The conceptual flow presented in Figure 1 offers an analytical framework for understanding the relationship between risk-based transformation and governance within the water security domain.

The concept of water security constitutes the theoretical foundation of this paradigm shift. UN-Water (2013) defines water security as the capacity to ensure sustainable access to sufficient quantities of acceptable-quality water for communities, while protecting ecosystems and effectively managing water-related risks. This definition reframes water management from a static concern with supply and quality to a dynamic and multidimensional governance challenge. It establishes a holistic perspective centred on risk prevention, decision-making under uncertainty, and the strengthening of long-term resilience.

One of the most visible practical manifestations of the water safety paradigm is the adoption of risk-based water safety frameworks. Water Safety Plans (WSPs), developed by the World Health Organization (World Health Organization [WHO], 2017), provide a preventive management model designed to systematically identify, assess, and control risks throughout the entire drinking water supply chain-from source to consumer.

The WSP approach moves beyond traditional compliance models based solely on end-product testing and instead promotes a process-oriented and proactive risk management logic. In doing so, it reframes safe water not as a reactive response to contamination events, but as a continuous and preventive governance process (Hrudey & Hrudey, 2006).

In much of the literature, risk-based water security approaches are treated primarily as technical and operational instruments. Their implications for decision-making processes, institutional relationships, and public accountability structures often remain underexplored. Yet the identification, evaluation, and prioritisation of risks inherently involve normative choices -such as determining which risks are acceptable, which mitigation measures should be prioritised, and which investments are justified. These judgments depend on managerial discretion, institutional capacity, and accountability arrangements (Aven, 2011: 721). For this reason, risk-based water security should be understood not merely as a technical safety strategy, but as a governance framework that reshapes institutional responsibilities and decision-making logics under conditions of uncertainty.

This study theoretically examines the transition from water services to water governance through the lens of risk-based water security approaches. Its core argument is that these approaches generate a governance framework that

transforms decision-making logics, institutional roles, and policy instruments. In this respect, the World Health Organization's Water Safety Plans and the OECD Principles on Water Governance are analysed in conjunction, with particular attention to how risk-based practices interact with and strengthen governance capacity (OECD, 2015).

Methodologically, the study is grounded in a theoretical review of the international literature. It adopts a holistic perspective on both the risk-based water security and water governance literatures, while examining internationally adopted policy instruments and governance approaches at a conceptual level. Rather than developing an empirical case analysis, the study seeks to provide an analytical synthesis of how risk-based water security functions across different governance contexts. This framework enables a systematic discussion of the ways in which risk-based approaches reshape governance capacity under conditions of uncertainty.

In recent years, water security has been increasingly reconceptualised in response to climate change, cascading crises, and growing governance complexity. UN-Water (2023) argues that water security must be understood not only in terms of technical infrastructure capacity, but also in relation to institutional resilience and risk management capability. Similarly, the OECD (2023) highlights that water governance in an era of global uncertainty requires restructuring through enhanced coordination, transparency, and multi-level decision-making mechanisms.

Within the Turkish academic literature, there is a growing recognition that water management should be addressed through a more holistic and risk-sensitive framework, particularly in relation to climate change, drought risk, and basin-level governance challenges. Recent studies emphasise that strengthening institutional capacity, improving data-sharing mechanisms, and prioritising risks -especially at the local level- are critical for advancing water security (Dinç, 2025; Şan, 2024; Yazıcı et al., 2019).

Against this backdrop, the present study seeks to demonstrate how a transition from a service-oriented model to a governance-oriented perspective in water management can be realised through risk-based water security approaches. Beyond contributing to the water governance literature, it proposes an analytical framework aimed at supporting policymakers and practitioners in strengthening governance capacity under conditions of uncertainty.

2. From Water Services to Water Governance

Historically, water safety was primarily defined in terms of the microbiological safety of drinking water and compliance with public health standards. Within

this framework, water management was largely approached as the provision of a technical service aimed at controlling health risks (World Health Organization & United Nations Children's Fund [WHO & UNICEF], 2000: 7-10). The dominant logic of this period rested on a compliance-based management model, in which water safety was equated with measurable quality parameters and infrastructure capacity (Doğu Kırkıcı, 2019). Institutionally, this approach corresponded to a sectoral decision-making structure heavily reliant on engineering expertise and performance indicators focused on outputs-namely, compliance with standards and uninterrupted service provision. Water security, in this sense, was framed as a technical achievement rather than a governance challenge. However, the literature increasingly highlights that early service-oriented conceptions of water safety have gradually expanded to incorporate governance and risk dimensions. Beyazıt and Çiftci (2019: 360-364) argue that while water security was initially associated with technical capacity, supply continuity, and quality standards, growing environmental uncertainties and institutional complexities have necessitated a broader and more governance-oriented perspective. This evolution reflects a fundamental shift: water security has emerged as a public policy domain shaped not only by service provision, but also by decision-making processes, institutional coordination, and risk management under conditions of uncertainty.

In recent years, water security debates have been substantially reframed in response to the climate crisis, cascading disaster risks, and growing governance vulnerabilities. Contemporary assessments argue that water security can no longer be evaluated solely in terms of technical supply reliability; it must also be understood in relation to institutional capacity, multi-level governance, and coordination mechanisms under conditions of uncertainty (United Nations World Water Assessment Programme [WWAP], 2023; Global Commission on the Economics of Water, 2023). Emerging perspectives -particularly those conceptualising water as a global common good- position water management as a multi-actor governance challenge rather than a purely sectoral service function.

Since the early 2000s, the concept of water security has expanded significantly under the pressures of climate uncertainty, water stress, rapid urbanisation, and ecosystem degradation. It has evolved into a multidimensional policy domain that extends beyond current water quality concerns to encompass long-term sustainability and the management of water-related risks (Cosgrove & Loucks, 2015: 4826-4828; UN-Water, 2013: 4-6). This conceptual broadening has shifted water security away from a narrow supply-and-quality problem toward a governance framework that integrates demand management, resource conservation, disaster and climate risk management, infrastructure resilience,

water loss reduction, and ecosystem integrity within a unified perspective (UN-Water, 2013: 4-6).

In the Turkish context, similar concerns have been raised. Changing precipitation patterns and increasing evaporation linked to climate change are expected to create structural vulnerabilities, particularly for reservoir and dam systems. Accordingly, service continuity can no longer be pursued solely through expanding supply capacity; it requires efficiency-oriented strategies and risk-sensitive planning approaches.

The concept of risk, which lies at the theoretical core of the transformation in water security, constitutes the central analytical axis through which water security becomes a governance issue. Risk extends beyond calculations of probability and consequence; it involves normative judgments regarding which risks are prioritised, which losses are considered acceptable, and which interventions are regarded as legitimate. As Aven (2011: 720-722) argues, risk assessment is inherently embedded in value judgments and decision contexts. It is therefore not merely a technical exercise, but a regulatory and governance process. Accordingly, the conceptual expansion of water security shifts decision-making from a compliance-with-standards logic to a framework of prioritisation and accountability under conditions of uncertainty.

A second turning point that renders the governance dimension of risk visible concerns the transformation of decision-making structures. Decisions are no longer grounded solely in the technical rationality of a single institution; rather, they emerge through multi-actor coordination, information-sharing mechanisms, and public accountability. The risk governance literature emphasises that risks are not only identified and measured, but also socially interpreted, negotiated, and publicly justified. In this perspective, risk governance is institutionalised through interconnected stages such as pre-assessment, risk appraisal, risk management, and risk communication (International Risk Governance Council [IRGC], 2017: 8-12).

Applied to water security, this framework places institutional authority and responsibility at the centre of management questions -not only where risk is generated, but who intervenes, with what mandate, and through which coordination mechanisms. Consequently, inter-institutional boundaries, role definitions, data-sharing practices, and coordination capacity -that is, the governance infrastructure- become integral components of water security.

Addressing water security within a risk-based framework also exposes the limitations of centralised and technocratic decision-making models. Studies on water management in Türkiye demonstrate that the division

of authority between municipal water and wastewater administrations and central institutions creates governance challenges, particularly in data production and risk management (Çiftci, 2019). Basin-level research further indicates that climate-induced uncertainties increase the need for flexible, multi-stakeholder decision-making structures (Dinç, 2025; Şan, 2024). These findings suggest that water security cannot be managed independently of institutional arrangements and that risk-based approaches are closely tied to governance capacity.

The policy-level implications of this theoretical framework are equally significant. Risk-based instruments generate not only technical standards but also institutional accountability mechanisms. In drinking water systems, for example, the systematic identification of risks from source to consumer, the establishment of control points, and the creation of monitoring and improvement cycles represent a shift from product-based compliance testing to process-oriented preventive management (WHO, 2022: 14-18). This transformation expands the temporal horizon of decision-making, making resilience and adaptability to future shocks as important as present compliance.

Furthermore, integrating water security with governance reshapes the nature of policy tools themselves. Technical indicators cease to function merely as performance metrics; they become instruments for monitoring institutional responsibility and enabling public justification. The principles of coordination, policy coherence, and accountability emphasised in the OECD framework extend the water security debate beyond infrastructure investment toward questions of public policy design and implementation capacity (OECD, 2015: 3-5). Within this framework, water security is no longer conceived as a technical service output; it is reconceptualised as a governance capacity defined through decision-making under uncertainty, institutional coordination, and accountability.

3. Risk-Based Transformation in Water Security

Risk-based transformation in water security refers to a fundamental shift from a model grounded in technical standards and reactive service delivery toward a holistic governance paradigm centred on decision-making under uncertainty, long-term resilience, and institutional learning. As climate change increasingly disrupts hydrological cycles, intensifies extreme weather events, and exacerbates socio-economic vulnerabilities, it has become increasingly untenable to treat water security as a static objective (Dışkaya, 2018).

A growing body of scholarship demonstrates that access to safe water can no longer be explained solely through quality and quantity indicators; rather, the

capacity to anticipate, prioritise, and manage risks has emerged as the defining dimension of water security (Borgomeo et al., 2014; Hall & Borgomeo, 2013; Sivapalan et al., 2011). In this respect, risk-based transformation reshapes not only conceptual understandings but also institutional behaviour and decision-making logics.

At the core of this shift lies a redefinition of the central policy question. While traditional approaches asked, "Is there sufficient water?", the risk-based perspective instead asks, "Which risks are being managed, by whom, and over what temporal horizon?" This reframing requires water infrastructure and management systems to develop flexibility and adaptive capacity in the face of multiple, interacting risks, rather than focusing on protection against isolated threats. Risk, therefore, is no longer confined to quantitative estimations of potential damage; it becomes inseparable from questions of legitimacy, acceptability, and sustainability in public decision-making under uncertainty (Borgomeo et al., 2014; Hall & Borgomeo, 2013).

One of the most visible implications of this transformation is the institutionalisation of preventive management. Whereas traditional models rely on reactive interventions after system failure, risk-based approaches prioritise early warning systems, scenario-based planning, and continuous monitoring mechanisms. Water security thus becomes a forward-looking strategic process oriented toward preparedness and adaptive capacity, rather than merely compliance with existing standards (Brown et al., 2012; Garrick & Hall, 2014).

This transformation also makes the governance dimension of water security explicit. The processes of identifying, assessing, and prioritising risks inevitably raise governance questions: Who holds decision-making authority? What forms of knowledge and data are considered legitimate? To whom are decisions accountable? Risk-based water security therefore functions as a governance paradigm that requires strengthened transparency, accountability, and participatory mechanisms (Meisch et al., 2012: 41-44; OECD, 2021: 19-23).

Furthermore, risk-based transformation positions water security as an inherently inter-sectoral policy domain. Research within the water-energy-food nexus demonstrates that water-related risks are deeply interconnected with energy policy, agricultural production, and urban development strategies (Hoff, 2011; Pahl-Wostl, 2015: 210-213). Risk-based water security approaches thus serve as instruments for enhancing cross-sectoral policy coherence and reinforcing governance capacity. Water security, in this sense, transcends

sectoral boundaries and becomes embedded within comprehensive public policy frameworks.

A critical dimension of this transformation is resilience. Folke et al. (2021: 15-18) emphasise that water security should be defined not only by the capacity to withstand shocks, but also by the ability to learn, adapt, and transform in response to them. Resilience-based approaches deepen the relationship between risk and governance by placing institutional learning, adaptive decision-making, and flexibility at the centre of water security.

Recent research in the Turkish context further illustrates the growing relevance of risk-based transformation. Basin-level studies highlight that water security cannot be achieved solely through supply-expansion strategies; rather, it requires risk-sensitive planning, basin-based governance, and strengthened institutional coordination (Varty Bayar, 2023; Yazıcı et al., 2019). These findings demonstrate that risk-based transformation has become central to contemporary water governance debates in Türkiye.

The fundamental dimensions of this shift are comparatively summarised in Table 1, which contrasts traditional water security paradigms with risk-based governance-oriented approaches.

Table 1. Governance Transformation in Water Security

Dimension	Traditional Water Security Approach	Risk-Based Water Security Approach
Conceptual focus	Public health compliance and drinking water safety	Multiple and systemic risks, uncertainty, and long-term sustainability
Primary objective	Compliance with technical and health standards	Risk anticipation, prioritisation, and management
Time perspective	Short-term, present-oriented	Long-term, intergenerational sustainability
Management philosophy	Reactive (post-incident response)	Preventive, adaptive and proactive
Risk awareness	Limited to technical and operational risks	Climate, infrastructural, environmental, and governance-related risks
Decision-making approach	Technocratic, expert-driven	Multi-level governance, coordination, and institutional learning
Policy orientation	Sectoral service provision	Strategic and cross-sectoral public policy

Referance: Prepared by the researcher.

The transformation outlined in Table 1 therefore signals a paradigmatic shift: water security is no longer defined by technical service performance, but by the governance capacity to anticipate, prioritise, and manage risks under uncertainty.

4. Risk-Based Governance Approaches in Water Security

In the water security domain, risk is no longer understood solely as a physical or environmental threat. Rather, it is conceptualised as a multidimensional phenomenon that is socially defined, institutionally prioritised, and politically mediated within governance processes. Risk-based governance approaches therefore demonstrate that water security cannot be reduced to technical performance indicators; it must instead be understood as a dynamic governance process shaped by uncertainty, institutional learning, and adaptive capacity (Folke et al., 2005: 443-447; Pahl-Wostl, 2015: 33-36).

Risk Governance: The risk governance perspective emphasises that risks are not merely technical phenomena calculated by experts; they are interpreted through social perceptions, political priorities, and institutional interests. Renn (2008: 65-72) conceptualises risk governance as a multi-actor process encompassing early warning, risk appraisal, management, and communication. Applied to water security, this framework requires that drought, flood, and infrastructure risks be addressed not only through engineering solutions but also through stakeholder engagement, inter-institutional coordination, and the cultivation of public trust (OECD, 2021: 34-37). Risk governance thus foregrounds legitimacy and accountability as integral components of water security.

Precautionary Governance: Precautionary governance highlights the responsibility of public authorities to act in the face of scientific uncertainty. Stirling (2010: 1029-1031) argues that governance in complex risk societies must remain sensitive to ambiguity and oriented toward preventing irreversible harm. In the context of climate change and hydrological uncertainty, this perspective supports early intervention, cautious planning, and the avoidance of delayed responses that may exacerbate systemic vulnerabilities (UN-Water, 2023: 11-14). Precaution, therefore, becomes a normative foundation for risk-based water security.

Adaptive Governance: Adaptive governance rests on the premise that risks are dynamic and evolving. Governance systems must therefore be structured as learning-oriented, flexible, and feedback-responsive institutions. Folke et al. (2005: 444-447) demonstrate that socio-ecological systems are inherently non-linear and subject to continuous change; governance processes must reflect

this dynamism. Pahl-Wostl (2015: 88-91) identifies water management as a prototypical domain for adaptive governance, given the constant interaction between climatic variability, demand fluctuations, and infrastructural constraints. Adaptive governance reframes water security as a continuous process of institutional adjustment rather than a fixed outcome.

Resilience-Based Governance: Resilience-based governance centres on the capacity of water systems to absorb shocks, maintain functionality, and transform when necessary. Walker and Salt (2006: 5-8) define resilience as the ability of a system to adapt without crossing critical thresholds that lead to collapse. Within water security debates, resilience shifts attention from efficiency alone to robustness, redundancy, and transformation capacity (OECD, 2020: 19-23). Water security, in this sense, is defined not only by operational reliability but also by systemic endurance under crisis conditions.

Anticipatory Governance: Finally, anticipatory governance focuses on institutionalising responses to future risks in the present. Quay (2010: 499-502) underscores the importance of forward-looking governance, particularly in managing climate-related water risks. Anticipatory approaches seek to identify emerging vulnerabilities, integrate scenario planning, and build long-term institutional foresight. In doing so, they extend water security beyond current supply-demand balances to include intergenerational risk management (Tõnurist & Hanson, 2020).

Taken together, these governance approaches demonstrate that risk-based transformation in water security is not confined to technical reform. It represents a structural reorientation of governance itself -toward precaution, adaptation, resilience, and anticipation under conditions of deep uncertainty.

Table 2. From Traditional Water Security to Risk-Based Water Governance

Traditional Water Security Approach	**Risk-Based Water Governance Approach**
Is treatment capacity sufficient?	Do institutions possess the capacity to manage uncertainty and systemic risk?
Is the water quality standard met?	Are cumulative, emerging, and interdependent risks being continuously assessed and monitored?
Is the distribution network operational?	Is infrastructure resilient to climate variability, extreme events, and compound shocks?
Is supply sufficient to meet demand?	Are supply, demand, climate, and financial risks managed in an integrated manner?
Service continuity	System resilience, adaptive capacity, and organisational learning

Referance: Prepared by the researcher.

Table 2 provides a comparative overview of how the transformation in the understanding of water security has produced differentiation in decision-making logic, institutional capacity, and policy priorities. The traditional water security approach primarily evaluates water services through technical performance indicators, focusing on criteria such as treatment capacity, network functionality, and compliance with quality standards. Within this framework, security is largely defined by whether the system is operational and capable of meeting predefined technical benchmarks.

By contrast, the risk-based governance perspective reframes water security as a strategic public policy domain rather than a technical infrastructure output. It emphasises institutional learning, multi-actor coordination, and the capacity to manage uncertainty as central components of security. In doing so, it shifts the evaluative focus from system functionality alone to governance capacity under conditions of risk and complexity.

5. Institutional and Policy Implications of Risk-Based Water Governance

Risk-based water governance represents a structural transformation that extends water management beyond the provision of technical services toward a governance architecture grounded in uncertainty management, institutional coordination, and adaptive capacity. In this perspective, risk is not limited to the identification of physical threats; it also entails prioritisation under uncertainty, the justification of resource allocation, and the clarification of institutional responsibilities (OECD, 2021: 22-24). Accordingly, risk-based governance requires concrete managerial reforms, particularly in the reconfiguration of decision-making logics, institutional roles, and policy instruments.

- ***Transformation of Decision-Making Logic***

A risk-based approach shifts water management away from deterministic and short-term planning toward flexible and adaptive models capable of operating under uncertainty. Contemporary scholarship emphasises that planning based solely on historical data is increasingly inadequate under climate change and hydrological variability. Instead, scenario-based approaches that incorporate probabilistic reasoning and iterative learning are required (Borgomeo et al., 2014; Brown et al., 2012).

This shift reframes the objective of water management from seeking an "optimal solution" to managing acceptable levels of risk across multiple future scenarios. Decision-making thus becomes a process of negotiating trade-offs rather than applying purely technical calculations. Risk prioritisation increasingly incorporates multidimensional criteria -such as social vulnerability, ecosystem

sensitivity, and economic exposure- alongside engineering assessments (UN-Water, 2021: 10-12). As a result, risk-based governance enhances transparency and accountability by requiring decisions to be publicly justified through risk maps, scenario analyses, and monitoring indicators.

• ***Redefining Institutional Roles and Responsibilities***

Risk-based governance also transforms institutional mandates. Under traditional service-delivery models, water authorities were primarily responsible for infrastructure operation and technical performance. In contrast, risk-based approaches assign these institutions expanded roles in risk monitoring, early warning, scenario development, and crisis preparedness (OECD, 2021: 27-30).

Water management therefore becomes inherently cross-sectoral, requiring coordination with environmental agencies, disaster management authorities, energy and agricultural sectors, and urban planning institutions. International policy frameworks consistently emphasise that strengthening horizontal and vertical coordination mechanisms is essential for managing systemic water risks (OECD, 2021). Risk-based governance thus promotes a management architecture that reduces institutional fragmentation, enhances data-sharing practices, and institutionalises joint decision-making platforms.

• ***Transformation of Policy Tools***

Risk-based transformation also reshapes the nature of policy tools. Whereas traditional models prioritised infrastructure expansion and technical compliance standards, risk-based governance foregrounds preventive and dynamic instruments such as early warning systems, risk-monitoring platforms, adaptive planning tools, and scenario modelling (OECD, 2021).

These instruments function not only as technical control mechanisms but also as governance tools that support institutional accountability and public justification. Financial instruments are similarly evolving. Under conditions of climate risk and water stress, infrastructure investment strategies increasingly require risk-sensitive financing models that prioritise long-term resilience over short-term cost efficiency (OECD, 2020: 18-20). Budget planning and investment prioritisation thus become integral components of risk-based governance.

• ***Strengthening Accountability and Transparency***

Risk-based water governance emphasises not only the technical robustness of decisions but also their public legitimacy. Choices concerning which risks to prioritise, which investments to defer, and which communities are most vulnerable have significant distributive implications. Consequently,

mechanisms such as data transparency, performance monitoring, and stakeholder participation become central elements of governance (Meisch et al., 2012; OECD, 2021).

In the Turkish context, limited participatory mechanisms and weak institutional transparency in local water authorities have been shown to constrain the implementation of risk-based approaches (Çiftci, 2019: 127-128). Building public trust -particularly in times of crisis- depends not only on technical effectiveness but also on open, participatory, and accountable governance processes (UN-Water, 2021).

• ***Redefining Water Security as Governance Capacity***

Taken together, these transformations fundamentally redefine the meaning of water security. Security is no longer measured solely by the performance of physical infrastructure, but by the institutional capacity to anticipate uncertainty, prioritise risks, coordinate across sectors, and adapt to crises. Risk-based water governance thus reframes water security as an indicator of governance capacity and managerial flexibility rather than an infrastructure performance metric.

Access to safe water, in this context, depends not only on treatment capacity but also on the ability of institutions to manage uncertainty, justify policy choices, and sustain resilience over time (OECD, 2021; UN-Water, 2021).

6. General Assessment and Conclusion

The longstanding conceptualisation of water security as a public service defined by technical capacity, infrastructure adequacy, and compliance with quality standards has become increasingly insufficient in the face of contemporary climatic uncertainty, ecological fragility, and institutional complexity. Climate change, intensifying water stress, rapid urbanisation, and governance fragmentation have transformed water security from a service output measured through supply and quality indicators into a multidimensional public policy domain centred on risk reduction and uncertainty management.

This transformation demonstrates that water security can no longer be confined to the technical question of "how much water is provided." Rather, it must be understood as a governance capacity shaped by the identification, prioritisation, and management of risks under conditions of uncertainty.

The theoretical framework developed in this study shows that this transformation operates at three interrelated levels: decision-making logic, institutional structures and roles, and the nature of policy instruments.

First, the logic of decision-making has shifted. Traditional approaches relied predominantly on technical adequacy and engineering standards. In contrast, risk-based governance requires prioritisation under uncertainty, deliberation over acceptable levels of risk, and the consideration of long-term and intergenerational consequences. Water management thus becomes shaped not only by technical expertise but also by normative judgments and processes of public justification.

Second, institutional roles and governance arrangements have evolved. Risk-based water security necessitates inter-agency coordination, data-sharing mechanisms, multi-stakeholder participation, and strengthened accountability structures. Water security is no longer the sole responsibility of technical water authorities; it intersects with planning, environmental management, disaster governance, finance, and energy policy. This expansion underscores that water security cannot be separated from institutional capacity and governance infrastructure.

Third, policy instruments have undergone substantive transformation. Risk-based approaches move beyond reactive, compliance-oriented control toward preventive, process-based, and adaptive management tools. Early warning systems, scenario-based planning, resilience assessments, and institutional learning mechanisms enable water security to be governed not only in terms of current performance, but also in terms of adaptive capacity to future shocks. These instruments function not merely as technical measurement devices, but as governance mechanisms that support institutional accountability and public legitimacy.

When risk governance, precautionary governance, adaptive governance, resilience-based governance, and anticipatory governance perspectives are considered collectively, water security emerges not as a static condition of "safe water," but as a continuously reproduced governance process under uncertainty. Risks are not simply calculated; they are socially interpreted, institutionally structured, and politically prioritised. In this sense, water security becomes an indicator of a system's capacity to manage complexity, learn from disruption, and adapt over time.

The principal contribution of this study lies in repositioning risk-based approaches -often treated in the literature as technical management tools- within a broader governance transformation framework. Rather than interpreting the evolution of water security as a mere expansion of scope, the study conceptualises it as a structural reconfiguration of decision-making logic, institutional arrangements, and policy instruments. Water security is thus

reframed as a strategic governance domain defined by public accountability, institutional coordination, and adaptive capacity under uncertainty.

Future research should empirically test this theoretical framework across diverse governance contexts and develop measurable indicators of risk-based governance capacity at multiple scales. Such efforts would further demonstrate that risk-based water security is not only a conceptual paradigm shift, but also a tangible process of institutional restructuring with concrete governance outcomes.

In conclusion, risk-based water security should be understood not as a technical toolkit, but as a governance paradigm that generates institutional capacity and reshapes public decision-making in water management.

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