IMPLEMENTATION OF THE STRATEGIC ACTION PROGRAMME (SAP) OF THE DINARIC KARST AQUIFER SYSTEM: IMPROVING GROUNDWATER GOVERNANCE AND SUSTAINABILITY OF RELATED ECOSYSTEMS

OUTPUT 2.1.

BILATERAL GROUNDWATER GOVERNANCE DIAGNOSTIC ANALYSIS TBA NERETVA

FEBRUARY 2026

Contents

List of Tables

PREPARED BY DIKTAS II PROJECT TEAM

Zoran Nakić

Selma Čengić

Marinko Vranić

Anita Bušljeta Tonković

Marina Funduk

Nino Serdarević

Romario Zoga

1 Introduction

1.1 Purpose and Scope of the Bilateral GGDA for TBA Neretva

The Bilateral Groundwater Governance Diagnostic Analysis (BGGDA) for the Neretva Transboundary Area (TBA) is designed to provide a harmonized assessment of groundwater governance across the Croatian and Bosnian-Herzegovinian segments of this transboundary area of concern. Its overarching purpose is to identify governance gaps, opportunities, and priority measures that will strengthen sustainable management of the TBA in line with regional and international standards.

This analysis builds upon the foundational work of the DIKTAS I project, including the Transboundary Diagnostic Analysis (TDA) and the Strategic Action Programme (SAP), and is implemented under DIKTAS II to advance institutional cooperation and policy alignment. It applies the methodological principles of the Global Framework for Action to Achieve the Vision on Groundwater Governance, developed under the GEF/FAO initiative, ensuring consistency with globally recognized best practices.

The scope of the BGGDA encompasses three core dimensions of groundwater governance:

- Legal and regulatory frameworks, including compliance with EU Water Framework Directive and Groundwater Directive provisions;
- Policy and planning instruments, with emphasis on integration across sectors such as water, agriculture, energy, and spatial development;
- Socio-economic drivers and indicators, addressing pressures from tourism, agriculture, and infrastructure development in the Dinaric karst region.

The analysis will systematically review institutional arrangements, enforcement capacities, and data-sharing mechanisms, highlighting disparities and opportunities for harmonization between the two countries. It will also consider the socio-economic reliance on groundwater for drinking water supply, energy production, and biodiversity conservation.

By providing a comparative diagnostic, the BGGDA aims to establish a common understanding of governance challenges and to propose actionable recommendations for bilateral cooperation. These recommendations will serve as a basis for the future joint action program, monitoring programs, and capacity-building initiatives, contributing to the long-term resilience of the TBA Neretva under changing climatic and socio-economic conditions.

1.2 Methodological Approach and Alignment with DIKTAS II Framework

The Bilateral Groundwater Governance Diagnostic Analysis (BGGDA) for the TBA Neretva adopts a structured, comparative methodology grounded in internationally recognized principles of groundwater governance. It follows the Global Framework for Action to Achieve the Vision on Groundwater Governance, ensuring consistency with global best practices and DIKTAS II objectives. The approach builds on the outputs of DIKTAS I, particularly the TDA and SAP, and integrates lessons learned from national governance diagnostics in Croatia and Bosnia and Herzegovina.

The methodology emphasizes a stepwise diagnostic process, starting with stocktaking of legal, policy, and institutional frameworks, followed by identification of gaps, opportunities, and priority measures for harmonization. It applies a three-dimensional governance lens - legal and regulatory frameworks, policy and planning instruments, and socio-economic drivers - while incorporating cross-cutting issues such as enforcement capacity, stakeholder participation, and gender mainstreaming. Comparative

analysis is central to the approach, enabling identification of differences and convergence points between the two countries.

Alignment with DIKTAS II is ensured through direct linkage to Component 2 (Institutional Strengthening for Improved Groundwater Governance) and its outputs, particularly Output 2.1 on governance diagnostics in all project countries and Output 2.2 on harmonization of legal and policy instruments. The BGGDA also supports Component 1 (Facilitating Multi-country Cooperation) by providing evidence for bilateral agreements and joint management mechanisms. Methodological tools include indicator frameworks for monitoring governance performance and participatory processes involving national institutions and stakeholders.

The analysis adopts an adaptive management approach, allowing flexibility to incorporate available data, stakeholder's role, and evolving policy contexts during implementation. It ensures coherence with EU Water Framework Directive (WFD) and Groundwater Directive (GWD) requirements, while respecting national legal systems and bilateral agreements. Ultimately, the methodological design aims to produce actionable recommendations that are scientifically robust, institutionally feasible, and aligned with the long-term vision of sustainable and equitable management of the Neretva TBA under DIKTAS II.

1.3 Overview of the TBA Neretva: Hydrogeological, Geographical and Environmental Context

The Neretva Transboundary Aquifer (TBA) spans Bosnia and Herzegovina and Croatia within the Adriatic basin and is formed in thick Mesozoic limestones and dolomites of the Dinaric karst. These fractured and cavernous rocks create highly permeable aquifers with rapid conduit flow and short residence times. Recharge occurs mainly from precipitation and sinking streams on poljes, with infiltration often exceeding 60%. Groundwater velocities reach centimetres per second, confirming strong connectivity between recharge zones and major springs, including coastal vruljas sensitive to sea-level changes and salinity intrusion.

Physiographically, the area includes rugged karst relief with dolines, ponors, and poljes, bounded by the Adriatic coast and high carbonate massifs. The Neretva River dominates surface drainage and forms a delta where freshwater, brackish, and marine environments interact. The climate is Mediterranean along the coast, shifting inland to continental; high seasonal rainfall and rapid infiltration cause large spring-flow variations and turbidity spikes after storms. Summer low flows and tidal influence allow saline intrusion into low-lying aquifers and estuaries.

Hydrogeologically, conduit development follows major faults, while flysch and marls act as barriers, concentrating discharge at structural outlets. Vulnerability is high: filtration is minimal, recharge is diffuse, and pollutants can spread quickly from poljes and peri-urban areas. Water quality is generally good but episodic contamination occurs after heavy rain.

Environmentally, the Neretva delta hosts groundwater-dependent ecosystems of international importance. Risks include sanitation gaps (septic tanks), informal waste disposal, diffuse agricultural pollution, and upstream hydropower altering flows and salinity. Seasonal tourism increases water demand and infrastructure stress. These pressures, combined with fragmented monitoring and non-harmonized protection zones, underline the need for coordinated governance, joint monitoring, and integrated management to safeguard drinking-water sources and sensitive ecosystems.

1.4 Structure of the Bilateral GGDA

The Bilateral Groundwater Governance Diagnostic Analysis (BGGDA) for the TBA Neretva is organized into eight chapters, each addressing a specific dimension of governance. Following the introductory chapter, which explains the purpose, scope, and methodology, the analysis begins with a detailed review of the legal framework. This section presents international instruments, EU Directives, and the Bilateral Agreement relevant to the TBA Neretva. It compares the legal frameworks governing groundwater in Croatia and Bosnia and Herzegovina, focusing on their relevance for the TBA Neretva and alignment with EU Directives, including issues such as groundwater ownership, permitting, pollution control, and enforcement mechanisms. Finally, it identifies gaps and opportunities for harmonization. The next chapter examines institutional arrangements and cross- sectoral coordination in Croatia and BIH including institutions and stakeholders directly relevant for TBA Neretva. The following chapter elaborate policy and planning instruments, assessing national water strategies, river basin plans, and sectoral policies, while highlighting integration with EU requirements. Socio-economic indicators and pressures are then analysed to provide a comparative profile of demographic trends, groundwater use, infrastructure status, and environmental risks, including contamination and waste management challenges. Transboundary cooperation forms the core of the sixth chapter, evaluating existing bilateral arrangement between Croatia and BIH, proposing mechanisms for stakeholder engagement and opportunities for strengthening cooperation. Based on these findings, the recommendations chapter outlines targeted measures for legal harmonization, policy integration, socio-economic resilience, and improved monitoring, supported by an indicator framework aligned with DIKTAS II objectives.

The concluding chapter synthesizes key insights and defines strategic priorities for governance improvement. Annexes provide supporting materials such as legal and policy references and stakeholder lists.

The structure of the BGGDA ensures a logical progression from diagnostic assessment to actionable recommendations, offering a comprehensive yet practical framework for strengthening bilateral groundwater governance in TBA Neretva.

2. Legal Framework Analysis – TBA Neretva

2.1 International instruments, EU Directives and Bilateral Agreement Relevant to TBA Neretva

Bosnia and Herzegovina and Croatia are signatories to most of the same international conventions and frameworks on transboundary water management. Both countries are contracting parties to the UNECE Water Convention (1992) and the Danube Convention (1994, ratified 1996), as well as signatories of the Framework Agreement on the Sava River Basin (2002, ratified 2003). which promotes joint planning and data exchange.

The Draft Articles on the Law of Transboundary Aquifers annexed to the UNGA Resolutions 63/124 (2008) and 68/118 (2013) offer guidance to governments for cooperation and arrangements on their transboundary aquifers.

Republic Croatia and B&H are member countries of the International Sava River Basin Commission (ISRBC), established in 2006. The other member countries are also Slovenia and Serbia. It was created to implement the Framework Agreement on the Sava River Basin. Main tasks of the commission are:

establish an international navigation regime on the Sava River; ensure sustainable water management; prevent and limit hazards such as floods, droughts, and pollution.

In Croatia, implementation is led by the Ministry of Environmental Protection and Green Transition, with operational roles carried out by Croatian Waters, the State Hydrometeorological Institute and Sava Commission in Zagreb. In Bosnia and Herzegovina, implementation of international instruments is primary responsibility of state Ministry of Foreign Trade and Economic Relations (MoFTER) which needs to coordinate the implementation and compliance to international obligations with the entity-level ministries and agencies.

Collaboration in the Adriatic Sea catchment is regulated by the Barcelona Convention (1976, revised 1995) and both countries are the parties of this Convention. Croatia is additionally party to the Athens Protocol (1980, revised 1995). For these frameworks, the Ministry of Economy and the Ministry of Environmental Protection and Green Transition are responsible for implementation, including the ICZM Protocol and national coastal strategies.

Both countries are signatory of the Convention on the Transboundary Effects of Industrial Accidents (1992), while Croatia has additionally ratified the Protocol on Water and Health.

Both countries are active participants in the Adriatic Ionian Initiative (2000), which provides a platform for regional cooperation among Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Slovenia, and Serbia & Montenegro. The Joint Commission for the Protection of Adriatic Waters (1977), based on the 1974 Agreement between Yugoslavia and Italy, continues to function with Croatia, Italy, Slovenia, and Montenegro as members.

While Croatia benefits from a consolidated institutional framework, Bosnia and Herzegovina faces slow coordination process between entities and limitations in institutional capacities for effective transboundary water management.

The bilateral agreement between Croatia and Bosnia and Herzegovina on water management relations (1996) establishes obligations for coordinated measures in transboundary basins, including the TBA Neretva. However, this agreement is largely generic and does not explicitly address groundwater, focusing instead on general water management, pollution control, and infrastructure maintenance. Updating this agreement, specifically in relation to groundwater monitoring, data exchange, and aquifer-specific management, would significantly strengthen transboundary governance and make it more effective for DIKTAS II objectives. The details of this update are provided in *Chapter 6.1*.

The governance of transboundary groundwater in the TBA Neretva region is primarily shaped by the EU Water Framework Directive (WFD) and the Groundwater Directive (GWD), which set the foundation for integrated water resource management and the achievement of “good status” for all water bodies. Croatia has fully transposed these directives through its Water Act and River Basin Management Plan (RBMP), ensuring systematic monitoring, delineation of groundwater bodies, and the application of threshold values for pollutants. While Bosnia and Herzegovina advance in WFD implementation, with FBiH achieving over 90% alignment, progress in RS remains lower. Compliance with the GW Directive is considerably lower across both entities, with gaps in defining groundwater-dependent ecosystems and harmonizing methodologies for chemical status assessment.

Beyond WFD and GWD, several other EU directives influence groundwater governance in the TBA Neretva context. The Environmental Liability Directive (2004/35/EC) underpins remediation

obligations and accountability for environmental damage, while the Public Access to Environmental Information Directive (2003/4/EC) promotes transparency and stakeholder engagement. The Nitrates Directive (91/676/EEC) is relevant for controlling diffuse agricultural pollution, a significant pressure in karst areas. Additionally, the Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) safeguard groundwater-dependent ecosystems within Natura 2000 sites, reinforcing biodiversity protection. The Urban Waste Water Treatment Directive (91/271/EEC) addresses wastewater management, which is critical for reducing contamination risks in sensitive recharge zones. Croatia has integrated these directives into its legal framework, whereas Bosnia and Herzegovina has only partially aligned, with implementation gaps in ecological connectivity and nutrient management.

Overall, while Croatia exhibits strong alignment with EU directives and robust institutional mechanisms, Bosnia and Herzegovina faces institutional and operational challenges that hinder full compliance and effective transboundary governance.

2.2 National Legal Instruments Governing Groundwater (Croatia and BiH)

Groundwater governance in the TBA Neretva is shaped by two distinct yet partially harmonized legal frameworks: Croatia's system, which is fully aligned with European Union directives, and Bosnia and Herzegovina's decentralized structure, which reflects its complex constitutional arrangement and ongoing EU approximation process. Both countries recognize groundwater as a public good and regulate its use, protection, and monitoring through primary water legislation complemented by environmental, spatial planning, and sectoral laws. However, the scope, clarity, and operationalization of these instruments differ significantly, influencing the effectiveness of transboundary groundwater management.

2.2.1. Core Legal Frameworks

In Croatia, the Water Act (Official Gazette Nos. 66/2019, 84/2021, 47/2023) serves as the cornerstone of groundwater governance. It fully transposes the EU Water Framework Directive (2000/60/EC) and the Groundwater Directive (2006/118/EC, 2014/80/EU), establishing environmental objectives, defining groundwater bodies, and prescribing monitoring obligations. The Act is operationalized through the River Basin Management Plan (RBMP) until 2027, which integrates chemical and quantitative status assessment, threshold values, and measures for groundwater-dependent ecosystems. Croatia's legal framework is complemented by the Environmental Protection Act, the Nature Protection Act, and sectoral regulations such as the Rulebook on Sanitary Protection Zones, which provide detailed hydrogeological criteria for karst aquifers - highly relevant for the Neretva TBA.

Bosnia and Herzegovina regulates groundwater primarily through entity-level Water Laws: FBIH Water Law, Official Gazette 70/06 and the RS Water Law (Official Gazette Nos. 50/06, 92/09, 121/12, 39/13, 44/15, 19/16, 1/20).) that are operationalized by RBMP. However, BIH has no dedicated legislation for groundwater management, nor karst systems, despite their dominance in the national hydrogeological setting Water laws define water as public property and require permits for abstraction and discharge. However, as WFD principles such as integrated river basin management and ecological flow are embedded, the Groundwater Directive is implemented to a limited extent, with gaps in chemical status assessment, trend reversal and threshold values, as not all WFD parameters are covered. Consequently, groundwater protection in both entities is treated only as a subset of surface water regulation, without recognition of the particular vulnerabilities of karstic aquifers or their ecological and quantitative dynamics. Reliance on entity water legislation creates fragmentation, for both, surface and groundwater bodies impacting efficient management of transboundary aquifers. BIH legal framework is complemented by the entities' Environmental Laws

the Nature Protection Laws which contribute to groundwater protection only indirectly through requiring environmental impact assessments for potential water-related impacts as well as establishing a framework for biodiversity conservation and designate protected areas. According to the entities Laws on Geological researches, Geological Surveys in Zvornik in RS and in Sarajevo in FBiH, hold valuable archives on aquifer stratigraphy, springs, and karst morphology—most of which exist only in analogue or unpublished formats

2.2.2. Monitoring and Status Assessment

Croatia applies a standardized methodology for groundwater monitoring, aligned with EU Common Implementation Strategy guidance. The Regulation on Water Quality Standards defines chemical status criteria and threshold values, incorporating site-specific considerations for karst systems. Monitoring networks cover quantitative and chemical parameters, ecological flows, and groundwater-dependent ecosystems, ensuring compliance with WFD and GWD requirements. Data are integrated into national information systems and made accessible under the INSPIRE Directive and the Act on the Right of Access to Information, promoting transparency.

In Bosnia and Herzegovina, monitoring obligations are legally prescribed but operationally weak. Entity rulebooks such as the Rulebook on Monitoring of Surface and Groundwater (FBiH) and the Rulebook on Monitoring of Water Quality (RS) - define parameters and frequency, yet implementation remains partial and uneven. Monitoring of groundwater bodies is carried out on several groundwater bodies in the Sava basin in F BiH, but it typically focuses on drinking-water sources—such as karst springs—rather than on groundwater bodies as integrated hydrogeological units and ecological indicators are rarely included. The lack of harmonized and coordinated methodologies, insufficient technical capacity, and limited data exchange between entities hinder comprehensive status assessment, particularly in karst areas where rapid infiltration and high vulnerability demand specialized approaches.

2.2.3. Sanitary Protection Zones

Both countries mandate sanitary protection zones for drinking water sources though approaches differ.

Sanitary protection zones in Croatia are regulated by the Rulebook on Conditions for Establishing Sanitary Protection Zones of Water Sources. The regulation prescribes up to four zones for karst aquifers, ranging from strict protection around the intake structure to broader zones that may extend to the hydrogeological catchment. Delineation is based primarily on hydrogeological investigations and flow-time calculations; vulnerability mapping, while recommended in technical practice, is not legally required. The Rulebook mandates an inventory of potential pollution sources (*details elaborated in Chapter 2.3.3.)* and prescribes protective measures; however, obligations are unevenly implemented. Municipal delays and weak enforcement leave SPZs and recharge areas vulnerable to legacy contamination, as further discussed *in Chapter 2.3.3.*

Bosnia and Herzegovina lacks harmonized methodologies across entities, resulting in inconsistent enforcement and monitoring. Sanitary protection zones in FBiH are governed by the Regulation on the Method for Determining Zones and Areas of Sanitary Protection of Water Sources. ("Official Gazette of FBiH", 88/12). This regulation prescribes up to four zones for karst environments and requires hydrogeological studies and vulnerability assessments as part of the delineation process. Protective measures include restrictions on construction, waste disposal, and certain agricultural practices. While the regulation provides a relatively detailed framework, implementation is inconsistent. Many municipalities have not adopted formal decisions on SPZs or integrated them into spatial plans,

despite clear legal obligations. RS Regulation on Protection Measures, Designation, Maintenance, and Marking of Sanitary Protection Zones ("Official Gazette RS", No. 76/16) defines three zones of sanitary protection, their spatial extent, and protection measures. Under the current Regulation in the RS, there are no specific criteria for delineating zones in karst areas i.e. it does not differentiate between karst and non-karst hydrogeological conditions. In both entities, monitoring within zones is very limited and remediation of existing pollution sources is rarely carried out. Enforcement is very limited taking into account lack of finance and human resources in inspection sector.

A critical gap in BiH is the lack of standardized entities' methodologies for vulnerability assessment and uniform application of technical criteria. Furthermore, SPZ requirements are not systematically integrated into sectoral policies such as agriculture, tourism, and spatial planning, increasing the likelihood of land-use conflicts and cumulative pressures on groundwater resources.

2.2.4. Regulation of Water Use and Discharge

Croatia enforces a clear permitting system for groundwater abstraction and wastewater discharge, supported by concession rules for large-scale uses. The Water Act prohibits direct discharges into groundwater and allows indirect discharges only under strict conditions, requiring risk assessments and compliance with emission limit values. However, regulation of artificial recharge remains underdeveloped, lacking detailed technical guidelines - a gap relevant for future climate adaptation measures in karst regions.

Bosnia and Herzegovina's Water Laws similarly prohibit direct discharges and regulate indirect discharges only under strict conditions through entity-level bylaws, such as the Rulebooks on Conditions for Discharging Wastewater into the Environment (FBIH) and Discharging Wastewater into surface waters and in Public Sewage Systems (RS). Yet, enforcement is weak, and compliance monitoring is sporadic. Legal provisions for artificial recharge exist in principle but are not operationalized, leaving karst aquifers vulnerable to uncontrolled interventions.2.2.5. Managing Agricultural Pressures on Groundwater and Associated Ecosystems

2.2.5. Regulation of Water Use and Discharge

Agricultural activities represent a significant source of diffuse pollution and quantitative pressure on groundwater in the Neretva TBA, particularly in karst areas characterized by high vulnerability and rapid infiltration. Both Croatia and Bosnia and Herzegovina formally recognize these risks in their water management strategies and river basin plans, yet the degree of regulatory detail and enforcement varies.

In Croatia, the Water Act and the River Basin Management Plan until 2027 incorporate measures to reduce nitrate and pesticide contamination, aligned with the EU Nitrates Directive and the Water Framework Directive. Sanitary protection zones impose strict restrictions on intensive agriculture in karst areas, including bans on fertilizer and pesticide use in Zones I and II, and conditional limitations in Zone III. The Common Agricultural Policy (CAP) Strategic Plan introduces eco-schemes and High Nature Value (HNV) grassland conservation programs, which prohibit agrochemical inputs and land reclamation works, indirectly contributing to groundwater protection. However, monitoring of diffuse pollution remains limited, and site-specific vulnerability assessments are not systematically applied. Irrigation is regulated through water permits, but quantitative impacts on groundwater are rarely assessed beyond basic abstraction reporting.

In Bosnia and Herzegovina, entity-level Water Laws prohibit activities that may endanger water quality within sanitary protection zones, and the Federation's regulation explicitly restricts agricultural

practices in karst environments. Nevertheless, enforcement is inconsistent, and many municipalities have not adopted formal decisions or integrated protection zones into spatial plans. Agricultural policies promote irrigation and intensification without robust safeguards for groundwater sustainability, and nitrate and pesticide monitoring is sporadic. Eco-conditionality under rural development programs is emerging but lacks systematic linkage to groundwater protection objectives. In practice, diffuse pollution from fertilizers and livestock effluents remains a major pressure, compounded by inadequate manure management and limited wastewater treatment in rural areas.

Both countries face common challenges: insufficient monitoring of diffuse agricultural pollution and weak integration of groundwater objectives into agricultural policies. Measures proposed in river basin plans include harmonized parameter lists for nitrate and pesticide monitoring, expansion of pilot sites to demonstrate good agricultural practices, and staged financing for remediation of hotspots.

2.2.6. Economic Instruments and Enforcement

Croatia integrates the polluter pays and cost recovery principles into its water legislation, aligning with Article 9 of the WFD. The Water Management Financing Act and related bylaws establish pricing methodologies that incorporate resource and environmental costs. Enforcement capacity is supported by Croatian Waters and the State Inspectorate, which conduct inspections and impose penalties for non-compliance.

In Bosnia and Herzegovina, these principles are legally recognized but not fully implemented. Fee structures for water abstraction and discharge exist, yet they do not reflect environmental costs. Law enforcement relies on entity water inspectorates, which face chronic understaffing and limited budgets, resulting in reactive rather than preventive compliance monitoring

2.2.7. Integration with Environmental and Spatial Planning Laws

Croatia's legal framework demonstrates strong integration of groundwater protection into spatial planning and nature conservation instruments. The Spatial Development Strategy explicitly recognizes groundwater as a strategic resource and mandates its inclusion in land-use planning, particularly through the delineation of sanitary protection zones around springs and wellfields. Natura 2000 provisions further reinforce this integration by safeguarding groundwater-dependent ecosystems within protected areas. Environmental Impact Assessments (EIAs) are mandatory for projects that may affect water resources, including infrastructure, tourism, and energy developments, ensuring that groundwater considerations are embedded in decision-making processes. Additionally, the Nature Protection Act transposes the Habitats and Birds Directives, linking biodiversity conservation with groundwater protection. Croatia's planning instruments also require that sanitary protection zones be incorporated into municipal and regional spatial plans, supported by technical studies and hydrogeological assessments. However, while the legal framework is robust, practical implementation varies, with delays in updating spatial plans and inconsistencies in integrating groundwater vulnerability mapping into sectoral strategies such as transport and energy.

In Bosnia and Herzegovina, entities' spatial planning laws formally require the inclusion of water protection zones in planning documents, but implementation is uneven and often delayed. The FBiH mandates the integration of sanitary protection zones into urban and spatial plans, based on hydrogeological studies, while RS applies similar requirements under its Spatial Planning and Construction Law. Despite these provisions, many municipalities have not adopted formal decisions or incorporated zones into planning instruments, primarily due to limited administration capacity and financing sources for protection measures implementation. According to the entities' Environmental Laws, Environmental impact assessments are legally required for projects with potential water-related

impacts, but enforcement is inconsistent, and groundwater-specific criteria are often absent. In both FBIH and RS, nature protection Laws provide a framework for biodiversity conservation and designate protected areas, but their linkage with groundwater protection is indirect and implementation remains uneven.

2.2.8. Observations for the TBA Neretva

From a comparative perspective, Croatia and Bosnia and Herzegovina exhibit different levels of regulatory development and operational capacity in groundwater governance, but neither country can be considered fully effective in practice.

Croatia's legal framework is formally aligned with EU directives and provides a structured basis for groundwater protection, including requirements for sanitary protection zones and integration into spatial planning. However, implementation remains uneven. Delays in updating spatial plans, inconsistent enforcement of zoning restrictions, and gaps in vulnerability mapping persist, particularly in rural and karst areas. While Natura 2000 provisions and the Spatial Development Strategy reference groundwater-dependent ecosystems, these commitments are not always translated into concrete measures at the local level. Environmental impact assessments are mandatory, yet groundwater-specific criteria are often applied superficially, and cumulative impacts from tourism and infrastructure projects are rarely assessed comprehensively.

In addition, agricultural pressures are significant in karst parts of the Neretva TBA. In Croatia, sanitary protection zones already impose strict limitations on fertilizers and pesticides in inner zones, and CAP eco-schemes (e.g., HNV grasslands) indirectly reduce agrochemical inputs; nonetheless, monitoring of diffuse pollution (nitrates/pesticides) and systematic use of site-specific vulnerability assessments remain limited, and irrigation permitting seldom includes robust quantitative impact analysis.

Entity-level Spatial Laws in BIH require the inclusion of sanitary protection zones in spatial plans, but enforcement is sporadic and often delayed. Vulnerability mapping and ecological connectivity assessments are largely absent, leaving transboundary aquifers exposed to cumulative pressures from land-use changes and seasonal water demand. Environmental impact assessments exist in law but lack standardized groundwater-related methodologies, and compliance monitoring is weak. Groundwater considerations are rarely mainstreamed into sectoral strategies such as agriculture, energy, and tourism, despite their significant influence on karst aquifers.

Adding to this, agricultural intensification without strong safeguards amplifies diffuse pressures in BiH: the Federation's regulation provides karst-specific restrictions within sanitary zones, but many municipalities have yet to adopt formal decisions; nitrate/pesticide monitoring is sporadic, eco-conditionality is emerging but not systematically linked to groundwater objectives, and manure management remains a recurrent gap in rural areas.

For the TBA Neretva, these shortcomings translate into practical challenges for harmonized monitoring, risk assessment, and protection of shared groundwater resources. Croatia's regulatory framework offers a stronger starting point for transboundary cooperation, but its operational gaps - particularly in enforcement and cross-sectoral integration-limit effectiveness. Bosnia and Herzegovina's fragmented administrative system requires significant strengthening to achieve comparable standards.

The absence of explicit groundwater provisions in the 1996 bilateral agreement between the two countries further underscores the need for legal and institutional convergence. Updating the 1996 agreement to include these groundwater-specific obligations - together with joint sanitary-zone

criteria, monitoring protocols, and data-sharing - would provide a critical step toward integrated governance and improved resilience of the TBA Neretva. (More details in Chapter 6.1.)

2.2.9. Key Implications for Bilateral Governance in the TBA Neretva (Croatia and BIH)

The analysis of national legal instruments and planning frameworks for Croatia and Bosnia and Herzegovina reveals several critical implications for groundwater governance in the TBA Neretva. While Croatia's legal framework is formally aligned with EU directives and provides a solid foundation for groundwater protection, implementation on the ground is uneven and faces structural and operational challenges. Bosnia and Herzegovina, on the other hand, continues to struggle with fragmentation and limited technical capacity, which significantly constrains effective governance.

First, the difference in regulatory development between the two countries remains a barrier to coordinated management. Croatia has transposed the WFD and GWD and requires sanitary protection zones in spatial plans However, delays in updating spatial plans, inconsistent enforcement of zoning restrictions, and gaps in vulnerability mapping persist, particularly in rural and karst areas. Bosnia and Herzegovina's entity-level water laws incorporate WFD principles but only partially reflect GWD requirements, leaving critical gaps in chemical status assessment, trend reversal, and ecological connectivity. Sanitary protection zones are required to be integrated into spatial plans. However, there is a lack of determination of sanitary protection for many water sources and legal binding decisions on their protection including inconsistent enforcement of zoning restrictions.

Second, technical standards for karst aquifer protection differ substantially. Croatia applies detailed hydrogeological criteria for delineating sanitary zones, yet practical enforcement is often weak, and remediation programs are inconsistently implemented. Illegal waste disposal and insufficient wastewater treatment continue to threaten groundwater quality even under a robust legal framework. Bosnia and Herzegovina lacks harmonized entities methodologies for vulnerability mapping and sanitary zone delineation, and monitoring remains focused on drinking water sources rather than groundwater bodies.

Third, enforcement capacity and institutional coordination are problematic in both countries, albeit to different degrees. Croatia benefits from centralized oversight by Croatian Waters and the Ministry of Environmental Protection and Green Transition, but resource constraints and uneven local capacities hinder systematic compliance monitoring. Bosnia and Herzegovina faces even greater challenges: inspectorates operate with minimal staff and budgets, resulting in reactive enforcement and weak deterrence. While both countries recognize the polluter pays and cost recovery principles, Croatia's application of these principles is partial and often contested, and Bosnia and Herzegovina lacks any consistent methodology for integrating environmental costs into water pricing.

Fourth, integration with environmental and spatial planning laws remains insufficient in practice. Croatia's Spatial Development Strategy and Natura 2000 provisions formally link groundwater protection with biodiversity conservation, yet sectoral strategies - such as energy and tourism - do not consistently operationalize these requirements. Bosnia and Herzegovina's planning instruments mandate the inclusion of sanitary zones, but implementation is sporadic, and groundwater considerations are rarely mainstreamed into agriculture or infrastructure development. Environmental impact assessments are legally required in both countries, but groundwater-specific criteria are often absent or inadequately applied. A draft plan for the Natura 2000 ecological network in BiH was prepared, proposing 122 areas covering 956,776 ha, about 20% of the state territory (Milanović and Golob, 2015). However, establishing entities ecological networks require further activities. Harmonization of sectoral regulations with EU law is necessary, alongside identification of

other ecologically significant areas (such as water protection zones, hunting and fishing areas) and their inclusion in the ecological networks.

Fifth, diffuse agricultural pressures in karst parts of the Neretva TBA require explicit bilateral attention. In Croatia, inner sanitary zones restrict fertilizers/pesticides and CAP eco-schemes help reduce agrochemical inputs but monitoring of nitrates/pesticides and site-specific vulnerability assessment remain limited; in BiH, karst-specific restrictions exist on paper yet municipal adoption and enforcement lag, monitoring is sporadic, and manure management gaps persist. These differences hinder coherent risk management across the shared aquifer.

Finally, as a particularly significant matter for transboundary cooperation, it should be noted that the provisions of the existing bilateral agreement between Croatia and Bosnia and Herzegovina, dating from 1996, are rather generic and do not explicitly address groundwater management. (*This issue is elaborated in a subsequent Chapter 6.1).*

Implications for the TBA Neretva can be summarized as follows:

- Legal/technical harmonization for karst: adopt shared criteria for sanitary protection zones and vulnerability mapping to ensure comparable safeguards on both sides of the border.
- Agricultural pressures: agree harmonized parameter lists for nitrate/pesticide monitoring, establish pilot sites to demonstrate good agricultural practice and build trust, and apply staged financing for remediation of agricultural hotspots.
- Operational capacity: strengthen enforcement, monitoring networks and cross-sectoral coordination (water–agriculture) with priority support in BiH.
- Planning integration: embed groundwater objectives and GWDE considerations into spatial and sectoral plans beyond formal references, with routine compliance checks.
- Bilateral instrument: update the 1996 agreement to include groundwater-specific obligations and mandate an operational bilateral mechanism to oversee implementation.

2.3 Comparative Legal Analysis: Croatia vs BiH

This chapter provides a structured comparison of the legal frameworks governing groundwater in Croatia and Bosnia and Herzegovina, focusing on their relevance for the TBA Neretva. The analysis examines how each country defines and regulates groundwater within its national legislation, identifies key similarities and differences, and evaluates the implications for transboundary governance under DIKTAS II. The comparative review is organized into four critical dimensions: Groundwater Ownership and Use Rights, Licensing and Permitting Procedures, Pollution Control and Sanitary Protection Zones, and Enforcement Mechanisms and Institutional Capacities. Together, these elements form the foundation for understanding legal asymmetries and operational gaps that influence the management of shared karst aquifers.

2.3.1 Groundwater Ownership and Use Rights

Both Croatia and Bosnia and Herzegovina legally define water resources, including groundwater, as a public good, prohibiting private ownership of aquifers or water bodies. However, the scope and clarity of these provisions, as well as their practical implementation, vary significantly between the two countries.

In Croatia, the Water Act (Official Gazette Nos. 66/2019, 84/2021, 47/2023) establishes groundwater as part of the national water estate, managed in the public interest. Ownership rights over groundwater are excluded, and its use is regulated through a system of permits and concessions.

Water abstraction for public supply, agriculture, and industry requires a Water Use Permit issued by Croatian Waters, while large-scale or economically significant uses - such as hydropower or mineral water exploitation - require a concession granted by the Ministry of Environmental Protection and Green Transition. These permits and concessions are time-bound (typically 12 years for permits and up to 40 years for concessions) and subject to compliance with environmental standards and monitoring obligations. The Water Act also integrates the polluter pays and cost recovery principles, requiring users t. pay fees that reflect resource and environmental costs. Despite this robust legal framework, enforcement challenges persist. Monitoring of abstraction volumes is uneven, particularly in rural areas, and illegal water use remains a concern.

In Bosnia and Herzegovina, groundwater is similarly defined as a public good under entity-level Water Laws - the Federation of BiH Water Law. These laws prohibit private ownership and regulate use through permits and, in some cases, concessions. However, the permitting system is fragmented across entities and cantons, resulting in overlapping competencies and procedural inconsistencies. In the Federation of BiH, water permits for smaller abstractions are issued by cantonal authorities, while larger uses fall under the jurisdiction of entity-level water agencies. In Republika Srpska, the Public Institution “Vode Srpske” manages permitting and monitoring. Concessions for hydropower and other major uses are governed by separate concession laws, adding another layer of complexity. While both entities recognize the polluter pays principle, cost recovery is only partially implemented, and water pricing structures do not systematically incorporate environmental costs. Monitoring obligations exist in law but are weakly enforced due to limited technical capacity and financial resources. Illegal abstractions and unregistered wells are common, particularly in rural and karst areas, where oversight is minimal.

A critical difference between the two countries lies in the integration of groundwater use rights with spatial planning and environmental protection. Croatia’s legislation explicitly links water permits to compliance with sanitary protection zones and in BiH water permits take into account sanitary zones and source protection, though many zones have not yet been formally proclaimed or integrated into spatial plans, making the linkage with spatial planning and environmental protection less explicit and implementation less consistent. This gap exposes groundwater sources to uncontrolled land-use changes and pollution risks.

Both countries face shortcomings in operationalizing groundwater ownership and use rights in practice. In Croatia, the main issues include delayed spatial planning updates, insufficient monitoring of abstraction volumes, and weak enforcement of restrictions in sanitary zones. In BiH, the main challenges include the incomplete proclamation of sanitary protection zones, their limited integration into spatial plans, inconsistent enforcement of restrictions, and weak institutional coordination between water management and environmental authorities.”. For the TBA Neretva, these shortcomings translate into risks of over-abstraction, contamination, and uncoordinated development on both sides of the border

2.3.2 Licensing and Permitting Procedures

Licensing and permitting systems regulate abstraction, discharge, and other activities that may impact aquifer integrity. Both Croatia and Bosnia and Herzegovina legally require permits for groundwater use, yet their frameworks differ significantly in terms of structure, clarity, and enforcement, with implications for transboundary management in the TBA Neretva.

In Croatia, the Water Act establishes a two-tiered system: Water Use Permits for standard abstractions and Concessions for economically significant or large-scale uses. Croatian Waters issues permits for

public water supply, irrigation, and industrial use below defined thresholds, typically valid for 12 years. Concessions, granted by the Ministry of Environmental Protection and Green Transition, apply to hydropower generation, mineral and geothermal water exploitation, and abstractions exceeding 10,000 m^3 annually, with durations of up to 40 years. Both instruments require compliance with environmental standards, monitoring obligations, and payment of water-related fees under the Water Management Financing Act. The permitting process is linked to spatial planning and sanitary protection zones, ensuring that hydrogeological studies inform decisions. However, practical challenges persist: delays in processing applications, insufficient integration of vulnerability assessments, and weak monitoring of compliance. Illegal abstractions and underreporting of water volumes remain issues, particularly in rural karst areas where enforcement capacity is limited.

In Bosnia and Herzegovina, entity-level Water Laws govern permitting so responsibilities are divided among entities authorities. In the Federation of BiH, water permits for smaller abstractions are issued by cantonal ministries, while larger uses fall under the jurisdiction of entity water agencies (AVP Sava and AVP Jadran). In Republika Srpska, the Public Institution "Vode Srpske" manages permits for all significant uses. Concessions for hydropower and other major activities are regulated by separate concession laws, adding complexity and procedural delays. While legal provisions require permits for abstraction and discharge, implementation is inconsistent. Monitoring obligations are weakly enforced, and many water sources remain with ought legally binding protection and unregistered. The lack of harmonized criteria for karst aquifers and vulnerability assessments further undermines the effectiveness of permitting decisions. Environmental impact assessments are formally required for projects with potential water-related impacts, but groundwater-specific methodologies are rarely applied, and cumulative effects are not systematically evaluated.

A key difference lies in the integration of permitting with broader governance instruments. Croatia's framework, despite operational gaps, demonstrates stronger linkage between permits, sanitary protection zones, and river basin management plans. Bosnia and Herzegovina lacks such systemic integration; permitting decisions often occur in isolation from spatial planning and sectoral strategies, increasing the risk of uncontrolled land-use changes and pollution near sensitive recharge zones. Both countries recognize the polluter pays principle, yet cost recovery mechanisms are more advanced in Croatia, where water pricing methodologies incorporate resource and environmental costs. In BiH, fee structures vary across entities and cantons, and enforcement is sporadic.

For the TBA Neretva, these disparities create significant challenges for coordinated groundwater management. Croatia's permitting system offers a clearer legal basis but suffers from enforcement weaknesses, while in BiH the permitting framework is marked by procedural complexity due to shared responsibilities among entities and weak enforcement.

2.3.3 Pollution Control and Sanitary Protection Zones

Pollution control and the establishment of sanitary protection zones (SPZs) are essential components of groundwater governance, particularly in highly vulnerable karst systems such as the TBA Neretva. Both Croatia and Bosnia and Herzegovina have legal provisions addressing these issues, but their frameworks differ in technical detail, enforcement capacity, and practical implementation. For the TBA Neretva, which is entirely located within the Federation of BiH, the effectiveness of measures in this entity is of primary importance.

In Croatia, pollution control is embedded in the Water Act and supported by implementing regulations. Direct discharges of pollutants into groundwater are strictly prohibited, while indirect discharges - such as infiltration of treated wastewater - are permitted only under strict conditions and

subject to risk assessments. The Regulation on Emission Limit Values for Wastewater sets pollutant thresholds and monitoring requirements in line with EU standards. However, gaps remain in regulating artificial aquifer recharge and assessing cumulative impacts on groundwater-dependent ecosystems. Enforcement of discharge restrictions is uneven, particularly in rural karst areas where illegal waste disposal and insufficient wastewater treatment persist. The River Basin Management Plan (RBMP) identifies these pressures as significant risks, calling for improved monitoring and remediation measures.

The Croatian's Rulebook on Conditions for Establishing Sanitary Protection Zones mandates an inventory of potential pollution sources and prescribes protective measures, including prohibitions on waste disposal, hazardous construction, and certain agricultural activities. In theory, these measures are complemented by monitoring obligations and remediation programs. These provisions are critical for safeguarding springs and recharge areas in the Neretva basin In practice, however, implementation is uneven. Many municipalities delay incorporating SPZs into spatial plans, despite legal requirements, and enforcement of restrictions within zones is inconsistent. Remediation programs for legacy pollution sources are often incomplete or not implemented, leaving sensitive recharge areas exposed to contamination risks..

In BIH, pollution control is defined under the entities Water Laws and supported by environmental regulations. Groundwater protection measures are embedded in the entities Water Laws and regulations. The Water Laws (RS, FBiH) specify that direct discharge of wastewater into groundwater is prohibited. However, indirect discharge is allowed only under the conditions and in the manner determined by law and by-laws. There are corresponding Regulations on the conditions for discharging wastewater into public sewage systems and surface waters in RS ((Official Gazette of RS No. 44/01), as well as regulation Rulebook on the Conditions for Discharging Wastewater into the Environment and Public Sewage Systems ("Official Gazette of FBiH", 26/20, 96/20), defining technical and sanitary requirements for discharging wastewater, maximum allowable pollutant concentrations, monitoring and reporting requirements. However, monitoring of compliance and enforcement is weak, technical guidelines for risk assessment are underdeveloped, and illegal waste disposal and uncontrolled wastewater infiltration remain widespread, particularly in rural karst areas. The lack of systematic evaluation of impacts on groundwater-dependent ecosystems further undermines pollution control efforts.

The FBIH regulation on protection zones distinguishes karst environments and mandates vulnerability assessments, while RS applies uniform criteria without reflecting hydrogeological complexity. Karst-specific protective measures are explicitly defined in the FBH Regulation while RS applies general groundwater protection criteria. Enforcement is inconsistent, and many municipalities have not adopted formal decisions or integrated zones into spatial plans, despite legal obligations.

Environmental laws in both entities include provisions that prohibit or restrict the discharge of pollutants into groundwater, through environmental permitting and impact assessment mechanisms.

Artificial aquifer recharge can be legally addressed through provisions in the water laws of both entities but it is necessary to prepare a detailed Environmental Impact Assessment and obtain the appropriate permits from the competent authorities proving that it does not have adverse effect to water resources.

From a comparative perspective, Croatia shows stronger alignment with EU directives and provides more detailed technical standards for SPZs, yet it continues to face challenges in enforcing restrictions within zones and in incorporating SPZs into spatial plans. The FBIH, where the entire TBA Neretva is

located, despite having regulations that acknowledge karst vulnerability, faces persistent challenges with the legal proclamation of many SPZs, their integration into spatial plans, and the implementation, monitoring, and inspection of sanitary protection zones. It also struggles with illegal waste disposal and inadequate wastewater treatment, which remain major threats to groundwater quality.

Given the significance of diffuse agricultural pressures in karst systems, sanitary zone measures should be specified with greater operational clarity. In Croatia, Zones I-II already prohibit fertiliser and pesticide use, while Zone III allows limited application under strict conditions (e.g., seasonal windows, dosage controls, low-drift application techniques, and compliant manure storage). These requirements should be consistently embedded in water use permits and spatial plans and aligned with CAP eco-schemes that restrict agrochemical inputs on HNV grasslands. Priority actions include strengthened hotspot monitoring for nitrates and pesticides at vulnerable points (springs, swallow holes, shallow wells), and the routine use of site-specific vulnerability assessments when issuing irrigation permits and planning works.

In the Federation of BiH, although regulations recognise karst-specific restrictions within sanitary zones, implementation is uneven across municipalities/cantons.To operationalise controls, agricultural support should be linked to conditions that protect groundwater (mandatory bans in Zones I-II, nutrient management plans, covered manure storage, and vegetated buffer strips along losing streams and ponors). Authorities should also standardise parameter lists for nitrate/pesticide surveillance, establish joint pilot sites to demonstrate good agricultural practice, and apply rapid measures at known hotspots (improper manure platforms, direct discharges). For the TBA Neretva, a coordinated sanitary protection zone criteria, harmonised monitoring protocols, and time-bound remediation of agricultural hotspots would materially reduce transboundary contamination risk while remaining consistent with existing legal frameworks on both sides.

2.4 Identified Legal Gaps and Opportunities for Harmonization

The comparative review of legal frameworks governing groundwater in Croatia and Bosnia and Herzegovina reveals substantial asymmetries in regulatory maturity, operationalization, and integration with EU directives, which directly affect the governance of the TBA Neretva. While Croatia exhibits formal alignment with the Water Framework Directive (WFD) and Groundwater Directive (GWD), Bosnia and Herzegovina remains only partially compliant, with fragmented implementation across entities and cantons. These disparities create significant challenges for harmonized management and underscore the need for targeted legal and institutional convergence.

A primary gap in Bosnia and Herzegovina is absence of harmonised implementation of entities Laws, which results in inconsistent methodologies for groundwater status assessment, sanitary protection zone delineation, and pollution control. The Groundwater Directive is only partially transposed, leaving critical provisions - such as trend reversal, threshold value determination, and protection of groundwater-dependent ecosystems - either incomplete or absent. Monitoring obligations exist in law but are weakly enforced, and ecological indicators are rarely integrated into groundwater assessments. In contrast, Croatia has fully transposed both directives, established standardized monitoring protocols, and defined threshold values for pollutants, although gaps persist in regulating artificial recharge and cumulative impacts on karst ecosystems.

Both countries share deficiencies in regulating indirect wastewater discharge and artificial aquifer recharge. Croatia prohibits direct discharges and allows indirect discharges under strict conditions, yet lacks comprehensive technical guidelines for risk assessment and monitoring. Bosnia and Herzegovina's legal framework similarly prohibits direct discharges but provides no operational

methodology for evaluating indirect infiltration risks, leaving karst aquifers vulnerable to contamination. Remediation measures for contaminated soil and groundwater are legally mandated in both jurisdictions but remain inconsistently implemented, particularly in rural and karst areas where enforcement capacity is limited.

Sanitary protection zones represent another critical area of divergence. Croatia applies detailed hydrogeological criteria for delineating zones, supported by (optional) vulnerability mapping and flow-time calculations, whereas Bosnia and Herzegovina lacks harmonized methodologies across entities. FBIH prescribes karst-specific criteria, including vulnerability assessments, while RS applies uniform standards that disregard hydrogeological complexity. In practice, both countries struggle with delayed incorporation of protection zones into spatial plans and incomplete enforcement of restrictions, exposing sensitive recharge areas to uncontrolled land-use changes.

Despite formal prohibitions in sanitary zones, Croatia does not systematically embed nitrate and pesticide monitoring or vulnerability-based conditions into irrigation and land-use permits, while Bosnia and Herzegovina shows uneven municipal enforcement and weak linkage of farm subsidies to groundwater safeguards. Harmonization should focus on adopting joint karst-specific standards for Zones I-III, codifying bans and conditional uses of fertilisers and pesticides, and embedding these requirements in water permits and spatial plans. Shared monitoring protocols for nitrates and priority pesticides at vulnerable points, combined with cross-border pilot sites and time-bound remediation of agricultural hotspots, would provide a practical pathway for legal and methodological convergence under DIKTAS II.

Integration of groundwater considerations into spatial planning and sectoral policies remains insufficient in both countries. Croatia's Spatial Development Strategy and Natura 2000 provisions formally link groundwater protection with biodiversity conservation, yet operationalization is uneven, and cumulative impacts from tourism and infrastructure projects are rarely assessed comprehensively. Bosnia and Herzegovina faces even greater challenges: groundwater is marginally addressed in agriculture, energy, and tourism strategies, and vulnerability mapping is largely absent from planning instruments. Environmental impact assessments are legally required in both jurisdictions but lack standardized groundwater-specific methodologies, limiting their effectiveness in karst environments.

Economic instruments also reveal gaps. Croatia incorporates the polluter pays and cost recovery principles into its water legislation and tariff-setting methodologies, albeit with partial implementation and contested application at the local level. Bosnia and Herzegovina recognizes these principles in law but has not integrated environmental costs into water pricing, resulting in inadequate financial resources for monitoring and enforcement. This shortfall is compounded by chronic underfunding of water agencies and inspectorates, which constrains compliance monitoring and remediation efforts.

Opportunities for harmonization are evident across several dimensions. First, both countries should adopt standardized methodologies for vulnerability mapping and risk assessment of indirect discharges, ensuring consistency with EU guidance documents. Second, Bosnia and Herzegovina requires accelerated transposition of the Groundwater Directive, including provisions for chemical status assessment, trend reversal, and ecological connectivity. Third, integration of groundwater considerations into spatial planning and sectoral strategies must move beyond declarative commitments toward enforceable measures, supported by technical guidelines and monitoring protocols. Fourth, economic instruments should be aligned to reflect environmental and resource

costs, enabling sustainable financing of groundwater protection measures. Finally, it is necessary to include groundwater-specific obligations, harmonized sanitary zone criteria, joint monitoring programs, and data-sharing mechanisms, providing a robust legal foundation for transboundary cooperation under DIKTAS II.

In summary, Croatia offers a stronger regulatory and institutional baseline for groundwater governance, than Bosnia and Herzegovina which faces gaps that hinder effective implementation. Harmonization efforts should prioritize legal convergence, methodological standardization, and capacity building, ensuring that both countries meet identical standards and safeguard the ecological integrity of the TBA Neretva.

2.5 Summary Tables: Legal Framework Comparison – HR vs BiH (TBA Neretva)

Table 1 Summary table 2.3.1.-2.3.2. - Groundwater ownership and use rights & Licensing and permitting procedures (HR vs BiH)

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Legal status of groundwater	Public good; private ownership prohibited under Water Act	Public good; private ownership prohibited under Water Law	Public good; private ownership prohibited under Water Laws
Legal framework	Water Act (OG 66/2019, 84/2021, 47/2023); fully aligned with EU WFD & GWD	Water Law, WFD transposition almost completed; GWD up to 30%	Water Law, partial WFD transposition; GWD largely missing
Ownership & use rights	Groundwater cannot be privately owned; use regulated through permits and concessions	Groundwater cannot be privately owned; rights regulated through permits and concessions; decentralized governance	Same principle; rights regulated through permits and concessions; centralized at entity level
Permitting system	Two-tier: Water Use Permits (≤12 yrs) and Concessions (up to 40 yrs); based on hydrogeological studies and compliance with environmental standards	Decentralized: permitting system (cantonal and entity level) based on FBIH Water Law (usage, discharge) Concessions regulated separately in accordance to FBIH Law on concessions and Cantonal Laws on concessions	Centralized: permitting system (entity level) based on RS Water Law (usage, discharge) Concessions regulated separately in accordance of RS Law on concessions
Integration with spatial planning	Strong legal link; permits require compliance with sanitary protection zones and spatial plans	Legally required; implementation sporadic; many municipalities fail to establish zones	Legally required; implementation sporadic; many municipalities fail to establish zones
Polluter pays & Cost recovery	Embedded in law; fees reflect resource and environmental costs	Recognized in law but only partially implemented; fees do not reflect resource and environmental costs	Recognized in law but weak implementation; tariffs low; environmental costs not integrated

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Monitoring obligations	Mandatory reporting of abstraction volumes; enforcement uneven in rural areas	Legally required measurements and reporting but weakly enforced	Legally required but weakly enforced; measuring sporadic

Table 2 Summmary Table 2.3.3-Pollution Control and Sanitary Protection Zones (HR vs BiH)

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Legal framework	Water Act; Rulebook on SPZ; RBMP 2022–2027	Water Law; Regulation on SPZ; RBMP 2022–2027	Water Law; Regulation on SPZ; RBMP 2017–2021
Number of zones	4 zones (I–IV)	3–4 zones (zone IV: optional)	3 zones
Technical criteria for zone delineation	Hydrogeological study; karst-specific criteria; flow-time thresholds and apparent flow (AF) velocities: Zone II ≤ 1 day; V_{AF} 3.0 cm; Zone III 1 - 10 day; V_{AF}1.0 - 3.0 cm; Zone IV includes catchment beyond Zone III with flow through fracture-cavernous aquifers during high-water conditions (10–50 days depending on source type); exceptionally entire recharge area if apparent flow <1 cm/s.	Differ among entities; Detailed karst methodology; vulnerability mapping mandatory; flow-time thresholds (zone II – minimum 1 day; zone III – minimum 10 days)	Differ among entities Uniform criteria for all mediums; flow-time (7, 90, 180 days); minimum distances (50m, 250m, 200m)
Inventory of pollution sources	Mandatory in technical study	Mandatory in SPZ Program (Study)	Mandatory in SPZ Program (Study)
Protective measures – Zone I	Physical fencing; ban on all activities except maintenance	Physical fencing; ban on all activities except maintenance	Ban on construction, waste disposal, agriculture
Protective measures – Zone II	Ban on waste disposal, industry, agriculture (except ecological)	Ban on agriculture, waste disposal, hazardous construction	Ban on construction, waste disposal; agriculture partly allowed

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Protective measures – Zone III	Ban on waste disposal, hazardous construction, and polluting facilities; agriculture allowed only under ecological standards; certain developments (e.g., waste management centers) permitted only with detailed hydrogeological study and strict protective conditions	Broader land-use restrictions; mandatory environmental impact assessments for new projects; agriculture and construction regulated; zone may include entire hydrogeological catchment; vulnerability mapping required	Outer zone: general restrictions on construction, excavation, and waste disposal; agriculture partly allowed; no karst-specific criteria (uniform approach)
Protective measures – Zone IV	Passive protection measures; includes catchment beyond Zone III; land-use control and spatial planning	Optional zone; applied in highly sensitive karst systems; passive measures (land-use control, planning); long-term monitoring and planning functions	Not defined (only three zones exist)
Monitoring within zones	Monitoring is mandatory in all zones but is primarily carried out at water abstraction points (springs and wells) used for public supply. It includes water quality (physical-chemical and microbiological parameters) and, where relevant, quantity (spring discharge). Monitoring requirements are defined in the Decision on the Protection of Drinking Water Source and implemented by water utilities under the supervision of Croatian Waters and the Public Health Institute. In karst areas, continuous monitoring is emphasized due to high vulnerability	Monitoring is mandatory in all zones and defined in the Sanitary Protection Programme. Parameters include physical-chemical and microbiological indicators; frequency and number of points are determined by consumer numbers, risk level, and distance from the intake. Monitoring is performed by water utilities and controlled by cantonal inspectorates; methodology is not standardized between entity level	Monitoring is included in the Sanitary Protection Programme; carried out at abstraction points and in Zone I, occasionally in Zones II and III. Parameters include chemical and microbiological indicators; frequency is not clearly prescribed and depends on local conditions. There is no karst-specific methodology, and systematic monitoring of water quantity (spring discharge) is not implemented
Remediation	Prescribed in Rulebook & RBMP; often not implemented	Prescribed in Program; rare implementation	Prescribed in Program, rare implementation
Integration into spatial plans	Legally required; implementation occasionally slow	Legally required; many municipalities often non-compliant	Legally required; municipalities often non-compliant

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Regulation of wastewater discharge	Direct discharge prohibited; indirect under strict conditions; MAR guidelines missing	Direct discharge prohibited; indirect under strict conditions; lacks technical guidance	Direct discharge prohibited; indirect under strict conditions; lacks technical guidance

Table 3 Key summary table 2.4a -. Identified Legal Gaps (HR vs BiH)

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
EU directive transposition	WFD and GWD fully transposed; minor gaps in operationalization (e.g., cumulative impact assessment)	WFD largely transposed (>90%); GWD only partially implemented (30%); lack provisions for trend reversal and ecological connectivity, and not established a WFD/GWD-compliant methodology for assessing chemical status or defining groundwater threshold values."	WFD partially transposed (~75%); GWD largely missing; lack provisions for trend reversal and ecological connectivity, and not established a WFD/GWD-compliant methodology for assessing chemical status or defining groundwater threshold values
Groundwater-dependent ecosystems (GWDE)	Legally recognized under Nature Protection Act and Natura 2000; weak integration into planning and monitoring	Not explicitly defined; addressed indirectly via environmental and nature protection laws; no operational criteria	Not explicitly defined; addressed indirectly via environmental and nature protection laws; no operational criteria
Sanitary protection zones (SPZ)	Detailed hydrogeological criteria exist; vulnerability mapping optional; enforcement uneven; delays in spatial plan integration	Karst-specific methodology legally required; vulnerability mapping mandatory; implementation sporadic; many municipalities lack formal decisions	Uniform criteria applied; ignores karst complexity; no vulnerability mapping; enforcement weak
Monitoring framework	Standardized methodology aligned with EU CIS guidance; integrated into RBMP; gaps in karst-specific monitoring and ecological indicators	Monitoring obligations exist through water Law and RBMP; gaps in karst-specific monitoring (focused on drinking water sources) and gap in ecological indicators, lack of standardized methodology among entities;	Monitoring obligations exist through water Law and RBMP; gaps in karst-specific monitoring (focused on drinking water sources) and gap in ecological indicators, lack of standardized methodology among entities;

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Pollution control & Wastewater regulation	Direct discharge prohibited; indirect allowed under strict conditions; lacks technical guidelines for indirect wastewater discharge and risk assessment	Direct discharge prohibited; indirect allowed under strict conditions; lacks operational guidelines and monitoring protocols and risk assessment or technical guidance	Direct discharge prohibited; indirect allowed under strict conditions; lacks operational guidelines and monitoring protocols and risk assessment or technical guidance
Pollution control from agriculture	Gaps in embedding nitrate/pesticide monitoring and vulnerability-based conditions into permits; enforcement uneven; CAP eco-schemes not fully integrated with groundwater safeguards	Karst-specific restrictions exist but municipal adoption and enforcement weak; nitrate/pesticide monitoring sporadic; poor linkage of farm subsidies to groundwater protection	Uniform criteria ignoring karst complexity; agriculture partly allowed in SPZ; no systematic nitrate/pesticide control; enforcement capacity weak
Artificial recharge regulation	No comprehensive legal framework for MAR; absence of technical standards and risk assessment procedures	Legal basis exists in principle; no operational methodology or technical standards	Legal basis exists in principle; no operational methodology or technical standards
Integration of SPZ with spatial planning	Legally required; delays in incorporating SPZ into spatial plans; cumulative impacts rarely assessed	Legally required; many municipalities non-compliant; weak enforcement mechanisms	Legally required; many municipalities non-compliant
Economic instruments	Polluter pays and cost recovery principles embedded; partial implementation; contested locally	Recognized in law; distributed among Federal and cantonal levels and Environment fund; collected amount insufficient for water requirements; environmental/resource costs absent	Recognized in law; distributed among RS and municipal levels and Environment fund; collected amount insufficient for water requirements; environmental/resource costs absent
Remediation of contaminated sites	Legally mandated in RBMP and SPZ programs; implementation inconsistent; no dedicated law for remediation	Prescribed by legislations; weak enforcement; remediation rarely implemented	Prescribed by legislations; weak enforcement; remediation rarely implemented

Table 4 Key summary table 2.4.b -Identified Opportunities for Harmonization (HR vs BIH)

Legal dimension	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
EU directive compliance	Maintain full WFD/GWD alignment; introduce detailed guidance for cumulative impact assessment	Accelerate full GWD transposition; adopt provisions for chemical status, trend reversal, and ecological connectivity, develop methodology for threshold values and chemical status assessment	Accelerate full GWD transposition; adopt provisions for chemical status, trend reversal, and ecological connectivity, develop methodology for threshold values and chemical status assessment
Groundwater-dependent ecosystems (GWDE)	Operationalize Natura 2000 commitments; integrate GWDE criteria into RBMP and EIA procedures	Define GWDE explicitly in water Law; Introduce GWDE definition and protection measures; link to biodiversity strategies; integrate into RBMP and spatial planning	Define GWDE explicitly in water Law; Introduce GWDE definition and protection measures; link to biodiversity strategies integrate into RBMP and spatial planning
Sanitary protection zones (SPZ)	Harmonize SPZ delineation with vulnerability mapping as mandatory; strengthen enforcement and integration into spatial plans	Ensure full compliance with the legal requirement to identify all water abstraction springs and to establish all protection zones through systematic vulnerability mapping."	Revise SPZ regulation to include karst-specific criteria; introduce vulnerability mapping and risk-based zoning and uniform enforcement, identify all water abstraction springs and establish protection zones
Monitoring & Data systems	Expand karst-specific monitoring; integrate ecological indicators; improve interoperability of national databases	Start karst-specific monitoring; integrate ecological indicators; develop unified methodology for groundwater monitoring establish data platform used by both entities	Start karst-specific monitoring; integrate ecological indicators; develop unified methodology for groundwater monitoring establish data platform used by both entities
Pollution control & MAR regulation	Develop technical guidelines for Managed Aquifer Recharge (MAR) and indirect discharge risk assessment	Introduce detailed risk assessment procedures for indirect discharges; adopt MAR guidelines	Introduce detailed risk assessment procedures for indirect discharges; adopt MAR guidelines
Pollution control from agriculture	Harmonize nitrate/pesticide monitoring protocols; embed vulnerability-based conditions into permits; align CAP eco-schemes with groundwater protection	Standardize karst-specific restrictions and enforcement; link farm subsidies to groundwater protection; adopt joint monitoring parameters for nitrates/pesticides	Introduce karst-sensitive SPZ criteria; codify bans/conditional agrochemical use; harmonize monitoring and remediation standards with HR and FBiH
Integration with spatial planning	Enforce mandatory inclusion of SPZ and vulnerability maps in all spatial plans; strengthen cross-sectoral coordination	Ensure SPZ integration into spatial plans; link groundwater protection to land-use decisions	Mandate SPZ and vulnerability mapping in spatial plans; introduce karst-specific planning criteria; Ensure SPZ integration into spatial plans; link

Legal dimension	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
			groundwater protection to land-use decisions
Economic instruments	Improve implementation of polluter pays and cost recovery; align tariffs with environmental/resource costs	Revise fee system to reflect resource and environmental costs; harmonization among entities	Revise fee system to reflect resource and environmental costs, harmonization among entities
Remediation framework	Adopt dedicated by-law for remediation of contaminated groundwater; enforce SPZ remediation programs	Develop clear procedures for remediation under water and environmental laws; ensure funding mechanisms	Develop clear methodologies and procedures for remediation under water and environmental laws; ensure funding mechanisms

3.Institutioan arrangements

3.1 Institutional Roles and Capacities in Croatia and BiH

The main actors in groundwater governance and management in Croatia operate at multiple levels. At the national level, the Ministry of Environmental Protection and Green Transition (Directorate for Water Management and Sea Protection) and Croatian Waters are responsible for preparing legislation strategic planning, supervision, and implementation of water resource management policies. The Ministry of Environmental Protection and Green Transition is responsible for national water policy, groundwater protection standards, and alignment with EU Water Framework Directive and Groundwater Directive requirements. It sets the regulatory framework that governs groundwater abstraction, protection zones, and monitoring. The Croatian Institute of Public Health – Andrija Štampar Institute and the network of county institutes regularly conduct analyses of drinking water quality. Thay have well-developed laboratory systems for water quality control, yet continuous investment in equipment and staff training remains necessary, particularly in karst and rural regions. Croatian Waters and new Water Institute Josip Juraj Strossmayer possess substantial technical expertise and long-standing experience in planning, monitoring, and managing water resources, though modernization and digitalization efforts are constrained by limited budgets. In Croatia, central technical capacity is strong, but local level implementation is constrained, particularly in relation to agricultural practices and diffuse pollution. Downstream exposure to upstream pressures limits the effectiveness of national measures alone.

The following are the primary institutions at the Neretva TBA territory:

- At the regional and local levels, county and municipal governments in the Dubrovnik Neretva County and Lower Neretva Valley are responsible for spatial planning, local sanitation systems, waste management, and inspection at local level. Their capacity is constrained by limited budgets, fragmented settlements, and high dependence on agricultural water use.

- Public water utilities operate local drinking water systems dependent on groundwater and springs. While operationally competent, they have limited leverage over agricultural practices and upstream transboundary pressures.
- Non-governmental organizations also play important roles in raising awareness and implementing water protection projects.

The state Ministry of Foreign Trade and Economic Relations in Bosnia and Herzegovina has jurisdiction on defining policy, and basic principles, coordinating activities, and harmonizing the plans of entity authorities and institutions at the international level, among others in the fields of agriculture, energy, environmental protection, development and use of natural resources (incl. water) and tourism. The key actors relevant for groundwater management are the entity ministries responsible for water management – the Ministry of Agriculture, Water Management and Forestry (MoAWMF) of the Federation of BiH and the Ministry of Agriculture, Forestry and Water Management of the Republika Srpska. Their tasks delegated to water management sectors includes inter alia the strategic planning and implementation of water-related legislation. MoAWMF is also responsible for the supervision of the performance of the water management agencies/institutions. The entities Water Agencies/ Institution (Agency for watershed area of Adriatic Sea (AVP Jadran) and Agency for watershed area of Sava River (AVP Sava) and Public Institution "Vode Srpske" in RS (PI Vode Srpske) are responsible for overall water management including monitoring, issuing water permits, and planning groundwater protection measures. Within Public Institution 'Vode Srpske', there operates a specialized department responsible for the Trebišnjica River. The entity water agencies/public institution have competent technical staff but, the number of qualified employees is significantly below the level required to meet the expected demands of implementing EU legislation and regulations, to which Bosnia and Herzegovina has committed through its candidate status. Financial resources for managing water resources are very limited, including groundwater monitoring or upgrading / modernisation of databases / Water information systems. Budget allocations have been consistently absent for many years so. Hydrometeorological Institutes focus on meteorological and hydrological activities including monitoring and processing data. The entities' Institutes of Public Health are responsible for monitoring drinking water quality. Entities Geological Institutes contribute by collecting, analysing, and interpreting hydrogeological data essential for assessing groundwater quantity and quality. Generally, in B&H institutional fragmentation reduces operational efficiency. Permitting and enforcement processes are not efficient, and coordination between water, energy, environment, and spatial planning sectors remains weak.

In the Federation of BiH, cantonal ministries play a role in implementing water legislation (issuing water permits for smaller water abstractions and inspections). Public water supply companies are responsible for the abstraction, treatment, and distribution of groundwater for drinking purposes and are also involved in the monitoring and protection of water sources within sanitary protection zones. Municipal utilities face lack of qualified technical staff, chronic under-financing and rely heavily on donor support or loans for capital investment and training. Overall, financial and human resources capacity constraints hinder the systematic integration of groundwater considerations into planning and decision-making (World Bank 2022b; UNESCO-IHP 2024).

Civil society organisations (CZZS, Aarhus Centres, WWF Adria) and research institutions (university in Mostar) influence policy through advocacy and studies.

The following are the primary institutions operating at the Neretva TBA territory:

- Cantonal authorities and Ministries in the Herzegovina Neretva Canton, oversee water and environmental protection, spatial planning, and communal services. Their role is critical for

integrating groundwater considerations into land use decisions but is constrained by limited coordination across sectors.

- Municipal authorities in Konjic, Jablanica, Mostar, and downstream municipalities are responsible for wastewater management, local inspections, and spatial planning. Capacity varies significantly between municipalities, creating uneven levels of groundwater protection.
- Energy authorities and hydropower operators influence groundwater indirectly through river regulation and infrastructure operation. Their mandates are primarily sectoral, with limited integration of groundwater considerations into operational decision making.

3.2. Enforcement Mechanisms and Institutional Capacities

Enforcement mechanisms and institutional capacities for groundwater governance in Croatia and Bosnia and Herzegovina exhibit significant structural and operational differences, with implications for the management of the TBA Neretva. Croatia demonstrates a more centralized and legally coherent system, whereas Bosnia and Herzegovina operates under a decentralised framework shaped by its constitutional arrangement and entity-level autonomy.

In Croatia, enforcement is anchored in the Water Act and supported by a comprehensive set of implementing regulations aligned with EU Water Framework Directive (WFD) and Groundwater Directive (GWD) requirements. Croatian Waters acts as the central implementing authority, complemented by the Ministry of Environmental Protection and Green Transition and the State Inspectorate. These institutions possess clear mandates for issuing permits, monitoring compliance, and imposing sanctions. Enforcement tools include administrative measures, financial penalties, and mandatory remediation programs, integrated into River Basin Management Plans (RBMPs). The system benefits from structured inspection protocols and a relatively stable financing mechanism under the Water Management Financing Act, which ensures cost recovery and supports compliance monitoring. However, operational challenges persist, particularly in rural and karst areas where illegal abstractions and delayed incorporation of sanitary protection zones into spatial plans undermine effectiveness.

Institutional capacity in Croatia is comparatively strong at the national level, with Croatian Waters and specialized institutes demonstrating technical expertise and experience in groundwater management. Financial sustainability is supported through water-related fees and EU funding streams, while human resources are reinforced by structured roles and certification systems. Nonetheless, local-level capacities remain uneven, and enforcement often relies on reactive rather than preventive measures.

In Bosnia and Herzegovina, enforcement is decentralized across entities, cantons, and municipalities, resulting in some cases in overlapping competencies and procedural inconsistencies. Entities' Water Laws provide the legal basis for compliance monitoring and sanctions, but implementation is hindered by chronic understaffing, limited budgets, and weak coordination. Entity water agencies (AVP Sava, AVP Jadran, and PI Vode Srpske) are responsible for permitting and monitoring, while inspectorates conduct inspections and impose penalties. However, enforcement is largely reactive, triggered by complaints or visible violations, and lacks systematic risk-based planning. Financial mechanisms for cost recovery exist in law but are inadequately operationalized; water tariffs fail to incorporate environmental and resource costs.

Institutional capacity constraints in BiH are acute. Technical expertise is concentrated within entity agencies, but staffing levels are insufficient to meet the demands of EU approximation and RBMP implementation. Cantonal and municipal authorities often lack qualified personnel and rely heavily on donor-funded projects for monitoring and infrastructure upgrades. Budgetary allocations for

groundwater protection are minimal, and investment planning is sporadic. These limitations severely restrict the ability to enforce monitoring, sanitary protection zones, monitor abstraction volumes, and control pollution in karst areas.

Both countries share common weaknesses, including insufficient integration of groundwater considerations into spatial planning and sectoral policies, as well as gaps in regulating cumulative pressures from tourism, agriculture, and infrastructure development. However, Croatia's centralized structure and alignment with EU directives provide a stronger foundation for enforcement and institutional strengthening, whereas Bosnia and Herzegovina requires substantial changes to strengthen inter – entity joint planning and resource deficits.

For the Neretva TBA, these disparities translate into practical challenges for harmonized governance. Croatia's enforcement mechanisms, while imperfect, offer a basis for transboundary cooperation, but their effectiveness is limited by uneven local implementation. Bosnia and Herzegovina's decentralised system and weak institutional capacity pose greater risks, necessitating targeted capacity-building, standardized methodologies, and enhanced financing mechanisms

3.3. Cross-sectoral Coordination Mechanisms

At the national level In Croatia, collaboration between the Ministry of Environmental Protection and Green Transition, Croatian Waters, and the Croatian Institute of Public Health occurs regularly through the implementation of the Water Act and the River Basin Management Plan. However, horizontal coordination between sectors, particularly tourism, agriculture, and energy, remains mostly project-based rather than systematically institutionalized. Cooperation between public authorities and non-governmental organizations exists through campaigns and environmental projects but lacks formal mechanisms for participation in policy-making. Overall, inter-agency cooperation is functional but would benefit from stronger cross-sectoral integration and more

At the institutional level, Croatian Waters, the Croatian Institute of Public Health (CIPH), and the Croatian Meteorological and Hydrological Service (DHMZ) exchange data through formal reporting mechanisms under the Water Framework Directive (WFD) and through the national environmental information system. However, data exchange across sectors remains fragmented. The private sector and local utilities often rely on summary reports rather than direct access to raw datasets (e.g., continuous groundwater monitoring series or spatial data on karst aquifers). While inter-agency cooperation is supported by open data initiatives and formal agreements under NIPP and INSPIRE, structured and interoperable data sharing between public authorities, research institutions, and private operators is still limited.

There is no single national data platform integrating all groundwater and groundwater-dependent ecosystem (GWDE) datasets, particularly those relevant to karst regions: technical and organizational differences between institutions (e.g., metadata standards, GIS formats) hinder full interoperability; private entities, including consultants, utilities, and land users, face barriers in accessing detailed or real-time groundwater data.

The practical exchange of groundwater data across institutions and with private stakeholders remains limited, especially for detailed monitoring and karst-related datasets.

In BIH, the horizontal integration with sectors such as agriculture, energy, and spatial planning is modest. Legal mechanisms for cooperation exist in Water Laws and Environmental Laws, but coordination is not regular or systematic. Groundwater protection measures are rarely included in physical plans, irrigation, or land-use policies. Coordination between the water sector and other

sectors - energy, agriculture, planning, health is irregular. It occurs mainly through donor-driven projects such as DIKTAS-2, GCF/UNDP, and World Bank initiatives. No permanent inter-sectoral platform exists to align groundwater management with socio-economic priorities.

Entity water laws reference cooperation between agencies for shared water bodies. In practice, joint planning across entities is not implemented. River basin management plans are prepared separately, despite basins spanning both entities. This division highlights the lack of integrated management.

In FBiH, water agencies provide online data. Available datasets include water levels, water quality, monitoring networks, groundwater cadastre, and GIS maps. These are interactive, regularly updated, and only partly downloadable. The Hydro Meteorological Institute publishes reports ranging from daily bulletins to annual analyses, using data from water agencies' monitoring stations and its own, yet deficiencies lie in the rather slow processing of data, with time lags of up to five years. Data sharing is carried out upon request rather than regularly through established protocols or systematic procedures, resulting in fragmented and inconsistent practice. In RS, water agencies and hydrometeorological institutes collect hydrological and quality data, but dissemination is irregular. Public access is limited to summary reports or project outputs. Raw data on groundwater levels, abstraction, or chemistry are rarely available online. RS maintains time series but does not publish open datasets.

Geological surveys in both entities hold archives on aquifers and karst morphology. Most remain analogue or unpublished. Some datasets have been digitized under donor projects, but continuity is uncertain after projects end.

No unified water information system exists in BIH. Data exchange across entities and sectors is limited. Knowledge-sharing frameworks remain fragmented, preventing integrated understanding of karst aquifers and groundwater-dependent ecosystems eventhou systematisation of data collection, monitoring, and decision-making is required for sustainable groundwater management.

3.4. Observations for the TBA Neretva

Institutional issues further add complexity to governance in both in both countries. Croatia benefits from centralized oversight by Croatian Waters and the Ministry of Environmental Protection and Green Transition, but resource constraints and uneven local capacities limit effective enforcement. Bosnia and Herzegovina relies on decentralized structures, with overlapping competencies among entities, cantons, and municipalities, resulting in slow decision-making and weak compliance monitoring. While both countries recognize the polluter pays and cost recovery principles, Croatia's application of these principles is partial and often contested, and Bosnia and Herzegovina lacks harmonized fee structures and systematic integration of environmental costs into water pricing.

3.5. Summary Tables on institutional arrangements and coordination

Table 5 Summary Table 3.1- Key Institutions and their roles (HR vs BiH)

Institutional Level	Croatia (HR)	Bosna I Hercegovina (BIH
National Ministries	Ministry of Environmental Protection and Green Transition (Directorate for Water Management and Sea Protection). Defines legislation, strategic planning, supervision.	State Ministry of Foreign Trade and Economic Relations (MoFTER). Coordinates policy, principles, and harmonization of entity plans at international level.
Central Water Institutions	Croatian Waters – main technical body for implementation, supervision, permits, monitoring.	**FBiH:** Ministry of Agriculture, Water Management and Forestry; Agencies for Adriatic (AVP Jadran) and Sava (AVP Sava). **RS:** Ministry of Agriculture, Forestry and Water Management; Public Institution "Vode Srpske". Define legislation, strategic planning, supervision at entity level
Specialized Institutes	Croatian Institute of Public Health; Water Institute Josip Juraj Strossmayer; Andrija Štampar Institute; county public health institutes (drinking water quality). DHMZ (hydrology, meteorology).	Entities Geological Institutes (Sarajevo, Zvornik) – hydrogeological data. Entities Hydrometeorological Institutes –monitoring and processing hydrology, meteorology. Entities Institutes of Public Health – drinking water quality monitoring. Universities (Sarajevo, Tuzla, Mostar, Banja Luka) – research and policy input.
Regional / Local Authorities	County public institutions and municipal utilities (e.g., Ličke vode, Dubrovnik, Split, Rijeka). Manage water supply, wastewater, sanitary zones.	Cantonal Ministries in FBIH -Defines legislation, strategic planning, supervision at Cantonal level including specialised institutes for health, spatial planning etc Municipal utilities – abstraction, treatment, distribution of groundwater. Local governments – spatial planning, sanitation, waste management.
Civil Society / NGOs	Green Action, Croatian Water Pollution Control Society, WWF Adria, ZMAG, Rotary Croatia. Awareness, advocacy, projects.	Center for environment protection (CZZS), Aarhus Centres, WWF Adria, local NGOs- Advocacy, awareness, reporting.
NERETVA TBA – Croatia	At the regional and local levels, county and municipal governments in the Dubrovnik Neretva County and Lower Neretva Valley Public water utilities operate local drinking water systems dependent on groundwater and springs. Non-governmental organizations	Cantonal authorities and Ministries in the Herzegovina Neretva Canton, Municipal authorities in Konjic, Jablanica, Mostar, and downstream municipalities Energy authorities and hydropower operators influence groundwater indirectly through river regulation and infrastructure operation.

Table 6 Summary Table 3.2- Institutional Capacities and Enforcement Mechanisms (HR vs BiH)

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	**Republika Srpska (RS)and**
Institutional structure	Centralized: Croatian Waters (implementation), Ministry of Environmental Protection and Green Transition (policy), State Inspectorate (control)	Decentralized: Entity Ministry for Agriculture, Water and Forestry; Entity Water Agencies (AVP Sava, AVP Jadran), Hydro meteoritical Institute, Geology Institute Cantonal ministries; municipal utilities,	Centralized: Entity Ministry for Agriculture, Forestry and Water PI "Vode Srpske"; Hydro meteoritical Institute, Geology Institute municipal utilities

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
Mandates & Competencies	Clear mandates for permitting, compliance monitoring, and sanctions; integrated into RBMPs	Entity and Cantonal level institutions: Planning, permitting monitoring Overlapping competencies among entity and cantonal level, weak coordination municipalities implement local measures	Entity level: Planning, permitting monitoring; municipalities implement local measures; limited coordination
Regulatory authorities (permits, concessions)	Croatian Waters (permits); Ministry of Environmental Protection and Green Transition (concessions)	Water Agencies (AVP Sava, AVP Jadran) – permits for water resources of federal importance; cantonal authorities for permits of local significance; FBIH Government based on FBIH Concession Commissions' proposal in accordance to FBIH Law on concessions and Cantonal Governments based on Cantonal Concession Commissions' proposal	PI "Vode Srpske" for permits (Permits) RS Government based on RS Concession Commission proposal in accordance to RS Law on concessions (Concessions)
Inspection & Compliance monitoring	Structured inspection protocols; proactive and risk-based in theory; enforcement supported by financing mechanisms	Reactive inspections; triggered by complaints; no systematic risk-based planning; understaffed; monitoring mandated but sporadic implementation for GW	Reactive inspections; limited coverage; monitoring focused on drinking water sources, monitoring mandated but weak implementation for GW
Sanctioning tools	Administrative measures, financial penalties, mandatory remediation programs; cost recovery embedded in law	Cost recovery embedded in law, sanctions legally defined but weakly applied; enforcement often delayed	Cost recovery embedded in law, sanctions legally defined but weakly applied; enforcement often delayed
Financial mechanisms for enforcement	Stable financing via Water Management Financing Act; water-related fees support monitoring and compliance	Fee structures exist but insufficient for financing water sector needs; environmental/resource costs not integrated; chronic underfunding	Fee structures exist but insufficient for financing water sector needs; environmental/resource costs not integrated; chronic underfunding
Technical capacity	Strong at national level; EU-funded modernization; karst-specific expertise available	Adequate at entity level, limited technical capacity at lower administrative levels; outdated equipment;	Adequate at entity level, limited technical capacity at lower administrative levels; outdated equipment;

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
Human resources	Adequate at central level; structured roles and certification systems; local-level capacity uneven	Acute shortages at entity and cantonal levels; no systematic training	Shortages at entity and municipal levels; training sporadic
Enforcement & Institutional capacity for sanitary protection zones	Centralized enforcement by Croatian Waters, Ministry and Inspectorate; monitoring relatively strong mandatory but uneven	Enforcement at all levels weak;many municipalities lack formal decisions on SPZ	Centralized at entity level; Enforcement weak; monitoring minimal

Table 7 Summary table 3.3-Cross-sectoral Coordination and Opportunities for Harmonization (HR vs BiH)

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
National-level coordination	Strong at national level; weak horizontal integration with sectors (agriculture, tourism, energy); local enforcement uneven Regular collaboration between Ministry of Environmental Protection, Croatian Waters, and Public Health Institute under Water Act and RBMP. Horizontal coordination with tourism, agriculture, energy mostly project-based, not institutionalized. NGOs involved via campaigns, but no formal policy-making role.	MoFTER responsible for coordination and harmonization of entities activities. Slow and often inefficient coordination. Coordinated planning across entities not implemented, RBMP prepared separately withought cooperation, despite shared basins	
Institutional-level coordination	Croatian Waters, CIPH, and DHMZ exchange data via WFD reporting and national environmental information system. Supported by NIPP and INSPIRE.	Highly fragmented - overlapping competencies among entities, cantons, municipalities Legal mechanisms exist in Water and Environmental Laws, but coordination irregular. Horizontal integration with agriculture, energy, spatial planning modest. Cooperation mainly donor-driven (DIKTAS-2, GCF/UNDP, World Bank). No	Centralized at entity level; Horizontal integration with agriculture, energy, spatial planning minimal and occurs mainly through donor driven projects Entity water Laws reference cooperative planning for shared basins, but not implemented.

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
		permanent inter-sectoral platform. Entity water Law reference cooperative planning for shared basins, but not implemented.	
Data sharing – public authorities	Formal reporting mechanisms exist. Fragmentation across sectors persists. No single national platform integrating all GW/GWDE datasets. Metadata and GIS differences hinder interoperability.	Data exchange across entities limited. Knowledge sharing across entities limited preventing integrated understanding of karst aquifers and groundwater dependent ecosystems Water Agencies provide online datasets (levels, quality, cadastre, GIS maps), partly downloadable. Geological surveys hold analogue archives, digitization limited.	Data exchange across entities limited. Knowledge sharing across entities limited preventing integrated understanding of karst aquifers and groundwater dependent ecosystems PI collect hydrological and quality data, dissemination irregular, raw datasets rarely accessible.
Data sharing – private sector & stakeholders	Private sector and utilities rely on summary reports, not raw datasets. Barriers to accessing detailed or real-time GW data.	Public access limited to some interactive datasets available. Private stakeholders face barriers.	Public access limited to summary reports only. Private stakeholders face barriers.
Unified information system	Absent. No integrated national platform for GW/GWDE, especially karst.	Absent. No unified WIS across entities. Fragmented knowledge-sharing frameworks prevent integrated understanding of karst aquifers and GWDE.	
Opportunities for Harmonization	Strengthen horizontal integration with agriculture, tourism, and energy sectors; formalize inter-sectoral platforms	Propose changes to establish clear division of responsibilities and avoid overlapping between entities and cantons responsibilities Establish formal systematic inter-entity coordination, planning and data sharing mechanism	Improve coordination between PI Vode Srpske and other sectors Establish formal systematic inter-entity coordination, planning and data sharing mechanism

4. Policy and Planning Framework – TBA Neretva (Croatia and BiH)

4.1 National Water Strategies and River Basin Management Plans

The Croatian Water Management Strategy of 2008 highlights the importance of protecting groundwater, particularly in karst regions where aquifers are highly vulnerable to pollution and essential for drinking water supply. The document follows European directives and the precautionary principle, stressing the need to reduce pollution from point and diffuse sources and to strengthen monitoring systems. Pursuant to the objectives set forth in Strategy delineation and establishment of sanitary protection zones around well fields and springs and appropriate protective measures will need to be undertaken. It highlights the need for tailored technical solutions and stricter measures in karst areas due to rapid groundwater flow and limited natural filtration. The Strategy also foresees harmonization of monitoring networks, adoption of new technical standards, implementation of automated data collection and transmission systems. A key component is the integration of water quality indicators into national databases and the establishment of regular reporting mechanisms, such as annual water status reports and six-year river basin management plans Although it recognizes the hydrogeological complexity of karst, it does not explicitly define measures for groundwater-dependent ecosystems, but however, it does propose the adaptation of monitoring programs to protected and sensitive zones, which implicitly includes karst systems.

The Croatian National Development Strategy until 2030 integrates environmental sustainability and resource protection across several strategic goals, yet it does not explicitly address groundwater or groundwater-dependent ecosystems. While it emphasizes ecological transition, climate neutrality, and sustainable resource management, groundwater remains outside the focus, with no concrete measures for its protection.

The Croatian River Basin Management Plan until 2027 provides the most detailed framework for groundwater. Aquifers are delineated according to hydrogeological criteria, and both quantitative and chemical status are assessed. The plan is aligned with the EU Groundwater Directive, prohibits direct discharges into groundwater, and addresses the vulnerability of coastal aquifers to salinization in karst regions. Groundwater-dependent ecosystems are explicitly considered, and monitoring programs are expanded to detect changes in groundwater levels and quality, especially near sensitive habitats. Attention is given to karst, with precise measures and monitoring protocols incorporating statistical trend analyses and background levels of sulphates, chlorides, and electrical conductivity. The plan acknowledges the unique dynamics of the Dinaric karst - rapid flows, short residence times, and episodic turbidity - and introduces an environmental connectivity test to ensure that groundwater abstraction does not negatively affect surface waters or terrestrial ecosystems. It also establishes the Surface Water Test, which evaluates groundwater chemical status in relation to its impact on connected surface waters. Integrated monitoring is achieved through harmonized sampling protocols, shared parameters, and coordinated stations, while common protection goals combine chemical and quantitative criteria for groundwater with ecological and chemical criteria for surface waters, fully aligned with the EU Water Framework Directive.

In conclusion, Croatian documents show varying degrees of inclusion of groundwater. The Water Management Strategy provides a strong framework for karst aquifers and monitoring, the National Development Strategy largely overlooks groundwater, while the River Basin Management Plan offers the most comprehensive and integrated approach, with special emphasis on karst, monitoring, and connectivity tests between groundwater and surface waters.

Water Management Strategy of FBiH (2022–2032) sets high-level objectives such as protecting water quality and ensuring good status of water bodies, ensuring sustainable use of resources, safeguarding drinking water, managing risks from extreme events, and adapting to climate change. It identifies measures to align water management with EU directives. It establishes the intensification of cooperation between the water sector and other sectors as a priority for ensuring the protection and sustainable use of water resources. However, it is noted that situation with groundwater monitoring is complex, since in the Sava River Basin there is not enough stations, and at the existing stations quality monitoring was only initiated in 2020. In the Adriatic Sea Basin, quantitative monitoring has not been established at all karst springs used for water supply. Strategy does not define groundwater-dependent ecosystems (GWDE), nor does it propose ecological criteria for their protection. It recognizes that karst covers a significant part of the territory, particularly within the Adriatic basin, but leaves it insufficiently addressed. For a significant number of water springs in FBIH, including karst springs, protection zone studies have not been prepared in accordance with the current valid Regulation. Implementation of measures for drinking water protection zones are mostly insufficient or absent.

RS Integrated Water Management Strategy (2014–2025) also highlights groundwater as strategically important, proposing monitoring improvements, protection of infiltration zones, and creation of a centralized groundwater database. It includes measures to strengthen inspection and control of wastewater discharges into subsurface systems. Yet, like the FBiH strategy, it does not define GWDE or provide specific measures for their protection. References to EU directives are present, but concrete compliance measures for groundwater and karst aquifers are absent. Ecological modelling and site-specific protection of sensitive aquifers, particularly karst systems, are not included. Based on information from “Environmental strategy and Action Plan for RS 2023-2033” (ESAP), groundwater monitoring has been focused on checking the quality of groundwater used for water supply, while systematic monitoring requires significantly greater financial investments than currently available, both in infrastructure and on an annual basis for ongoing activities. For the groundwater body groups (GWBGs), a risk assessment was carried out regarding the non-attainment of environmental protection objectives due to quantitative and qualitative pressures. The existing legislation related to the establishment of sanitary protection zones around drinking water sources has not been fully implemented.

River Basin Management Plans (RBMPs) prepared in both entities provide more detailed elaboration on groundwater. In FBiH, the third cycle of RBMPs for Sava river basin and Adriatic river basin (2027–2032) are under preparation, while in RS the second cycle of RBMPs for Sava river basin and Adriatic river basin are ongoing.

All RBMPs define and delineate groundwater bodies and include monitoring, but implementation varies. In FBiH, the Sava RBMP initiated systematic quantitative groundwater monitoring for certain GWBs in 2019, and qualitative monitoring in 2020, while monitoring in the karst area, which represents the largest part of the Adriatic Sea river basin in the FBIH, is carried out by measuring flow at major springs or at immediately associated downstream watercourses. Both RS RBMPs mention groundwater monitoring, but they do not comprehensively assess chemical and quantitative status. Across all RBMPs, coverage needs expansion, data quality improvement, and integration of ecological considerations, particularly in karst areas.

The entities’ RBMPs reflect principles of the EU Water Framework Directive and partially align with the Groundwater Directive. They address pollution from point and diffuse sources, over-abstraction, and pressures on drinking water sources. Karst aquifers are acknowledged as highly vulnerable due to

rapid flow and limited natural filtration. However, GWDE are not explicitly defined, and no targeted measures for karst systems are provided beyond general monitoring and pollution control. Ecological connectivity tests or modelling tools to assess impacts on surface water or terrestrial ecosystems dependent on groundwater are absent.

Entity-specific challenges are noted. In FBiH, urban wastewater, industrial discharges, dumping sites and utilization of water potential – non-compliance with provisions on releasing the environmental flow at small hydropower plants, are identified as major pressures. Cumulative impacts from tourism in coastal karst zones and diffuse agricultural pollution are not comprehensively addressed. In the Sava River Basin exist over 200 springs and in the Adriatic Sea Basin over 70 springs. For a significant number of drinking water springs in the Federation of Bosnia and Herzegovina, protection zone studies have not been prepared, or were prepared under earlier regulations and have not been harmonized with the currently valid Regulation. In RS, the RBMPs highlights nitrate contamination and abstraction stress, sets threshold values and background concentrations for pollutants, and identifies protected zones around drinking water sources.

4.2 Integration of Groundwater into Relevant Sectoral Policies and Planning Instruments

Groundwater management in Croatia is formally anchored in the Water Act and the River Basin Management Plan (RBMP) until 2027, which establish vertical coordination between national, regional, and local levels. These instruments define strategic objectives for monitoring, source protection, and compliance with EU directives. They represent the most developed planning tools for groundwater, ensuring systematic integration into water resource governance.

The Water Management Strategy of Croatia (2008) is formally presented as a framework for coordinating sectoral strategies, including those related to agriculture, environment, tourism, traffic, and energy. It is partially harmonized with these sectors, with alignment most evident in strategic documents such as the Agriculture Strategy of the Republic of Croatia until 2030 and the Spatial Development Strategy of the Republic of Croatia.

Beyond the water sector, integration into other planning instruments remains partial.

The Agriculture Strategy of the Republic of Croatia until 2030 is focused on sustainable water use in agricultural production. It promotes improved access to irrigation and increased efficiency in water use, particularly in karst areas where groundwater is the main source. However, sustainability criteria for groundwater abstraction are not systematically included, leaving risks of over-abstraction and nitrate pollution. The strategy supports environmentally friendly practices and encourages the transition to organic farming, which indirectly contributes to reducing groundwater pollution from agrochemicals. Strategy addresses irrigation and pollution control in line with the EU Nitrates Directive.

Croatian Spatial planning laws recognize water protection zones and sanitary areas, yet groundwater vulnerability is not consistently mapped or embedded into broader land-use decisions. Croatian Spatial Development Strategy promotes integrated land use planning that considers hydrogeological characteristics. It recognizes groundwater as a strategic natural resource and emphasizes its protection within the broader framework of sustainable spatial planning. It highlights that nearly 90% of water used for public supply is abstracted from aquifers, supports the delineation of sanitary protection zones around springs, yet underscoring the importance of safeguarding groundwater reserves, especially in karst regions. However, while groundwater is acknowledged as critical, the

strategy does not provide operational mechanisms for its protection across all sectors, relying instead on alignment with environmental legislation and planning instruments

The Sustainable Tourism Development Strategy of the Republic of Croatia until 2030 emphasizes the importance of preserving natural resources as part of its broader environmental goals. It emphasizes water supply and wastewater infrastructure in coastal areas, reflecting seasonal demands. Tourism strategies recognise negative impacts of tourism on the environment and promotes sustainable spatial planning and infrastructure development to mitigate risks, particularly in ecologically sensitive areas such as karst terrains. It highlights the value of karst landscapes and natural resources but lack operational mechanisms for aquifer protection or water-balance monitoring.

Transport Development Strategy of the Republic of Croatia (2017–2030) emphasizes the need for environmentally responsible planning and implementation of transport infrastructure, particularly in karst. It mandates Environmental Impact Assessments (SEIA) for all major projects, ensuring that groundwater protection is integrated into transport development.

The Energy Development Strategy of the Republic of Croatia until 2030 with an outlook to 2050, together with the Revised National Energy and Climate Plan (NECP), promotes sustainable energy development but only indirectly addresses groundwater protection. It recognizes the strategic role of hydropower and calls for alignment with bilateral agreements for transboundary projects. Energy planning emphasizes hydropower development, but groundwater is considered only indirectly, mainly in relation to dam stability rather than aquifer dynamics.

The health sector provides the most direct planning link to groundwater through regular drinking water quality monitoring conducted by national and county public health institutes. This ensures public safety but does not extend to broader aquifer protection.

Environmental strategies include groundwater within general objectives of resource protection, yet they omit specific indicators for groundwater-dependent ecosystems (GWDE).

The National Development Strategy of the Republic of Croatia until 2030 emphasizes green and digital transitions, climate neutrality, and sustainable resource management, particularly under Strategic Goal 8: "Ecological and energy transition for climate neutrality" and Strategic Goal 9: "Food self-sufficiency and development of the bioeconomy". It acknowledges the importance of integrated planning and cross-sectoral coordination

Overall, Croatia demonstrates strong integration of groundwater within water-sector planning instruments, but cross-sectoral incorporation remains fragmented. Groundwater is acknowledged in agriculture, energy, tourism, spatial planning, and health, yet often without explicit safeguards or measurable targets. Strengthening inter-sectoral coordination, embedding groundwater sustainability criteria into sectoral policies, and expanding public awareness are essential steps to achieve comprehensive integration of groundwater into national planning instruments.

Groundwater planning in Bosnia and Herzegovina is primarily framed through the River Basin Management Plans (RBMPs) prepared in both entities. These plans delineate groundwater bodies and establish monitoring, but implementation varies. Coverage of GW chemical and quantitative status remains weak and ecological considerations -particularly for vulnerable karst areas - are limited. Although RBMPs reflect EU Water Framework Directive principles and partially align with the Groundwater Directive, they do not explicitly define groundwater-dependent ecosystems (GWDE) or include targeted legal instruments for their protection. Karst aquifers are acknowledged as vulnerable,

but measures remain general, focusing on pollution control and source protection without ecological modelling or connectivity tests.

Entities Agricultural Development Strategies (2021–2027) promote irrigation expansion without groundwater-sustainability criteria, risking over-abstraction in semi-arid karst zones such as Popovo Polje. FBIH Agricultural Strategy emphasizes the importance of Green Agenda and related Action Plan for medium-term strategic planning of agricultural development in FBiH, in the context of climate change. Agricultural policies include nutrient and pesticide management, but irrigation subsidies and fertilizer-use policies are not linked to groundwater-quality monitoring, raising risks of over-abstraction and nitrate pollution.

Spatial planning strategies recognize karst landscapes as valuable assets but lack mechanisms for aquifer protection or water balance monitoring. It addresses groundwater mainly through source-protection zones, often unenforced. Groundwater vulnerability is not consistently mapped or embedded into land-use decisions.

Tourism strategies in karst regions (Trebinje, Mostar, Livno) adopt sustainability principles but lack hydrogeological data or water-balance monitoring. Tourism strategies recognize karst landscapes as valuable assets but lack mechanisms for aquifer protection or water-balance monitoring. FBIH tourism strategy highlights that legislation in FBiH includes specific environmental requirements, but coordination among relevant actors is lacking. Achievement of sustainable tourism requires efficient use of water and energy, use of recycled products in accommodation facilities, and introduction of environmentally friendly labels.

Transport-infrastructure policy considers hydrological impacts only through project-level EIAs, not strategy.

Energy strategies recognize groundwater / karstic and groundwater dependent ecosystems (GWDE), yet without measurable targets or budgetary commitments. Energy planning considers groundwater only in context of hydropower licensing and in relation to dam seepage rather than aquifer dynamics.

Public health regulations focus narrowly on drinking water quality at the source, without extending to aquifer protection.

In Environmental strategies groundwater / karstic and groundwater dependent ecosystems (GWDE) are mentioned, but without measurable targets or budgetary commitments. Entities Environmental Protection Strategies and Action Plans – ESAP (RS 2022; FBiH 2023) introduce integrated resource-management principles. Thay aim to reduce pollution and protect natural resources but omit specific groundwater indicators and do not mainstream GWDE.

Overall, sectoral alignment is moderate, constrained by administrative fragmentation and the absence of a unified national framework linking water, agriculture, environment, and spatial planning. Bosnia and Herzegovina acknowledges the importance of groundwater but does not systematically integrate it into sectoral planning instruments. RBMPs provide the most structured framework yet remain limited in scope and ecological depth. Other sectors - agriculture, energy, tourism, spatial planning, and health - address groundwater only indirectly, often through project-based initiatives or donor-driven programs.

In BIH's both entities FBIH and RS, horizontal integration between water policies and agriculture, energy, and spatial planning remains limited. Groundwater protection measures are rarely incorporated into physical plans, irrigation, or land use policies. Strengthening cross-sectoral

coordination, embedding groundwater sustainability criteria into sectoral policies and developing targeted instruments for karst and GWDE are essential steps toward effective integration of groundwater in sectoral planning frameworks.

4.3 Comparative Analysis of Policy Coherence and Implementation

4.3.1 Alignment with EU WFD and GWD

The Water Management Strategy of Croatia aligns closely with WFD and GWD. It adopts the WFD goal of "good status" for all waters, integrating ecological and chemical criteria. It emphasizes sustainable use via integrated river basin management, applies the "polluter pays" principle, and introduces water pricing and cost recovery (Art. 9 WFD). Groundwater protection is ensured through monitoring, delineation of protection zones, and control of hazardous substances (GWD). The Strategy supports cross-sectoral coordination, public participation, monitoring, reporting, and adaptive management. It mirrors WFD's long-term planning with dual 15-year investment cycles to 2038, prioritizes aquifer protection, and strengthens institutional capacity for groundwater monitoring. Integration into spatial planning, environment, agriculture, energy, and tourism reflects WFD's call for embedding water policy in broader frameworks.

National methodology in RBMP 2027 defines background concentrations and threshold values tailored to karst hydrogeology, using BRIDGE project and CIS Guidance No. 18. Classification tests include saline intrusion, surface water interaction, and terrestrial ecosystem impacts, as outlined in CIS Guidance. Precautionary principle is explicitly applied in threshold setting, especially for drinking water zones and sensitive ecosystems. Monitoring in karst includes specific parameters (nitrates, chlorides, ammonium, EC, phosphates) as indicators of anthropogenic impact.

The framework for drinking water abstraction in Croatian shows ambiguity. The Water Act and RBMP recognize sanitary protection zones, but not full designation of groundwater bodies as required by WFD. Protection relies on sanitary zones, leaving the relationship with groundwater bodies undefined. Chemical status assessment includes the DWPA test, checking thresholds and pollutant trends. Strategic groundwater reserves are designated under WMS as protected areas but not fully integrated into the WFD concept. Overall, Croatia emphasizes sanitary zones but falls short of fully aligning with WFD's requirement to designate entire groundwater bodies for drinking water abstraction.

Transposition of the WFD in BiH is uneven: FBiH has achieved about 95%, RS about 75%. Both entity Water Laws include WFD principles such as integrated basin management, groundwater status assessment, pollution prevention, and ecological flow. The GWD transposition is weak, below 30%, with no dedicated regulation; only partial implementation of chemical status, pollution prevention, trend reversal, and threshold values.

In FBiH, the Water Law reflects WFD objectives. The Rulebook on Monitoring of Surface and Groundwater defines parameters and frequency for chemical and quantitative monitoring. The Rulebook on Classification of Water Bodies sets criteria for status assessment and threshold values, partly aligned with GWD. In RS, the Water Law also incorporates WFD principles. The Rulebook on Monitoring of Water Quality establishes sampling and reporting procedures, while the Rulebook on Classification of Water Bodies defines groundwater status categories and threshold values, again partial GWD alignment.

GWDEs are not defined in water laws. In FBiH, the Environmental Protection Law requires EIAs to consider wetlands and springs. In RS, sensitive ecosystems are addressed in permitting, but GWDEs are not explicitly integrated. The FBiH Water Strategy (2022–2032) aligns with the WFD through water

quality protection, basin planning, pollution control, and monitoring, but lacks ecological criteria for groundwater and omits GWDEs. Economic instruments are mentioned but not applied. The RS Water Strategy (2014–2025) supports WFD goals of pollution reduction and monitoring, but lacks methodological definition of ecological status, classification of water bodies, and GWDE protection. Basin planning and economic tools are underdeveloped. The RS Environmental Protection Strategy (2022–2032) conceptually reflects WFD principles but lacks implementation instruments.

Groundwater quality standards and thresholds are only partly developed. A national methodology exists, incorporating karst characteristics, but full GWD requirements are not met. Standards cover chemical status and EU pollutant limits, with some national provisions, but monitoring and published criteria remain incomplete.

Drinking water abstraction areas are defined through sanitary protection zones in both entities, not through designation of entire groundwater bodies as required by WFD. FBiH defines zones in three or four levels based on vulnerability; RS applies zones around abstraction points with hydrogeological assessments. Neither entity links zones to groundwater body boundaries nor assesses chemical status across whole bodies. Strategic reserves are not formally defined. Reliance on sanitary zones creates a gap with WFD's framework for protected areas.

4.3.2. Transboundary Planning Instrument in the Context of Natura 2000 and Nature Protection s for TBA Neretva

In addition to RBMPs that define water resource management, relevant transboundary planning instruments include also those regulating nature protection.

Croatian Natura 2000 network was established by the Regulation on Ecological Network (2013). It preserves or restores favourable conditions for more than 1,000 endangered species and about 230 habitat types. Croatia's network covers 36.67% of land and 16.39% of the sea.

For Bosnia and Herzegovina, an analysis of the distribution of habitat types and species listed in these directives was carried out in BIH, through the IPA project "Support to the Implementation of the Birds and Habitats Directives in BiH (2012–2015)". A total of 70 different habitat types and 208 species were recorded, including 109 bird species. A database in standard formats was also created (UNECE 2018). A draft plan for the Natura 2000 ecological network in BiH was prepared. In total, 122 areas were proposed, covering 956,776 ha, about 20% of the state territory (Milanović and Golob, 2015). The project represents one step toward establishing the ecological network of FBiH which requires further multiple activities.

Alongside harmonization of sectoral regulations with EU law, identification of other ecologically significant areas (water protection zones, hunting and fishing areas, etc.) is also necessary, and their inclusion in the ecological network of the FBIH. To align with EU nature protection standards, it is necessary to include protected areas and other ecologically significant sites in a common ecological network, as prescribed by the Law on Nature Protection of the FBIH.

The results of the IPA project were integrated into the Spatial Plan of RS. Article 25 of the RS Nature Protection Law requires a regulation to establish the ecological network, define management and financing, and identify EU ecological areas for Natura 2000. Ecological network of RS is not yet established. Article 100 of the Law states international ecological areas will be defined upon BiH's accession to the EU.

For Croatia and BIH, international collaboration in the water sector constitutes the foundation of transboundary planning. Republic of Croatia and BIH are a contracting party to many international conventions and protocols. (*Chapter 2.1 and Table 11)*

4.4. Summary Tables: Policy and Planning Comparison – HR vs BiH

Table 8 Summary Table 4.1 -National Water Strategies and River Basin Management Plans

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
Water Management Strategy	2008. Strong focus on groundwater protection, especially karst. Precautionary principle. Sanitary zones required. Harmonization of monitoring networks, automated data collection. No explicit GWDE measures.	**(2022–2032):** General objectives aligned with EU directives. Groundwater monitoring weak (Sava basin started 2019/2020; Adriatic basin lacks quantitative monitoring). Karst insufficiently addressed. Protection zones mostly absent or outdated. No GWDE defined.	Groundwater proposes monitoring improvements and database. No GWDE defined. Weak compliance with EU directives. Sanitary zones not fully implemented.
River Basin Management Plans (RBMPs)			
General characteristic	Most detailed planning framework. Aquifers delineated by hydrogeology. Quantitative and chemical status assessed. Aligned with WFD/GWD. Explicit GWDE consideration. Special measures for karst (trend analyses, background levels, connectivity tests). Integrated monitoring and reporting.	Most detailed planning framework Third cycle RBMPs (2027–2032) under preparation. Partially aligned with WFD. GW bodies monitoring started 2019–2020 only in FBIH Sava river basin .. GWDE not considered.	S Most detailed planning framework Second cycle RBMPs ongoing. Partially aligned with WFD. Monitoring mentioned but not comprehensive. GWDE not defined, karst measures general only., GW bodies monitoring not present.
Karst Aquifers in RBMP	Recognized as highly vulnerable. Tailored technical solutions, stricter measures. Connectivity tests between groundwater and surface waters.	Elaborated and recognized as significant but insufficiently addressed. Monitoring gaps, lack of ecological modelling. No connectivity tests. Karst monitoring limited to spring flows- only in FBIH Sava River basin started systematic GW monitoring.	
Sanitary Protection Zones in RBMP	Framework established. Required around well fields and springs. Not included the whole water body.	Elaborated - many springs lack updated protection zone studies. Not encompass the whole water body	Required around well fields and springs. Not encompass the whole water body Many springs lack updated protection zone studies.
Monitoring & Data	Harmonized networks, automated systems, national databases, annual reports.	Started systematic GW bodies monitoring in 2019 and 2020 in the Sava RB. In Adriatic RB monitoring limited to supply sources. No annual reports.	Monitoring limited to supply sources. Infrastructure and funding insufficient. No database. No annual reports
Groundwater-Dependent Ecosystems (GWDE)	Not explicitly defined in the strategies but implicitly included in	Not defined in RBMPs. No ecological criteria or targeted measures.	

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
	monitoring programs. Explicitly considered in RBMP.		

Table 9 Summary Table 4.2 Groundwater integration in Relevant Sectoral Policies and Planning Instruments

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
Water Management Strategy and RBMP	Framework for coordinating agriculture, environment, tourism, traffic, energy. Strong focus on groundwater, karst protection, sanitary zones, monitoring. Clear objectives for monitoring, source protection, EU compliance. Karst aquifers addressed with specific measures. GWDE considered.	General objectives aligned with EU directives. Groundwater monitoring weak, karst insufficiently addressed, protection zones mostly not designed or implemented. Based on water Laws, RBMPs in both entities delineate GW bodies, but monitoring weak. Karst acknowledged but measures general. GWDE not defined. Implementation of RBM fragmented between entities.	
Agriculture Strategy	Strategy promotes sustainable water use irrigation efficiency, pollution control (Nitrates Directive). Sustainability criteria for abstraction not systematic. Organic farming indirectly reduces pollution. Recognizes groundwater as main source in karst.	Strategies promote irrigation expansion without GW safeguards. Fertilizer/pesticide use not linked to GW monitoring. Risk of over-abstraction and nitrate pollution. Promote irrigation expansion without groundwater sustainability criteria. Risk of over-abstraction in karst (e.g., Popovo Polje). FBiH emphasizes Green Agenda but lacks groundwater safeguards.	
Spatial Development Strategy	Recognizes groundwater as strategic resource. Nearly 90% of public supply from aquifers. Recognizes sanitary zones and aquifers. Promotes integrated land use planning. Vulnerability mapping incomplete; no operational mechanisms.	Spatial planning strategies recognize karst landscapes but lack aquifer protection mechanisms. Vulnerability not mapped. Water source zones often unenforced. Source zones, often not included	
Tourism Strategy	Preserves natural resources. Focus on water supply and wastewater infrastructure in coastal areas. Seasonal demand considered. Strategy until 2030 highlights karst landscapes. Promotes sustainable planning and infrastructure. No operational aquifer protection or water-balance monitoring.	Tourism strategies highlight karst as asset. Sustainable tourism goals mention efficient water use but no aquifer protection Tourism strategies in karst regions adopt sustainability principles. Lack hydrogeological data and water-balance monitoring. GW protection absent. FBiH includes environmental requirements but lacks coordination	
Energy Strategy	Recognizes hydropower. Calls for alignment with bilateral agreements on transboundary projects. Hydropower emphasized. GW considered indirectly (dam stability). NECP promotes sustainability but no direct GW protection.	Energy strategies mention groundwater and GWDE but without measurable targets or budgets. GW only in hydropower licensing, focused on seepage. No aquifer dynamics considered. No measurable targets for GW protection.	
National Development Strategy	Integrates sustainability, climate neutrality, resource management. Emphasizes	No equivalent national strategy	

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)and
	cross-sectoral coordination. Groundwater not explicitly addressed.		
Transport Strategy	Emphasizes environmentally responsible planning, especially in karst areas SEIA mandated for major projects. GW protection integrated into project assessments.	Transport policies consider hydrological impacts only through project-level EIAs, not strategic planning. Transport policies consider hydrological impacts only through project-level EIAs, not strategic planning. Hydrological impacts considered only via project-level EIAs. No strategic GW integration.	
Health	Direct link: drinking water quality monitoring by public health institutes. Ensures safety but not aquifer protection.	Focus on drinking water quality at source. No broader aquifer protection.	
Environmental Protection Strategies (ESAP)	Integrated resource management principles. Groundwater indirectly included via WFD/GWD alignment. Include GW in general resource protection. No specific GWDE indicators. ESAPs mention integrated resource management. GW indicators absent. GWDE not mainstreamed.	Introduce integrated resource management but lack of groundwater indicators. GWDE mentioned but no measurable targets Entities' ESAPs (Environmental Strategies and Action Plans) mention integrated resource management. GW indicators absent. GWDE not mainstreamed. .	

Table 10 Summary Table 4.3.1 Alignment with EU WFD and GWD

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Transposition of WFD	Fully transposed into national law. Annex II & V implemented. Strong compliance.	FBiH ~95% transposed,	~75%. principles included but gaps remain.
Transposition of GWD	Fully transposed. Annex I implemented. Standards operationalized.	Weak (<30%). No dedicated regulation. Partial implementation only.	
Water Act / Legal Basis	Provides full legal basis for GW standards, pollutant thresholds, monitoring.	Sanitary zones recognized. GW bodies not fully designated as required by WFD. Strategic reserves defined but not fully integrated.	Entity Water Laws include WFD principles. Rulebook not aligned with GWD
Groundwater Quality Standards	Regulation defines chemical status, risks, thresholds. National methodology tailored to karst. Precautionary principle applied.	Methodology exists but incomplete. Standards partly developed. Monitoring and published criteria insufficient.	

Aspect	Croatia (HR)	Bosna I Hercegovina (BIH)	
		Federation of BiH (FBiH)	Republika Srpska (RS)
Monitoring & Classification	Systematic monitoring. RBMP defines background concentrations, saline intrusion, connectivity tests. Karst-specific parameters included.	FBiH started systematic monitoring only in 2019–2020.	Monitoring limited. No ecological connectivity tests.
Groundwater-Dependent Ecosystems (GWDE)	Considered in RBMP. Not explicitly defined in strategy but implicitly included.	Not defined in water laws or strategies. Environmental laws mention wetlands/springs but no systematic integration.	
River Basin Management Plans (RBMPs)	Fully aligned with WFD/GWD. Integrated monitoring, ecological and chemical criteria. Special focus on karst.	Reflect WFD principles, partial GWD alignment. GW bodies delineated but monitoring starts in 2019 only in FBIH Sava Reiver Basin. Karst measures general only.	
Drinking Water Abstraction	Sanitary zones recognized. GW bodies not fully designated as required by WFD. Strategic reserves defined but not fully integrated.	Sanitary zones recognized but not implemented in many localities. GW bodies not fully designated as required by WFD. Strategic reserves not defined. No linkage to chemical status.	
Economic Instruments	"Polluter pays" principle, water pricing, cost recovery applied.	Mentioned in strategies but not operationalized.	
Cross-Sectoral Integration	Water policy embedded in spatial planning, agriculture, tourism, energy. Public participation and adaptive management included.	Weak. Horizontal integration modest. GW rarely incorporated into agriculture, energy, or spatial planning. Coordination in and between entities missing.	

Table 11 Summary Table 4.3.2 Transboundary Planning Instruments for TBA Neretva

Transboundary Instrument	Croatia (HR)	Bosnia and Herzegovina (BiH)
Natura 2000 / Ecological Network	Established by Regulation on Ecological Network (2013). Covers 36.67% of land and 16.39% of sea. Protects >1,000 species and ~230 habitat types. Fully operational.	IPA project (2012–2015) identified 70 habitat types and 208 species (109 birds). Draft plan prepared: 122 areas, 956,776 ha (~20% territory). FBiH requires further activities; RS ecological network not yet established. Full implementation pending EU accession.
(	Party to: Water (Helsinki) Convention (1992), Protocol on Water and Health, Danube Convention (1994, ratified 1996), Framework Agreement on Sava River Basin (2002, ratified 2003), Barcelona Convention (1976, revised 1995), Athens Protocol (1980, revised 1995), Convention on Transboundary Effects of Industrial Accidents (1992). Active in Adriatic Ionian Initiative (2000). Member of Joint Commission for Adriatic Waters (1977).	Contracting party to same frameworks: Helsinki Convention, Danube Convention, Framework Agreement on Sava River Basin, Barcelona Convention and protocols. Member of Adriatic Ionian Initiative and ISRBC (2006).

5. Socio-economic Indicators and Pressures – TBA Neretva

5.1 Demographic Characteristics and Settlement Structure of the TBA Neretva

Demographic characteristics within the TBA Neretva play a central role in shaping groundwater demand, sanitation pressures and long-term adaptive capacity. Population size, spatial distribution of settlements and demographic trends determine both the scale and localization of groundwater

abstraction, wastewater generation and diffuse pollution pathways in a highly vulnerable karst environment.

The TBA Neretva is characterized by a mixed settlement structure, combining small urban centres, semi-urban zones and many rural and dispersed settlements. These are predominantly located within karst fields, valleys and foothill zones that function as key groundwater recharge and discharge areas. As a result, even moderate demographic pressures can translate into disproportionately high impacts on groundwater systems.

Population estimates presented in this section are derived from DIKTAS Phase I documentation, national census data (2011–2021) and GIS-based analysis of the transboundary aquifer boundary, supplemented by expert judgement to account for temporal changes and partial overlap between administrative units and the TBA. Figures are therefore expressed as indicative ranges, suitable for aquifer-scale socio-economic assessment rather than precise administrative accounting.

5.1.1 Croatia

The Croatian part of the TBA Neretva encompasses the Imotski and Vrgorac together with few municipalities' karst area, including the urban centre of Imotski and surrounding rural settlements located within or adjacent to the Imotski field. GIS-based delineation of the aquifer boundary indicates that only a portion of the administrative territory of the City of Vrgorac, City of Metković and neighboring municipalities falls within the TBA, necessitating an adjustment of census-based population figures.

Based on spatial analysis and demographic data, the permanent population residing within the Croatian part of the TBA Neretva is estimated at 15 000 - 20 000 inhabitants. Settlement density is moderate in the urban core and low in surrounding rural areas, with a dispersed settlement pattern typical of karst regions.

Demographic trends over the last decade indicate population decline and pronounced ageing, consistent with broader patterns observed in Dalmatinska zagora. Census data show a reduction in total population between 2011 and 2021, accompanied by an increasing share of elderly residents and a shrinking working-age population. These trends have direct implications for groundwater management, as ageing and depopulating communities often rely on decentralised water supply and sanitation systems with limited capacity for maintenance and upgrading.

Seasonal population fluctuations occur during summer months due to tourism and even more, temporary return migration, leading to short-term increases in water demand and wastewater generation, particularly in and around the Imotski urban area and recreational zones within the karst fields.

5.1.2 Bosnia and Herzegovina

On the Bosnia and Herzegovina (BiH) side, the TBA Neretva includes settlements associated with the Ljubuški-Trebižat karst system, encompassing semi-urban areas, densely populated rural villages and dispersed households. GIS-based analysis indicates a slightly higher number of permanent residents within the TBA, as a larger proportion of municipal territories falls within the aquifer boundary compared to the Croatian side.

The population residing within the BiH part of the TBA Neretva is estimated at approximately 25,000–30,000 inhabitants. Settlement density is higher than in the Croatian part, particularly in semi-urban zones linked to local economic activity, agriculture and aquaculture. While overall demographic

decline is less pronounced than in Croatia, ageing trends are also evident, especially in rural settlements.

A significant share of the population depends directly on groundwater for drinking-water supply, either through public water supply systems or individual abstractions. Widespread reliance on on-site sanitation systems remains characteristic of many settlements, creating continuous pressure on groundwater quality in highly vulnerable recharge and discharge zones.

Unlike the Croatian part, demographic pressure in the BiH part of the TBA is more continuous rather than seasonal, reflecting higher settlement density and sustained groundwater dependence throughout the year.

5.1.3 Quantitative Demographic Overview

To support a consistent and transparent socio-economic assessment at aquifer scale, Table 4.1 provides a consolidated quantitative overview of population distribution and settlement structure within the TBA Neretva, based on adjusted census data and GIS-derived aquifer boundaries.

Table 12 Summary able 5.1: Demographic Characteristics and Settlement Structure within the TBA Neretva

Area	Estimated population within TBA	Settlement density	Dominant settlement pattern	Demographic trend
Croatian part	15,000–20,000	Low–moderate	Urban core + dispersed rural settlements	Declining, ageing
BiH part	25,000–30,000	Moderate	Semi-urban + rural villages	Stable to slightly declining
Total TBA Neretva	**35,000–50,000**	Low–moderate	Dispersed, karst-adapted	Overall stagnation

These figures confirm that, while the TBA Neretva does not host a large population in absolute terms, groundwater dependency per capita is high, and demographic pressures are spatially concentrated in karst-sensitive areas. Seasonal population increases further amplify pressures during periods of reduced groundwater recharge.

5.1.4 Transboundary Synthesis

From a transboundary perspective, demographic pressures within the TBA Neretva are characterised by asymmetry in population distribution combined with shared groundwater vulnerability. The Croatian part is marked by depopulation and ageing, resulting in reduced institutional and household capacity for infrastructure maintenance and groundwater protection. In contrast, the BiH part experiences more continuous demographic pressure due to higher settlement density and sustained groundwater reliance.

Despite these differences, demographic drivers of groundwater pressure are functionally interconnected across the aquifer system. Settlement patterns, sanitation practices and seasonal dynamics in one part of the TBA can influence groundwater conditions elsewhere through rapid subsurface flow and strong hydraulic connectivity. This underscores the need for coordinated aquifer-scale groundwater management that accounts for demographic realities on both sides of the border.

5.2 Groundwater Use by Sector (Drinking Water, Agriculture, Industry, Tourism)

Groundwater represents the primary and, in many locations, the sole source of water within the TBA Neretva. Sectoral groundwater use reflects the interaction between demographic patterns, land use, economic activities and the hydrogeological characteristics of a highly permeable karst system with limited natural storage.

Although total abstraction volumes are moderate in absolute terms, dependency on groundwater is structurally high, and pressures are spatially concentrated in recharge-dominated areas, karst fields and zones of surface-groundwater interaction. Seasonal variability plays a critical role, with peak demand frequently coinciding with periods of reduced recharge.

Sectoral estimates presented in this section are based on adjusted population figures (Section 4.1), DIKTAS Phase I documentation, national water management data and expert judgement. All values are indicative and expressed as ranges appropriate for aquifer-scale assessment.

5.2.1 Drinking Water Supply

Drinking water supply constitutes the dominant form of groundwater use within the TBA Neretva. Most of the population relies directly on groundwater abstracted from karst springs and shallow aquifer zones, supplied through public water supply systems or individual abstractions.

Based on an estimated permanent population of 35,000-50,000 inhabitants within the TBA and an average domestic water consumption of 140–170 litres per capita per day, total groundwater abstraction for drinking water supply is estimated at approximately:

- 1.7–2.5 million m^3/year (average conditions)
- 2.1–3.2 million m^3/year (peak conditions, +20–30%)

On the Croatian side, abstraction is spatially concentrated around the Imotski urban area and surrounding settlements within the Imotski field. On the Bosnia and Herzegovina side, drinking water supply is more spatially distributed, reflecting higher settlement density and multiple abstraction points associated with the Ljubuški-Trebižat karst system.

Drinking water abstraction represents a continuous, year-round pressure on groundwater resources and forms the baseline against which other sectoral uses are assessed.

5.2.2 Agriculture

Agriculture represents the second most significant groundwater use sector within the TBA Neretva, primarily through small-scale irrigation and livestock-related water use. Agricultural activities within the TBA Neretva are concentrated in karst fields, where crop production occurs, while fruit and vegetable production represents the dominant agricultural orientation, largely supported by surface water and associated irrigation canals. Livestock farming plays a secondary role, with extensive sheep breeding, whereas cattle breeding is mainly small-scale. Overall, land-use patterns reflect a clear contrast between intensive irrigated valley agriculture and extensive, low-input practices in the surrounding karst landscape. Agricultural activities are concentrated in karst poljes and fertile valley areas, where groundwater availability and soil conditions support crop production.

Irrigation is predominantly seasonal and limited in scale, focusing on high-value crops, household plots and localized commercial production. Livestock water use is generally modest but spatially widespread.

Indicative groundwater abstraction for agricultural purposes is estimated at:

- 0.6–1.0 million m³/year (average)
- 0.9–1.4 million m³/year (dry-year conditions)

Although agricultural abstraction volumes are lower than those for drinking water, their spatial coincidence with recharge zones significantly increases groundwater vulnerability to both quantitative and qualitative pressures.

5.2.3 Industry

Industrial groundwater use within the TBA Neretva is limited and highly localized. There are no major water-intensive industrial facilities operating within the aquifer area. Groundwater use by industry is largely confined to small-scale processing facilities, workshops and service-oriented enterprises.

In line with DIKTAS Phase I methodology, industrial water use is considered as part of non-domestic consumption and is estimated by applying a proportional increase to domestic water use. Industrial groundwater abstraction is therefore estimated at approximately 0.1–0.2 million m³/year.

While quantitatively minor, industrial activities may pose localized groundwater quality risks depending on wastewater management practices and proximity to vulnerable karst features.

5.2.4 Tourism

Tourism-related groundwater use within the TBA Neretva is highly seasonal and spatially concentrated around areas of natural and recreational value. Key tourism nodes include karst landscapes, surface-groundwater interaction zones and waterfall systems, notably the Kravice area in Bosnia and Herzegovina and Blue Lake and Red Lake in Croatia.

Tourism increases water demand through accommodation facilities, hospitality services and recreational infrastructure. These pressures are typically concentrated during summer months, coinciding with peak agricultural demand and reduced groundwater recharge.

Indicative groundwater abstraction related to tourism is estimated at:

- 0.3–0.5 million m³/year (annual total)
- with short-term peak demand increases of up to 30–40% in localized areas

Despite its limited annual contribution, tourism represents a disproportionate seasonal stress factor, particularly in hydrogeologically sensitive settings.

5.2.5 Transboundary Synthesis

From a transboundary perspective, groundwater use within the TBA Neretva is characterised by asymmetric sectoral patterns combined with shared aquifer vulnerability. The Croatian part exhibits stronger seasonal variability linked to tourism and return migration, while the BiH part experiences more continuous pressure due to higher settlement density and sustained agricultural and domestic demand.

Across the entire TBA, drinking water supply remains the dominant groundwater use, followed by agriculture, tourism and small-scale industry and agriculture. The cumulative effect of these uses, rather than their individual magnitude, defines groundwater stress, particularly during dry periods.

5.3 Environmental Pressures Affecting Groundwater in the TBA Neretva

Groundwater within the TBA Neretva is exposed to a range of environmental pressures arising from human activities interacting with a highly vulnerable karst hydrogeological system. Due to rapid infiltration, limited natural attenuation capacity and strong hydraulic connectivity between surface and groundwater, even moderate pressures can result in significant impacts on groundwater quality and availability.

Environmental pressures within the TBA are primarily linked to settlement patterns, sanitation practices, land use and seasonal economic activities. These pressures are unevenly distributed spatially but functionally interconnected across the aquifer.

5.3.1 Domestic Sanitation and Wastewater

Domestic sanitation represents one of the most significant and continuous pressures on groundwater within the TBA Neretva. A substantial proportion of settlements, particularly rural and dispersed households, rely on individual septic tanks or simple cesspits, often without adequate sealing or treatment.

In many cases, septic systems are located directly above highly permeable karst substrates, facilitating rapid percolation of untreated or partially treated wastewater into the groundwater system. This creates a persistent risk of microbiological contamination and nutrient loading, especially in recharge zones and areas with shallow groundwater tables.

On the Bosnia and Herzegovina side, higher settlement density and more continuous population pressure intensify sanitation-related risks. On the Croatian side, pressures are more seasonal but still significant due to ageing infrastructure and limited maintenance capacity in depopulating rural areas.

5.3.2 Solid Waste and Illegal Dumping

Solid waste disposal, including informal and illegal dumping, constitutes a well-recognised regional challenge within the TBA Neretva. Karst depressions, sinkholes, abandoned quarries and ravines are frequently used as uncontrolled waste disposal sites, posing a direct threat to groundwater quality.

Illegal dumping is particularly problematic due to:

- the direct hydraulic connection between surface features and the aquifer,
- the absence of natural filtration in karst systems,
- limited monitoring and enforcement capacity at local level.

Leachate from mixed municipal waste can introduce organic pollutants, heavy metals and other hazardous substances into groundwater. While the spatial extent of such sites varies, their cumulative impact represents a high-risk pressure, especially in proximity to settlements and water abstraction points.

5.3.3 Agriculture and Livestock Activities

Agricultural activities contribute to groundwater pressures primarily through nutrient loading, pesticide use and livestock waste management. Small-scale irrigation, fertilisation and manure application are common practices in karst fields and fertile valley areas within the TBA.

Livestock farming, including cattle, sheep and goats, is typically extensive but spatially widespread. Inadequate manure storage and application practices can result in diffuse nitrate and microbiological contamination, particularly during rainfall events when infiltration rates are high.

Although agricultural water abstraction volumes are moderate (Section 4.2), the coincidence of agricultural activity with recharge areas amplifies the potential impact on groundwater quality.

5.3.4 Tourism-Related Pressures

Tourism-related pressures on groundwater are highly seasonal and spatially concentrated. Key tourism nodes within the TBA Neretva include natural attractions and surface-groundwater interaction zones, most notably the Kravice waterfalls area and Blue Lake and Red Lake.

Tourism increases both water demand and wastewater generation over short periods, often exceeding the design capacity of local water supply and sanitation systems. Temporary facilities, informal accommodation and recreational infrastructure may lack adequate wastewater treatment, increasing the risk of localized contamination.

Although tourism-related pressures are episodic, their timing frequently coincides with periods of reduced groundwater recharge, thereby amplifying stress on the aquifer.

5.3.5 Infrastructure Limitations and Monitoring Gaps

Infrastructure limitations and monitoring gaps represent a cross-cutting pressure factor affecting all sectors. Key challenges include:

- incomplete wastewater collection and treatment coverage,
- ageing or undersized water supply infrastructure,
- limited groundwater quality monitoring networks,
- fragmented institutional responsibilities across administrative boundaries.

These constraints reduce the ability of local authorities to detect, manage and mitigate groundwater pressures in a timely manner, particularly in transboundary contexts where data exchange and coordinated response mechanisms remain limited.

5.3.6 Transboundary Synthesis

Environmental pressures affecting groundwater within the TBA Neretva arise from a combination of chronic, low-intensity pressures (domestic sanitation, agriculture) and episodic, high-intensity pressures (tourism peaks, temporary return migration, illegal dumping events). While the nature and intensity of pressures differ between the Croatian and BiH parts of the TBA, their impacts are shared across the aquifer system due to strong hydraulic connectivity.

The cumulative effect of multiple pressure sources, rather than any single activity, defines groundwater vulnerability within the TBA. This highlights the importance of coordinated transboundary approaches to sanitation improvement, waste management, agricultural practices and monitoring, as a prerequisite for effective groundwater protection.

5.4 Hotspots and Areas of Elevated Groundwater Pressure

Within the TBA Neretva, groundwater pressures are spatially concentrated rather than uniformly distributed. Due to the karst nature of the aquifer, areas of elevated pressure are typically associated with the coincidence of human activities, shallow groundwater, high infiltration rates and limited natural attenuation capacity.

Hotspots identified in this section represent locations where quantitative stress, water quality risks or both are significantly higher than the TBA average. Their identification supports targeted risk management and prioritisation of measures at aquifer scale.

5.4.1 Suburban Zones and Public Water Supply Catchments (Croatia and BiH)

The most pronounced and continuous groundwater pressure hotspot within the TBA Neretva is in suburban and semi-urban zones of the Ljubuški-Trebižat area. These zones combine:

- relatively high population density,
- continuous drinking-water abstraction,
- widespread use of on-site sanitation systems,
- proximity to karst recharge and discharge features.

Public water supply catchments in this area are exposed to both quantitative stress, due to sustained abstraction, and qualitative risks linked to domestic wastewater and diffuse pollution. Given the hydraulic connectivity of the karst system, localised pressures in these zones may have broader downstream impacts within the aquifer.

The most significant groundwater pressure hotspot on the Croatian side of the TBA Neretva is associated with the urban and peri-urban area of the City of Imotski and surrounding municipalities within the Imotski field. This area represents the primary population concentration within the Croatian part of the aquifer and combines several pressure factors, including:

- relatively higher population density compared to surrounding rural settlements,
- concentrated and continuous drinking-water abstraction for public water supply,
- incomplete wastewater collection coverage and widespread reliance on on-site sanitation systems,
- direct location within a highly permeable karst field functioning as a recharge and flow-through zone.

Public water supply catchments serving Imotski and adjacent settlements are exposed to both quantitative and qualitative groundwater pressures. Sustained abstraction creates localized quantitative stress, while domestic wastewater from partially connected or non-connected households poses persistent contamination risks. Given the high hydraulic conductivity and rapid groundwater flow typical of the karst system, pressures generated in the Imotski urban area have the potential to propagate beyond the immediate zone, contributing to broader aquifer-scale impacts within the TBA Neretva.

5.4.2 Tourism Nodes in Protected and Recreational Areas (Croatia and BiH)

Tourism-related hotspots are associated with natural attractions and recreational zones characterised by high seasonal visitor numbers and sensitive hydrogeological settings. The Kravice waterfalls area represents a key example of such a hotspot within the TBA Neretva.

Seasonal tourism peaks lead to:

- short-term increases in water demand,
- concentrated wastewater generation,
- intensified pressure on local infrastructure.

Although pressures are episodic, their occurrence during summer low-flow periods significantly amplifies groundwater vulnerability. The absence of fully developed wastewater treatment in some tourism nodes further increases contamination risks.

Similarly to the BiH part of the TBA, tourism-related pressures on the Croatian side of the TBA Neretva are moderate, spatially dispersed and strongly seasonal, with the most pronounced influence observed in the City of Imotski and its immediate surroundings. Tourism activity is primarily oriented

towards natural attractions, notably Blue and Red Lakes, and is characterised by excursion-based visits, weekend tourism and small-scale private accommodation.5.4.3 Rural Settlements with Decentralized Sanitation (Croatia and BiH)

Dispersed rural settlements across both sides of the TBA constitute a diffuse but structurally significant hotspot category. These settlements are typically characterised by:

- individual wells and small local water supply systems,
- septic tanks or cesspits without adequate treatment,
- direct location above highly permeable karst substrates.

While individual pressure levels are low, the cumulative effect of numerous decentralized sanitation systems creates widespread groundwater quality risks, particularly in recharge zones within karst fields and valley floors.

5.4.3 Agriculture-Karst Interaction Zones

Agricultural hotspots are primarily located in karst fields and fertile valley areas, where irrigation, fertilisation and livestock activities coincide with high groundwater vulnerability. These zones represent critical interfaces between land use and groundwater protection.

Groundwater pressures in these areas arise from:

- seasonal irrigation abstraction,
- nutrient and pesticide application,
- livestock waste management.

Although agricultural water use volumes are moderate, the direct exposure of groundwater to surface activities in these zones elevates contamination risks, particularly during rainfall-driven infiltration events.

5.4.4 Waste Disposal and Informal Dumping Sites

Informal and illegal waste disposal sites represent high-risk point hotspots within the TBA Neretva. Karst depressions, sinkholes and abandoned extraction sites are frequently used for uncontrolled dumping of municipal and construction waste.

These locations pose a disproportionate threat due to:

- direct hydraulic connection to the aquifer,
- lack of containment or leachate control,
- limited monitoring and remediation capacity.

Even isolated dumping sites can have long-term impacts on groundwater quality, making this category a priority for targeted intervention.

On the Croatian side of the TBA Neretva, waste management strategies aligned with EU directives envisage the development of transfer stations, recycling yards and integrated waste management facilities, but implementation remains slow. As a result, the area continues to rely on existing non-hazardous landfills, which represent persistent point-source risks in a highly vulnerable karst environment.

5.4.5 Transboundary Interpretation of Hotspots

From a transboundary perspective, groundwater pressure hotspots within the TBA Neretva reflect the spatial concentration of human activities in hydrogeologically sensitive karst zones, combined with

strong hydraulic connectivity across the aquifer. Although the intensity and dominant drivers of pressure differ between the Croatian and BiH parts of the TBA, hotspot categories are functionally similar on both sides of the border, including:

- suburban and peri-urban zones,
- tourism nodes,
- agricultural karst fields,
- dispersed rural settlements and
- waste disposal sites.

The most continuous and pronounced pressures are associated with population concentration and public water supply catchments, while seasonal and episodic hotspots arise from tourism and agricultural activities, particularly during summer low-flow periods. Diffuse pressures from decentralised sanitation and point-source risks related to waste disposal contribute cumulatively to groundwater vulnerability across the aquifer.

Due to the rapid flow and limited attenuation capacity of the karst system, localised pressures in identified hotspots can propagate beyond administrative boundaries, generating transboundary impacts on groundwater quality and availability. This underscores the need for aquifer-scale prioritisation of mitigation measures, coordinated monitoring and harmonised management responses targeting shared hotspot types rather than isolated locations.4.5 Water Demand and Infrastructure Stress

Water demand and infrastructure stress within the Transboundary Aquifer Area (TBA) Neretva arise from the interaction between sectoral groundwater use patterns, seasonal variability and structural limitations of water supply and sanitation systems in a karst environment. While total abstraction volumes remain moderate at aquifer scale, system stress is driven by temporal concentration, spatial mismatches and limited infrastructure resilience.

The karst hydrogeological context further amplifies infrastructure-related risks, as groundwater availability and quality can change rapidly in response to climatic conditions and local pressures.

5.5 Water Demand and Infrastructure Stress

5.5.1 Drinking-Water Demand and Supply Systems

Drinking-water demand represents the baseline and most continuous pressure on groundwater resources within the TBA Neretva. Public water supply systems abstract groundwater from karst springs and shallow aquifer zones, while a certain share of households relies on individual abstractions.

Infrastructure stress arises from:

- dependence on a limited number of abstraction points,
- uneven distribution of supply capacity,
- ageing infrastructure in rural and depopulating areas.

In semi-urban zones, sustained demand places continuous pressure on groundwater resources, while in rural areas infrastructure stress is linked more to maintenance capacity and vulnerability to contamination than to abstraction volumes.

5.5.2 Sanitation Infrastructure and Wastewater Management

Sanitation infrastructure represents a critical bottleneck in groundwater protection within the TBA Neretva. Centralised wastewater collection and treatment coverage remains limited, particularly in rural and dispersed settlements.

As a result:

- the majority of wastewater is managed through on-site systems,
- treatment efficiency varies widely,
- infrastructure performance is difficult to monitor and regulate.

These limitations contribute to persistent groundwater quality risks, particularly in areas where sanitation infrastructure has not kept pace with settlement development or seasonal population increases.

5.5.3 Seasonal Demand Peaks and System Stress

Seasonal demand peaks constitute a key driver of infrastructure stress, particularly during summer months when:

- tourism-related water use increases,
- agricultural irrigation demand reaches its maximum,
- groundwater recharge is reduced.

These concurrent pressures can exceed the operational capacity of local water supply and sanitation systems, increasing the likelihood of supply interruptions, reduced water quality and environmental impacts.

Seasonal stress is especially pronounced in tourism nodes and agricultural zones located within highly vulnerable karst settings.

5.5.4 Infrastructure Capacity, Resilience and Operational Constraints

Infrastructure capacity and resilience within the TBA Neretva are constrained by several structural factors, including:

- limited redundancy in water supply systems,
- insufficient investment in upgrading ageing infrastructure,
- fragmented institutional responsibilities across administrative boundaries,
- gaps in monitoring and operational data.

In a karst environment characterised by rapid system response and limited buffering capacity, these constraints reduce the ability of infrastructure systems to absorb shocks and adapt to changing demand patterns.

5.5.5 Transboundary Synthesis

From a transboundary perspective, water demand and infrastructure stress within the TBA Neretva reflect shared vulnerabilities arising from differing local capacities. While infrastructure configurations and management practices vary between the Croatian and BiH parts of the TBA, stress mechanisms are similar and interconnected through the shared aquifer system.

Infrastructure stress does not result solely from absolute demand levels, but from the alignment of demand peaks, infrastructure limitations and hydrogeological sensitivity. Addressing these challenges requires coordinated planning, data exchange and targeted investment strategies at transboundary aquifer scale.

5.6 Socio-economic Vulnerability and Groundwater Risk

Socio-economic vulnerability within the TBA Neretva reflects the interaction between groundwater dependency, exposure to environmental pressures and the capacity of communities and institutions to prevent, manage and respond to groundwater-related risks. In a karst aquifer system characterised by rapid flow, limited natural attenuation and strong surface-groundwater connectivity, vulnerability is shaped less by absolute pressure levels and more by structural and institutional factors.

This section assesses vulnerability and risk through a qualitative, indicator-based approach consistent with the methodology applied in the TBA Neretva, focusing on drivers, exposure, sensitivity and adaptive capacity at aquifer scale.

5.6.1 Key Drivers of Socio-economic Vulnerability

The primary drivers of socio-economic vulnerability within the TBA Neretva include:

- High dependency on groundwater as the dominant source of drinking water for households, agriculture and tourism;
- Dispersed settlement patterns with widespread reliance on decentralised water supply and sanitation systems;
- Seasonal demand variability, particularly linked to tourism and agricultural activities;
- Demographic trends, including ageing populations and depopulation in rural areas, which reduce local capacity for infrastructure maintenance and environmental management;
- Institutional fragmentation across administrative and national boundaries.

These drivers create conditions in which relatively moderate pressures can result in disproportionately high socio-economic impacts if groundwater quality or availability is compromised.

5.6.2 Exposure and Sensitivity

Exposure within the TBA Neretva is shaped by the spatial coincidence of human activities with hydrogeologically sensitive zones, including recharge areas, karst fields and surface-groundwater interaction sites. Communities and economic activities located in these areas are directly exposed to changes in groundwater quantity and quality.

Sensitivity is elevated due to:

- limited availability of alternative water sources,
- dependence on small-scale and locally managed infrastructure,
- strong linkages between groundwater condition and key livelihood activities (agriculture, tourism).

As a result, disruptions to groundwater systems can have immediate impacts on public health, local economies and ecosystem services.

5.6.3 Adaptive and Response Capacity

Adaptive and response capacity within the TBA Neretva varies across the aquifer but remains moderate to limited overall. Key constraints include:

- uneven coverage and performance of water supply and sanitation infrastructure,
- limited financial and technical capacity at local level,
- gaps in groundwater monitoring and data availability,
- limited experience with integrated, aquifer-scale management.

At the same time, existing institutional structures and cross-border cooperation frameworks provide a foundation for improving adaptive capacity, particularly through targeted investments, capacity building and enhanced data exchange.

5.6.4 Overall Risk Characterization

Groundwater risk within the TBA Neretva can be characterised as moderate but structurally significant. While no immediate large-scale quantitative overexploitation is evident, the combination of high groundwater dependency, chronic low-intensity pressures and episodic stress events creates a persistent risk profile.

Risk is particularly elevated in:

- semi-urban zones with continuous abstraction and sanitation pressures,
- tourism nodes during peak seasons,
- rural areas with widespread decentralised sanitation and limited oversight.

These risk patterns are spatially heterogeneous but functionally interconnected across the aquifer.

5.6.5 Transboundary Risk Perspective

From a transboundary perspective, groundwater risks within the TBA Neretva are shared but asymmetrically generated. Differences in settlement density, infrastructure configuration and management capacity between the Croatian and BiH parts of the TBA influence the location and intensity of pressures, while impacts propagate across borders through the connected karst system.

This asymmetry highlights the importance of joint risk assessment, harmonised monitoring and coordinated response mechanisms to ensure equitable and effective groundwater protection.

5.6.6 Implications for Joint Action Program Development

The socio-economic vulnerability and risk profile identified in this section underscores the need for targeted, proportionate and coordinated measures within the Joint Action Plan. Priority areas include:

- strengthening sanitation and waste management in vulnerable zones,
- improving infrastructure resilience to seasonal demand peaks,
- enhancing groundwater monitoring and data sharing,
- supporting local adaptive capacity through institutional and community-level interventions.

Addressing socio-economic vulnerability at aquifer scale is essential for reducing long-term groundwater risks and ensuring sustainable use of the TBA Neretva

5.7 Synthesis of Socio-economic Pressures, Vulnerability and Risk

This section synthesises the key findings of Sections 4.1–4.6, integrating demographic characteristics, sectoral groundwater use, environmental pressures, hotspot distribution, infrastructure stress and socio-economic vulnerability within the TBA Neretva.

The synthesis confirms that groundwater pressures within the TBA Neretva are not driven by extreme abstraction volumes, but by the structural characteristics of the aquifer system and the socio-economic context in which groundwater is used. High dependency on groundwater, decentralised

settlement patterns, seasonal demand peaks, agriculture and limited infrastructure resilience collectively define a risk profile characterised by moderate quantitative stress and elevated qualitative vulnerability.

Differences between the Croatian and Bosnia and Herzegovina (BiH) parts of the TBA are evident in population distribution, infrastructure configuration and institutional capacity. However, due to strong hydraulic connectivity within the karst system, pressures generated in one part of the aquifer can result in impacts elsewhere, giving rise to shared transboundary risks.

The integrated assessment highlights the importance of coordinated groundwater management that addresses both chronic, low-intensity pressures (e.g. domestic sanitation, agriculture) and episodic, high-intensity stressors (e.g. tourism peaks, drought periods). The qualitative indicators summarised in Table 4.1 provide a consolidated overview of relative pressure levels, vulnerability drivers and risk relevance across the TBA.

Table 13 Summary of Socio-economic Indicators and Risk Levels in the TBA Neretva

Indicator Category	Key Indicator	Croatia	Bosnia and Herzegovina	Transboundary Relevance
Demography	Permanent population pressure	Low-Moderate	Moderate	Seasonal dynamics shared
Settlement structure	Degree of decentralization	High	Moderate	Diffuse pressure pathways
Drinking-water dependence	Reliance on groundwater for public supply	Moderate	High	Shared aquifer dependency
Service-area demand	Population served beyond TBA	Moderate	Moderate–High	Asymmetric pressure transmission
Sanitation	Reliance on septic systems	High	High	Shared contamination risk
Tourism pressure	Seasonal demand peaks	High (seasonal)	High (seasonal)	Synchronized peak stress
Infrastructure resilience	Capacity to absorb demand peaks	Moderate	Moderate	System fragility
Monitoring & control	Coverage and harmonization	Moderate	Low–Moderate	Limited early warning
Institutional capacity (including inclusiveness and stakeholder coordination)	Local implementation strength	Moderate	Moderate	Governance imbalance
Overall vulnerability	Combined socio-economic vulnerability	Moderate	High	High systemic sensitivity
Groundwater risk	Likelihood of quality/supply disruption	Moderate	High	Transboundary consequences

Note: Qualitative ratings (Low / Moderate / High) are based on the integrated assessment presented in Sections 4.1–4.6 and reflect relative conditions rather than quantified thresholds.

Key Synthesis Messages

- Groundwater dependency is high across the entire TBA, making socio-economic systems sensitive to even moderate changes in groundwater quality or availability.
- Decentralised sanitation and waste management remain a dominant shared pressure pathway, particularly in rural and peri-urban areas.
- Seasonal demand peaks, driven by tourism and agriculture, represent a recurrent stress factor that coincides with periods of reduced recharge.
- Institutional and infrastructure asymmetries contribute to uneven pressure generation but shared risk outcomes.
- Transboundary relevance is high, as cumulative and downstream impacts cannot be effectively managed through unilateral measures.

5.8 Gender Considerations in Groundwater Use and Vulnerability

Gender considerations within the Transboundary Aquifer Area (TBA) Neretva are closely linked to differentiated roles, responsibilities and exposure patterns related to water use, sanitation management and livelihood activities. While groundwater dependency affects all population groups, gender dimensions influence how pressures and risks are experienced, managed and addressed at household and community level.

This section integrates gender considerations as a cross-cutting socio-economic factor and focuses on practical implications for groundwater vulnerability and adaptive capacity rather than standalone gender analysis.

Gender Roles in Water Use and Household Management

In both the Croatian and Bosnia and Herzegovina parts of the TBA Neretva, women typically play a central role in household water management, including drinking water use, sanitation practices and hygiene-related activities. This role is particularly pronounced in rural and dispersed settlements where water supply and sanitation systems are decentralised and require daily management at household level.

As a result, women are often the first to experience the impacts of groundwater quality deterioration or supply interruptions, translating technical water issues into direct health, time and labour burdens.

Exposure and Vulnerability

Gender-related vulnerability is shaped by the interaction between groundwater dependency and socio-economic conditions. In rural areas with ageing populations, women frequently assume increased responsibility for household management and care activities, amplifying their exposure to water-related risks.

Seasonal demand peaks associated with tourism and agriculture can further intensify workloads related to water use and sanitation management. In such contexts, inadequate infrastructure disproportionately affects women, particularly where alternative water sources or sanitation services are limited.

Participation and Adaptive Capacity

Despite their central role in daily water management, women remain underrepresented in formal decision-making processes related to water supply, sanitation infrastructure and groundwater protection. This limits the integration of gender-specific knowledge and priorities into planning and management processes.

At the same time, women's practical experience with household-level water systems represents an important, underutilised resource for improving adaptive capacity, particularly in relation to early detection of water quality issues and community-based monitoring.

Implications for Groundwater Risk and Management

Gender dimensions influence both groundwater vulnerability and response capacity within the TBA Neretva. Failure to recognise differentiated roles and impacts can reduce the effectiveness of groundwater protection measures and infrastructure investments.

Integrating gender considerations into groundwater management at aquifer scale can:

- improve the relevance and acceptance of protection measures,
- enhance community-level adaptive capacity,
- support more inclusive and resilient governance arrangements.

These considerations are particularly relevant in transboundary contexts, where coordination mechanisms can benefit from inclusive stakeholder engagement and diversified knowledge inputs.

Transboundary Perspective

From a transboundary perspective, gender-related patterns of groundwater use and vulnerability are broadly similar across the TBA Neretva, reflecting shared socio-economic and cultural contexts. This creates opportunities for harmonised approaches to gender-sensitive groundwater management, capacity building and stakeholder engagement across borders.

5.9 Stakeholder Landscape and Engagement Dynamics

Effective groundwater management within the TBA Neretva depends on the interaction of a diverse set of stakeholders operating at local, regional and national levels across two countries. Stakeholder roles, influence and engagement capacity vary significantly, reflecting differences in institutional mandates, resource availability and proximity to groundwater pressures.

This section maps the stakeholder landscape relevant to groundwater use, protection and risk management in the TBA Neretva and assesses engagement dynamics in line with the approach applied in the TBA Neretva. The analysis focuses on functional relevance to groundwater management, rather than formal administrative hierarchies.

Stakeholder Groups and Roles

Stakeholders within the TBA Neretva can be grouped into several broad categories:

- Public authorities responsible for water management, environmental protection, spatial planning and public utilities;
- Water service providers, including public water supply and wastewater operators;
- Local governments, with direct responsibility for infrastructure development, land-use regulation and waste management;

- Economic actors, notably agricultural producers, tourism operators and small-scale industry;
- Civil society and local communities, including residents directly dependent on groundwater resources;
- Research and expert institutions, providing technical knowledge, data and analytical support.

Stakeholder influence on groundwater outcomes is uneven, with some actors generating pressures while others bear disproportionate impacts or responsibilities for mitigation.

Engagement Dynamics

Stakeholder engagement within the TBA Neretva is characterised by fragmentation and sectoral separation. Coordination mechanisms exist primarily at national or municipal levels, while structured, aquifer-scale engagement remains limited.

Key engagement challenges include:

- limited cross-sector coordination,
- uneven access to information and monitoring data,
- capacity constraints at local level,
- limited formal mechanisms for transboundary stakeholder dialogue.

At the same time, existing cooperation frameworks established under DIKTAS provide a foundation for strengthening stakeholder engagement through targeted capacity building and inclusive consultation processes.

Table 14 Stakeholder Landscape and Engagement Dynamics in the TBA Neretva

Stakeholder Group	Key Actors	Primary Role in TBA	Level of Influence	Level of Interest	Engagement Priority
National water authorities	Line ministries, water agencies	Policy, regulation, oversight	High	High	High
Environmental authorities	Environmental protection agencies	Groundwater protection, monitoring	Moderate-High	High	High
Local governments	Municipalities within TBA	Infrastructure, land use, waste	Moderate	High	High
Water utilities	Public water and wastewater operators	Abstraction, supply, sanitation	High	High	High
Agricultural producers	Farms, cooperatives	Irrigation, livestock	Moderate	Moderate	Medium
Tourism operators	Accommodation and recreation services	Seasonal water use	Low-Moderate	High	Medium
Small industry	Local enterprises	Limited abstraction, wastewater	Low	Moderate	Low-Medium
Local communities	Residents and households	Daily water use, sanitation	Low	High	High
Civil society	NGOs, community groups	Advocacy, awareness	Low-Moderate	Moderate	Medium
Research & experts	Universities, consultants	Data, analysis, guidance	Moderate	High	Medium

Note: Influence and interest levels are assessed qualitatively (Low / Moderate / High) based on the integrated socio-economic assessment and stakeholder engagement input.

Transboundary Stakeholder Perspective

From a transboundary perspective, stakeholder engagement dynamics are shaped by asymmetries in institutional capacity and governance structures between the Croatian and BiH parts of the TBA. While national authorities play a dominant role in setting policy and regulatory frameworks, effective groundwater protection requires stronger involvement of local governments, utilities and communities on both sides of the border.

Shared groundwater risks and interconnected pressure pathways highlight the need for:

- harmonised stakeholder engagement approaches,
- regular information exchange,
- joint consultation mechanisms at aquifer scale.

Implications for Implementation

The stakeholder landscape analysis underscores that successful implementation of groundwater protection measures within the TBA Neretva depends not only on technical solutions, but also on inclusive, well-structured stakeholder and community engagement. Strengthening coordination among high-priority stakeholders and creating opportunities for meaningful participation of local actors will be essential for effective and sustainable groundwater management.

6. Transboundary Cooperation – TBA Neretva

6.1 Integrating Groundwater Provisions through the Update of the Bilateral Agreement between Croatia and Bosnia and Herzegovina

Bilateral agreement concluded between Croatia and Bosnia and Herzegovina (1996) outlines joint responsibilities for managing shared river basins, including the TBA Neretva. The agreement lacks specific provisions on groundwater, including monitoring, data exchange, and aquifer management, offering instead a general framework for cooperation in areas such as overall water management, pollution prevention and infrastructure. The lack of measures for aquifer management, groundwater monitoring and systematic data exchange reduces its practical value for achieving DIKTAS II objectives.

Updating this agreement to include explicit references to groundwater, harmonized monitoring protocols, and alignment with DIKTAS Rulebook, particularly regarding sanitary protection zones, would significantly strengthen transboundary governance. Such revisions should also introduce joint technical guidelines and institutional mechanisms to operationalize cooperation, ensuring that both countries meet EU standards and regional sustainability goals.

On the basis of the signed bilateral Agreement, an inter-state Working Group was established tasked to prepare a draft Regulation on the determination of sanitary protection zones for water sources in the border area of BiH and Croatia. According to available information, the Regulation has been drafted some years ago, but it cannot enter into force until an international Agreement is signed on the proclamation of sanitary protection zones for water sources used for public water supply, where the zones extend into the territory of the other state (Agency for the Adriatic Sea River Basin, 2021).

6.2. Stakeholder Engagement and Public Awareness

This section evaluates engagement mechanisms, communication pathways, and awareness levels among key stakeholder groups influencing groundwater conditions in TBA Neretva.

Table 15 Stakeholder Engagement and Public Awareness

Key Stakeholder Groups	Engagement Gaps	Stakeholder Dynamics and Sensitivities
Public Water Utilities (BiH and HR)	Technically capable institutions with limited public communication on groundwater risks and transboundary linkages. Monitoring data are rarely shared in accessible formats.	High dependency on groundwater reliability. Strong operational incentives for protection, but limited mandate beyond supply operations.
Municipal Governments	Engagement largely administrative and compliance based. Limited participatory dialogue and weak coordination across municipalities and borders.	Responsible for sanitation and spatial planning. Capacity and commitment vary significantly between municipalities.
Rural Communities and Peri Urban Households	Low awareness of karst vulnerability and groundwater contamination pathways. Limited access to practical guidance on septic maintenance and waste disposal.	Diffuse but cumulative impact on groundwater quality. Limited capacity to manage risks individually.
Agricultural Users	Rarely engaged in groundwater protection planning. Awareness of diffuse pollution risks is uneven. Incentives for good practice are weak.	Strong economic reliance on groundwater, especially downstream in Croatia. Sensitive to regulatory restrictions.
Tourism Operators	Environmental engagement linked mainly to licensing or protected area rules. No systematic training on groundwater protection or wastewater management.	Seasonal pressure peaks. Economic dependence on clean water and environment creates potential leverage for engagement.
Hydropower Operators	Engaged through sectoral energy regulation, not groundwater governance. Limited recognition of groundwater surface water interactions.	Operational decisions influence basin wide hydrological dynamics. High institutional and economic influence.
Protected Area Authorities	Outreach focuses on biodiversity and tourism management. Groundwater specific messaging is not harmonised across borders.	Strong communication channels and visitor reach. Potential key partners for awareness campaigns.
Civil Society and NGOs	Active mainly on the BiH side. Involvement is informal and project based. Limited cross border cooperation.	Trusted local actors. Can support monitoring, awareness raising, and accountability.
Schools and Youth Groups	Largely absent from groundwater awareness activities.	Important long-term stakeholders for building groundwater stewardship culture.

Public information on groundwater vulnerability and transboundary connectivity in the TBA Neretva is limited. Engagement remains fragmented by sector and country, and no formal cross border stakeholder engagement platform exists**.**

6.3. Opportunities for Strengthening Cooperation

Opportunities for strengthening cooperation in the TBA Neretva build directly on the institutional asymmetries, stakeholder pressures, and governance gaps identified in the previous sections. Cooperation measures should focus on practical coordination mechanisms that align upstream activities with downstream risk management needs.

PILLAR 1: JOINT MONITORING AND INFORMATION EXCHANGE

A harmonised groundwater monitoring framework across Bosnia and Herzegovina and Croatia represents a core opportunity. Jointly agreed monitoring locations, parameters, and frequencies would improve comparability of data and support shared understanding of groundwater dynamics. Establishing a shared digital platform for groundwater and spring data, including abstraction volumes, water quality indicators, and seasonal variability, would strengthen transparency and early warning capacity. Regular joint interpretation workshops involving utilities, technical authorities, and research institutions would support coordinated decision making.

PILLAR 2: COORDINATED RISK MANAGEMENT AND PROTECTION MEASURES

Risk management can be strengthened through aligned protocols for pollution response and emergency communication. Jointly developed procedures for incident notification between water utilities and authorities would improve preparedness and reduce response time during contamination events. Mapping and prioritizing high risk recharge zones and settlements on a basin wide basis would enable coordinated sanitation and land use interventions. Developing shared technical guidance for septic tank management and rural wastewater improvements would support consistent protection standards across borders.

PILLAR 3: SUSTAINABLE LAND USE, ENERGY, AND TOURISM COORDINATION

Land use, hydropower, and tourism pressures require coordinated management approaches. Integrating groundwater protection considerations into spatial planning and hydropower operation discussions would improve alignment between sectoral decisions and groundwater sustainability. Developing shared environmental guidelines for tourism operators across the basin would help manage seasonal pressure and promote consistent wastewater and water use practices. Protected areas and visitor centres offer effective platforms for harmonised communication and stewardship messaging.

PILLAR 4: INSTITUTIONAL DIALOGUE AND STAKEHOLDER ENGAGEMENT

Establishing a permanent bilateral coordination group for groundwater in the TBA Neretva would provide a stable platform for routine dialogue, data exchange, and joint planning. Structured participation of municipalities, utilities, NGOs, agricultural representatives, tourism operators, and energy stakeholders would strengthen inclusiveness and accountability. Cross border training and exchange programmes for inspectors, utility staff, and local authorities would build trust and improve operational capacity.

Transboundary Interpretation

The effectiveness of cooperation in the TBA Neretva depends on aligning upstream economic activities with downstream vulnerability management. Joint monitoring, coordinated risk response, and structured stakeholder engagement provide the most realistic and impactful pathways for improving groundwater governance. A shift from project-based cooperation to permanent institutional coordination is essential for long term protection of the transboundary aquifer.

7. Recommendations and Measures – TBA Neretva

7.1 Legal Harmonization Measures

As a first step, Croatia (HR) and Bosnia and Herzegovina (BiH) should prepare an addendum to the 1996 Agreemnt on Water Management Relations, guided by the Joint Action Program (JAP) for the

Neretva transboundary aquifer (TBA) under the DIKTAS II project. The JAP should define a shared hydrogeological description of the Neretva TBA, including indicative boundaries, recharge characteristics, and connections to groundwater-dependent ecosystems (GDEs), and provide a common framework for subsequent technical and administrative cooperation. It should also formalize joint commitments to mutual recognition of cross-border sanitary protection zones (SPZ), harmonized monitoring of groundwater and GDEs, reciprocal incident notification and early-warning communication, and regular information exchange through a bilateral data interface operated under the mechanisms envisaged in DIKTAS II.

SPZs should be treated as the immediate priority for technical alignment in a karst setting. A common four-zone model for public water-supply sources should be adopted as the recommended standard, anchored in hydrogeological investigations, residence-time thresholds, and explicit vulnerability mapping. Where an SPZ extends across the border, mutual recognition, implemented through spatial plans and reflected in permitting, should ensure coherent land-use management and reduce uncertainty for operators. A uniform typology of prohibited, conditional, and generally compatible activities by zone should be established, with clear rules for tourism facilities, waste infrastructure, and agricultural practices prevalent in the Neretva basin. Conditional activities should be examined through groundwater-specific environmental impact procedures that draw on tracer tests or equivalent karst research tools. Integration of approved SPZs into spatial planning should follow agreed timelines, and officially adopted technical background documents, including maps, should have direct planning relevance.

Convergence in permitting and discharge control should complement these spatial measures. Procedural thresholds and documentation should be aligned through parallel by-laws and shared templates, considering HR's two-tier system of permits and concessions and entity arrangements in BiH. Application content, public-participation windows, validity periods, renewal conditions, and minimum monitoring plans should be standardized to the extent practicable. For indirect discharges, joint technical guidance should provide a common risk-assessment framework, including source-pathway-receptor analysis, preventive design measures, parameter lists, threshold values, and tests for trend assessment and trend reversal suited to karst vulnerability. A framework for managed aquifer recharge in karst should be developed for pilot applications, covering site selection, source-water quality, pre-treatment, hydraulic testing, operational monitoring, and cessation criteria.

Monitoring and information management should be strengthened through a joint program agreed under the JAP. Monitoring stations, measured parameters, and sampling frequencies should be harmonized, with emphasis on continuous or high-frequency monitoring at key public water-supply springs and control points in recharge areas. A shared digital platform using EU-compatible metadata should support near-real-time data exchange, routine trend analysis, and publication of validated summaries, with graduated access for authorities, utilities, and the public. Early-warning and incident communication should be governed by clear protocols that specify responsible contacts, alert timelines, follow-up reporting, and measures such as temporary abstraction reduction or emergency water supply when threshold values are exceeded.

Economic instruments should provide additional alignment. Abstraction and discharge fees should gradually reflect resource and environmental costs, and revenues should be earmarked for priority actions such as monitoring, SPZ implementation, upgrades to decentralized sanitation in sensitive areas, and remediation measures. When contamination events clearly cause cross-border impacts, cooperative cost-sharing arrangements should be activated through the bilateral mechanism. Access

to external funding should be facilitated through harmonized frameworks and a clearly sequenced implementation plan.

Compliance assurance should be strengthened through coordinated, risk-based inspection planning. Inspection plans should consider karst vulnerability, distance to groundwater recharge areas, and seasonal changes in tourism pressure. Regular transboundary compliance reviews should be established using a practical checklist. The checklist should verify inclusion of SPZs in spatial plans, appropriate handling of permitting in sensitive locations, sufficiency of monitoring coverage and reliability of data, and the effectiveness of incident reporting and management. Where existing or new contamination is identified, shared guidelines should be applied for contaminated-site investigation and groundwater remediation in karst areas. The guidelines should set out clear steps for site characterization, selection of containment measures, use of monitored natural attenuation where appropriate, and verification sampling, to ensure predictable and consistent remediation across jurisdictions.

Cross-sectoral integration should add resilience and reflect the prominence of agriculture in the Neretva basin. Spatial-planning documents should include explicit cross-references so that approved SPZ and vulnerability maps have direct weight in zoning, building permits, and strategic environmental assessments. Agricultural measures in outer zones and recharge areas should include nutrient-management plans, covered manure storage, vegetated buffers along losing streams and ponors, seasonal application windows, low-drift techniques, and alignment with rural-development support schemes to enable uptake by farmers. Tourism licensing in sensitive zones should introduce groundwater performance conditions for accommodation and recreational facilities, including sanitation design, seasonal load management, and waste handling. Energy and hydropower licensing should incorporate ecological-flow safeguards and connectivity tests to avoid adverse effects on GDEs. Public-health regulations should emphasize routine disclosure of drinking-water quality and participation of water utilities in joint monitoring arrangements to improve risk communication.

Harmonized public-participation rules for permits and SPZ decisions, access to technical studies, and clear timelines for comments should raise legitimacy and reduce disputes. Annual groundwater status notes, SPZ maps, and monitoring summaries should be published in a user-friendly format.

A sequenced implementation pathway is recommended as the most pragmatic way to operationalize legal harmonization measures. In an initial phase, HR and BiH should focus on the addendum to the 1996 Agreement based on JAP guidelines covering SPZ alignment, monitoring, early-warning templates, and remediation measures. A second phase should address spatial-plan integration, convergence of permitting and discharge guidance, use of the shared data platform, and the first cycle of cooperative reviews. A third phase should explore alignment of economic instruments, complete cross-sectoral legal insertions, and publish a joint five-year compliance and status report consolidating lessons learned and proposing refinements

7.2 Policy Integration and Planning Improvements

Groundwater governance in the TBA Neretva should be firmly integrated into all planning instruments that shape land use and economic activity across the basin. River Basin Management Plans in both countries already provide a technical foundation, but their objectives are not yet consistently embedded in spatial, agriculture, tourism, energy and transport planning relevant to the TBA. Planning documents should explicitly reference groundwater vulnerability, sanitary protection zones and karst-specific risks to ensure that decisions across sectors converge on basin objectives.

Spatial planning is the main entry point for integrating groundwater protection into development decisions. Sanitary protection zones and groundwater-vulnerability maps should be formally included in municipal, cantonal and county spatial plans, so they have direct planning relevance and prevent unsuitable construction in recharge areas and zones that are hydraulically connected to public springs. Water authorities should systematically provide early technical guidance during the preparation of spatial plans, ensuring that the location and design of new projects reflect groundwater flow paths, travel times and the low natural filtration capacity of karst. Where a protection zone crosses the state border, both countries should recognise it in their planning documents and permitting procedures to avoid regulatory gaps.

Agriculture needs clear and stronger integration into groundwater-related policies and planning, as irrigated farming and nutrient pressures are significant in the Neretva area. Agricultural strategies, subsidy schemes and irrigation programmes should include groundwater-sustainability criteria that follow river-basin objectives and sanitary-zone requirements. Irrigation support should be linked to the suitability of the water source, the use of efficient technologies, and regular monitoring of abstraction volumes. In recharge areas and outer sanitary zones, nutrient-management plans, covered manure storage and seasonal limits for fertiliser application should be mandatory. Monitoring of nitrates and pesticides at springs, losing streams and ponors should be coordinated and used in both agricultural advisory services and water-sector monitoring. Joint pilot sites could demonstrate low-input agricultural practices that are suitable for karst conditions.

Tourism planning should consider seasonal increases in water use and wastewater generation. Tourism development programmes, as well as permits for accommodation and recreational facilities in sensitive zones, should include groundwater-focused requirements for sanitation systems, peak-season load management and proper waste handling. Local development funds should prioritise upgrading septic tanks and introducing small cluster wastewater solutions in settlements located in recharge areas. The performance of these systems should be regularly reported using groundwater indicators provided by utilities and public health institutes.

Energy and transport planning should include clear measures to protect groundwater from the earliest stages of decision-making. Hydropower projects and relevant infrastructure should undergo environmental assessments that specifically consider karst characteristics, including groundwater connectivity, seepage risks, and possible impacts on springs and groundwater-dependent ecosystems during construction. Where relevant, minimum-flow requirements from water-sector plans should help guide early project scoping and the selection of suitable locations, without adding unnecessary regulatory procedures. This approach ensures that groundwater risks are addressed in advance and helps avoid costly changes later in the project cycle.

Data integration is essential for informed and consistent planning. Water, agriculture, tourism and public-health authorities should share key data, such as spring flows, abstraction volumes, nitrate and pesticide results, microbial indicators and seasonal demand peaks, through a joint data platform aligned with DIKTAS II. Planning documents should include a clear groundwater section using common indicators and maps, while water-sector plans should regularly incorporate data from other sectors to improve hotspot identification and guide priority actions across the aquifer.

Financial instruments should support better policy integration. EU-aligned programmes and national development schemes should identify priority investments that reduce groundwater risks in the TBA Neretva, including sanitation improvements in recharge areas, leakage reduction at public springs, karst-adapted monitoring stations and agricultural measures that help lower nutrient inputs. Funding

criteria should favour projects that clearly demonstrate risk-reduction benefits, and revenues from abstraction and discharge fees should be directed toward these priority measures.

Transparency and public involvement should be strengthened in all planning processes affecting the TBA. Sanitary protection maps, vulnerability data and monitoring data should be published in accessible formats. Consultations for spatial, agricultural and tourism plans should invite groundwater-related comments, and authorities should provide clear, evidence-based responses. For measures that may have transboundary impacts, both countries should follow established procedures for notification and technical exchange through the existing bilateral cooperation framework and the DIKTAS II mechanism.

Implementation can follow a phased pathway tailored to the Neretva context. In the first phase, all relevant plans can include explicit references to river-basin objectives and add concise groundwater-risk requirements, focusing on agriculture-planning linkages in recharge areas. In the second phase, spatial and agriculture plans can integrate approved sanitary zones and vulnerability maps. Monitoring protocols for nitrates and pesticides can be harmonised, and advisory roles of water authorities in plan and project preparation can be formalised. In the third phase, planning instruments can incorporate joint monitoring results, adjust irrigation and tourism provisions based on observed trends, and report on a shared indicator set that tracks risk reduction and service performance across the Neretva TBA.

7.3 Socio-economic Measures for Sustainable Groundwater Use

Socio economic measures in the TBA Neretva should target the human drivers of groundwater pressure and strengthen the capacity of local actors to protect karst aquifers in the long term. Measures must be differentiated by upstream and downstream context while remaining coordinated at basin level.

Improving wastewater management in rural and peri urban settlements is a priority across the basin. High risk settlements located in groundwater recharge zones should be identified jointly and prioritized for septic tank upgrades and sanitation improvements. Households and small businesses require clear technical guidance on proper septic design, maintenance, and monitoring. Simple reporting mechanisms for malfunctioning systems would help reduce contamination risks from decentralized sources.

Urban wastewater management in Bosnia and Herzegovina requires continued investment and operational strengthening. Reducing leakages, improving treatment efficiency, and controlling informal discharges in peri urban areas around Mostar, Konjic, and Jablanica would significantly reduce pressure on groundwater resources. Coordination between utilities and municipalities is essential to align infrastructure development with groundwater protection needs.

Agricultural practices in the Lower Neretva Valley should be supported through targeted measures that promote efficient irrigation, nutrient management, and reduced chemical use. Training programs and advisory services for farmers can improve awareness of groundwater vulnerability and promote good agricultural practices. Economic incentives and agri-environmental support schemes can encourage adoption of water saving technologies and pollution reducing measures.

Tourism related pressures can be addressed by promoting voluntary environmental performance standards for operators across the basin. Accommodation providers, rafting operators, and recreational facilities should be encouraged to adopt water efficient fixtures, appropriate wastewater solutions, and seasonal load management practices. Communicating groundwater protection

messages through tourism platforms, visitor centers, and booking channels would support responsible visitor behavior.

Public awareness remains a cross-cutting measure. Bilingual information campaigns on karst vulnerability, groundwater protection, and transboundary linkages should target communities, farmers, tourism operators, and schools. Involving youth groups and local associations can strengthen long term stewardship and social ownership of groundwater protection.

Economic instruments can support behavior change. Small scale incentive schemes for sanitation upgrades, water saving investments, and pollution reduction measures can leverage local action. Municipalities can reinforce these efforts by integrating groundwater protection requirements into development approvals and land use planning.

Strengthening communication between utilities and communities is also essential. Utilities should provide regular, accessible updates on groundwater status, risks, and trends to build transparency and trust and to support informed community participation.

7.4 Monitoring and Data Management Enhancements

Monitoring in the Neretva TBA should move from separate, site-by-site checks to a single system that covers the whole TBA and supports quick action in this fast-responding karst area. The network should be based on a common understanding of how the aquifer system works, including recharge zones, main flow paths, key springs and groundwater-dependent ecosystems. Monitoring sites should include public springs, recharge and transit zones, losing streams, ponors, and locations near tourism areas and agricultural hotspots. Measured parameters should include flow, groundwater level (if appropriate), temperature, electrical conductivity, turbidity, major ions, chlorides, nutrients, relevant pesticides and microbiological indicators. Sampling should match the fast changes typical of karst: continuous or high-frequency sensors at the most important springs, storm-event sampling after rainfall, and monthly sampling at other sites.

Harmonised methods are essential for comparability. Both sides should adopt aligned field protocols, laboratory methods, detection limits and QA/QC procedures defined under the Joint Action Program for the TBA Neretva, drawing on DIKTAS II guidance and existing national practices. A shared schedule for calibration and maintenance of automatic probes at major springs would improve early warning for turbidity spikes, salinity pulses and contamination events. Incident thresholds should be agreed in advance so that utilities and authorities can temporarily adjust abstraction, switch sources or increase treatment when thresholds are exceeded.

Given the strong agricultural footprint in the Neretva TBA, surveillance must systematically capture diffuse pressures. Nitrate and priority pesticide monitoring should be installed at springs receiving recharge from cultivated poljes, at losing streams and at representative shallow observation points in recharge zones. Results should be linked to agricultural advisory services to adjust practices during sensitive periods. In parallel, microbiological monitoring at springs influenced by decentralised sanitation should be intensified during wet-weather events to capture short-lived contamination.

Sanitary protection zones require operational monitoring rules tied to vulnerability. Inner zones should have continuous or event-triggered monitoring at the abstraction and at upstream control points; outer zones should follow a seasonal programme focused on nutrients, pesticides and microbiology, with additional checks during irrigation and peak tourism. Where zones cross the border or protect shared springs, selected parameter lists, thresholds and response actions should be identical and jointly reviewed each year.

Data management should move to a shared, cross-border platform agreed under DIKTAS II. This platform should allow fast data exchange and joint interpretation by both countries. Water authorities, utilities and public-health institutes should upload checked time-series data, field notes and lab results using the same formats and spatial references. The system should support near-real-time data from automatic stations at key springs, send event alerts, and display simple dashboards with agreed indicators. Access can be set at different levels, but annual summaries and online maps of sanitary zones, vulnerability areas and monitoring sites should be public to support transparent planning. The platform should operate within the DIKTAS II information-exchange mechanism and be linked with national databases to avoid duplication.

A joint set of indicators should track how well the monitoring system works, including coverage, data quality and how results are used. Key indicators include the share of priority springs with continuous sensors, how much of the recharge area is monitored for nutrients and pesticides, the speed of data transfer to the platform, how often joint reviews take place, and how many planning or permitting decisions rely on groundwater data. Indicators should be simple, measurable and reported in a short bilateral summary that also lists exceedances, incident responses and planned improvements.

Capacity building is essential. Priority actions include training on karst-specific network design, event-based sampling, sensor installation and maintenance, quality control and trend analysis. Joint field exercises at key springs should be carried out regularly. Laboratory capacity for pesticide analysis needs strengthening where gaps exist, and utilities should be supported in operating sensors and interpreting alarms. A small, dedicated budget for equipment, calibration and consumables will help prevent data gaps.

Monitoring results can directly feed into risk management and planning. Quarterly joint reviews can analyse trends, confirm hotspots and adjust measures in recharge areas, including irrigation rules, seasonal limits and sanitation upgrades. Findings may be reflected in spatial plans, tourism permits and agricultural support programmes, ensuring that vulnerable zones receive priority attention. Short, accessible reports will help utilities, municipalities and communities understand risks and take practical steps to protect drinking-water sources and ecosystems across the Neretva TBA.

7.5 Transboundary Cooperation and Governance Mechanisms

The protection of groundwater resources in the TBA Neretva depends on stable and structured cross border cooperation between Bosnia and Herzegovina and Croatia. Given the high degree of hydrogeological connectivity, isolated national measures are insufficient to manage shared risks.

Establishing a formal and permanent bilateral coordination mechanism for groundwater would provide a foundation for long term cooperation. This mechanism should facilitate routine dialogue, joint review of monitoring results, and coordination of management actions. Participation should include national authorities, utilities, cantonal and county administrations, municipalities, and relevant sectoral actors.

Harmonising groundwater monitoring and data exchange is a critical governance priority. Agreeing on common parameters, sampling frequencies, and data formats would improve comparability and support joint assessment of trends and risks. A shared digital platform accessible to both countries would enhance transparency and enable timely information exchange.

Joint identification and management of high-risk zones is essential. Mapping vulnerable recharge areas and high-risk settlements on a basin wide basis would allow coordinated prioritisation of

sanitation, land use controls, and protective measures. Aligning minimum technical standards for onsite sanitation systems would further reduce transboundary contamination risks.

Emergency preparedness and response require clear communication protocols. Establishing a joint notification and response procedure between water utilities and authorities would improve readiness and coordination during contamination incidents or sudden changes in groundwater conditions.

Effective governance also requires systematic stakeholder engagement. Municipalities, NGOs, community groups, agricultural representatives, tourism associations, and energy sector stakeholders should be included in cross border discussions to ensure that local knowledge and concerns inform decision making. Structured engagement would help build trust and shared responsibility across the basin.

Together, these measures establish a predictable, transparent, and cooperative governance framework capable of addressing both current pressures and future challenges in the TBA Neretva.

7.6 Indicator Framework for Joint Action Program

7.6.1 Proposed Indicators for Implementation Monitoring

The indicator framework for the Neretva TBA Joint Action Program (JAP) is designed to turn governance principles into measurable signals of progress. Indicators will be grouped into four categories: Institutional, Legal & Fiscal, Technical, and Policy Planning. This structure follows the approach set out in the "Global Framework for Action on Groundwater Governance", the final output of the FAO/UNESCO/IAH/World Bank/GEF "Groundwater Governance Project", which highlights that effective governance depends on strong institutions, clear legal and financial tools, sound technical measures, and planning based on evidence. Organizing indicators in this way ensures that monitoring covers not only activities but also the conditions and mechanisms that make long-term cooperation possible. It also aligns with the governance performance indicators presented in the Framework's annex, creating a link between global standards and the TBA Neretva-specific program.

Institutional indicators will show whether the arrangements and capacities needed for joint aquifer management are in place and functioning. They will track the work of the Joint Water Management Commission, the frequency and quality of stakeholder meetings, and whether decisions reflect stakeholder input. These indicators will confirm if cooperation is moving from informal coordination to structured and transparent processes. As part of the TBA Neretva JAP, they will demonstrate whether joint mechanisms are operating effectively, whether stakeholder engagement is inclusive, and whether capacity for monitoring and conflict resolution is being strengthened.

Legal & Fiscal indicators will measure whether laws, regulations, and financial tools are applied and support sustainable groundwater use. They will include licensing of wells and discharges, inspection and compliance rates, sanctions for violations, and cost-recovery mechanisms. These indicators will show if legal frameworks are harmonized across borders, if permits and sanctions are reducing risks, and if financial incentives are shifting behaviour toward efficiency and protection.

Technical indicators will assess the performance of measures that directly affect the aquifer and related ecosystems. They will track adoption of water-saving technologies, recharge volumes, groundwater level trends, and water quality changes. These indicators will confirm whether technical actions are achieving intended results, such as stabilizing flows and protecting vulnerable areas, and whether monitoring systems are fully operational and integrated across both countries.

Policy Planning indicators will verify that governance principles and technical evidence are being translated into actionable plans and review processes. They will measure whether operational plans are adopted and funded, targets for quantity and quality are defined, communication strategies are implemented, and conflict resolution mechanisms work. These indicators will ensure that progress is monitored against clear objectives and that plans are updated based on results and changing conditions.

Together, these four groups will provide a complete picture of implementation. Institutional indicators confirm governance structures; Legal & Fiscal indicators track compliance and incentives; Technical indicators measure physical and chemical responses; and Policy Planning indicators ensure actions are planned, financed, and reviewed. Applied across Chapters 8 to 12 of the TBA Neretva JAP, this framework will show what has been achieved and whether the foundations for effective transboundary groundwater governance are in place. It will allow the TBA Neretva JAP to report progress, identify gaps, and adapt measures based on evidence and stakeholder input.

7.6.2 Alignment with SAP and DIKTAS II Objectives

The proposed indicator framework for the Neretva TBA Joint Action Program (JAP) aligns closely with both the Strategic Action Program (SAP) objectives and the DIKTAS II project goals. SAP defines five long-term objectives: (1) ensuring sufficient groundwater quantity, (2) maintaining and improving groundwater quality, (3) protecting groundwater-dependent ecosystems (GDEs), (4) supporting equitable allocation of resources, and (5) raising awareness and building capacity. DIKTAS II operationalizes these through five components and six outcomes, focusing on governance, monitoring, harmonization of protection measures, and stakeholder engagement.

Institutional indicators directly support SAP Objective E (capacity building) and DIKTAS II Component 1 (multi-country cooperation). By tracking the establishment and functioning of joint bodies, expert groups, and stakeholder platforms, these indicators measure progress toward institutionalization of cooperation and conflict resolution mechanisms, which are essential for implementing SAP's vision of coordinated management.

Legal & Fiscal indicators correspond to SAP Objectives B and D and DIKTAS II Component 2 (institutional strengthening). Harmonization of sanitary protection zone criteria, enforcement of groundwater protection laws, and cost-recovery mechanisms are central to SAP's call for equitable and sustainable use. These indicators will demonstrate whether national frameworks are converging toward common standards and whether economic instruments are applied to discourage pollution and over-abstraction, in line with DIKTAS II outputs on legal harmonization and policy reform.

Technical indicators are fully aligned with SAP Objective A (groundwater quantity) and Objective B (quality), as well as DIKTAS II Component 3 (monitoring). They measure the implementation of modern multi-purpose monitoring networks, managed aquifer recharge, and remediation measures. These indicators provide evidence of progress toward SAP's priority action on joint monitoring and DIKTAS II's outcome of real-time data sharing and adaptive management.

Policy Planning indicators reinforce SAP Objective C (ecosystem protection) and DIKTAS II Components 4 and 5 (focus on vulnerable areas and awareness raising). By assessing adoption of operational plans, target-setting, and review cycles, these indicators ensure that technical and governance measures are embedded in actionable plans/strategies. They also support DIKTAS II's emphasis on communication, gender mainstreaming, and stakeholder involvement, creating transparency and accountability in implementation.

It should be emphasized that proposed indicator framework is a mechanism to operationalize SAP's strategic vision and DIKTAS II's adaptive management approach. It provides measurable benchmarks for governance, compliance, technical performance, and planning, ensuring that the JAP for Neretva TBA contributes to regional objectives for sustainable groundwater management and transboundary cooperation.

7.7 Summary Table: Recommended Measures

Table 16 Summary Table7.6.3: Recommended Measures

Category	Measure	Purpose	Expected outcome
Legal harmonization measures (6.1)	Addendum to the 1996 Agreement including groundwater; harmonised four-zone SPZ model with mutual recognition; common karst-specific vulnerability criteria; aligned rules for indirect discharges and irrigation permitting; legal basis for joint monitoring, early-warning, and data exchange adapted to strong agricultural pressures	Establish a coherent bilateral legal framework for the Neretva TBA that reflects karst vulnerability and intensive agricultural activity	Consistent SPZ protection; reduced regulatory gaps; predictable management of agricultural and tourism impacts; formalised joint monitoring and notification procedures
Policy integration & planning improvements (6.2)	Integrate SPZs and vulnerability maps into all spatial, agricultural, tourism, and energy plans; require early water-authority input in spatial planning; incorporate groundwater-sustainability criteria into irrigation programmes; include karst-specific requirements in tourism permits; strengthen cross-border planning for recharge areas	Ensure groundwater protection is systematically embedded across sectors that drive pressure in the Neretva basin, especially agriculture and tourism	Reduced land-use conflicts in recharge zones; agricultural measures aligned with groundwater vulnerability; better control of seasonal tourism impacts; more coherent sectoral planning across the TBA
Socio-economic measures for sustainable use (6.3)	Upgrade decentralized sanitation in high-risk settlements; reduce nutrient loads through nutrient-management plans, controlled manure storage, and fertiliser timing; support efficient irrigation; manage waste and illegal dumping; address peak-season pressure in tourism nodes; improve drinking-water resilience in both countries	Reduce socio-economic pressures on vulnerable karst areas and limit diffuse and seasonal contamination sources	Lower nitrate and pesticide risks; improved microbiological safety at springs; reduced tourism-season stress; more resilient and secure drinking-water supply

Category	Measure	Purpose	Expected outcome
Monitoring & data management enhancements (6.4)	Harmonised bilateral monitoring network covering springs, recharge zones, losing streams and agricultural hotspots; continuous sensors at key sources; nutrient and pesticide surveillance across cultivated poljes; joint protocols; interoperable DIKTAS II data platform; annual joint reporting with indicators	Provide a shared, credible evidence base for assessing groundwater status and managing agricultural and tourism pressures	Comparable datasets; early detection of pollution peaks; transparent data exchange; improved targeting of measures in high-risk recharge zones
Transboundary cooperation & governance (6.5)	Permanent bilateral coordination mechanism; joint emergency and incident-notification protocol; coordinated SPZ enforcement; structured engagement of municipalities, farmers, utilities and tourism operators; joint training in karst hydrogeology and diffuse agricultural pollution control	Move from project-based to institutionalised cooperation and ensure coordinated responses to shared risks	Faster cross-border response to contamination; improved enforcement capacity; stronger coordination with agriculture and tourism; regular joint decision-making
Implementation monitoring indicators (6.6.1)	Four-pillar indicator framework (Institutional; Legal & Fiscal; Technical; Policy & Planning) adapted to Neretva conditions, including indicators for irrigation impacts, nutrient-load reduction, seasonal tourism stress, and monitoring coverage	Enable structured and adaptive tracking of progress in a TBA with strong agricultural and seasonal pressures	Transparent evidence-based monitoring; early detection of gaps; adjustments to agricultural, sanitation and tourism measures; improved accountability across both countries

8. Conclusions

8.1 Key Findings from the Comparative Analyses

The comparison between Croatia and Bosnia and Herzegovina shows differences in how groundwater is managed. Generally, Croatia provides a stronger regulatory baseline, but operational enforcement should be improved further, while BiH faces systemic fragmentation and under resourcing. Croatia has a centralized, EU-aligned framework, with fully transposed WFD and GWD and detailed River Basin Management Plans. Bosnia and Herzegovina, by contrast, relies on fragmented entity laws, only partially aligned with EU directives.

Sanitary protection zones (SPZ) in Croatia are defined by clear hydrogeological criteria, time thresholds, and vulnerability mapping, but often delayed in spatial plan integration, while in BiH many municipalities have not prepared or updated SPZ studies. Sanitary protection zones differ between entities: FBiH applies karst-specific criteria, while RS uses uniform standards that overlook hydrogeological complexity. Croatia enforces sanitary zones centrally with uneven monitoring, while in BiH enforcement is fragmented or weak.

Monitoring remains a critical weakness. Croatia has expanded monitoring programs to include chemical and quantitative status, with specific protocols for karst aquifers and connectivity tests between groundwater and surface waters. Yet, data exchange remains fragmented and lacks a unified platform for systematic integration into planning and sectoral policies. In BiH, monitoring in karst is focused mainly on drinking water sources, with limited coverage of karst systems and no systematic ecological indicators.

Both Croatia and BiH prohibit direct discharges into groundwater. Croatia applies stricter conditions for indirect discharges but lacks MAR guidelines, while both entities in BiH allow indirect discharges under conditions but does not provide technical guidance Karst aquifers, recognized as highly vulnerable due to rapid flows and limited filtration, are addressed in Croatian RBMPs with tailored measures, but in BiH remain under-assessed and insufficiently integrated into planning instruments.

In Croatia, inspections follow structured, risk-based protocols and enforcement is stably financed through water-related fees while in BiH inspections are reactive, fee structures are fragmented and low. Croatia embeds water policy across spatial planning, agriculture, tourism, and energy with public participation, while in BiH water policy plays is not adequately embedded across other sectors, inter-entity cooperation weak, and groundwater rarely integrated into other sectors.

Both countries lack full integration of groundwater into agriculture, tourism, and energy strategies. 1996 bilateral agreement does not explicitly address groundwater, leaving cooperation without operational mechanisms.

Given the current divergent situation between Croatia and Bosnia and Herzegovina, the following measures are required to establish a coherent framework for joint management of the Neretva transboundary aquifer.

Joint legal harmonization is essential, including:

- An addendum to the 1996 Water Management Contract should be elaborated to include a shared hydrogeological reference for the Neretva aquifer, mutual recognition of cross-border sanitary protection zone(s), harmonized monitoring, reciprocal incident notification, and regular data exchange through a bilateral platform.
- Harmonisation regarding sanitary protection zones, including introduced four-zone model for karst sources based on hydrogeological investigation and vulnerability mapping. Cross-border zones must be mutually recognized and integrated into spatial plans, with clear rules for activities to ensure coherent land-use management.
- Permitting and discharge control procedures need to be harmonized based on Croatia system using shared templates and joint technical guidance. BIH and Croatia should also develop a common framework for managed aquifer recharge in karst, enabling coordinated pilot projects under controlled conditions.
- Establishment of joint monitoring program with harmonized networks, parameters, and sampling, supported by continuous monitoring at key springs and seasonal checks in recharge zones. Digital platform for real-time data exchange and codify early-warning protocols should be available to ensure rapid communication and coordinated emergency measures.

Both countries should:

- align abstraction and discharge fees to reflect environmental costs and establish cooperative cost-sharing for cross-border impacts.
- strengthen enforcement through aligned, risk-based inspections and annual transboundary compliance reviews.
- adopt shared guidelines for contaminated-site investigation and groundwater remediation in karst to ensure predictable and coordinated action.
- harmonize public-participation rules with clear timelines and access to studies should strengthen legitimacy. Annual groundwater notes, SPZ maps, and monitoring summaries must be published in a transparent, user-friendly format.

Groundwater governance in the TBA Neretva must be integrated into all relevant planning instruments. Both countries shall ensure that River Basin Management Plan objectives are explicitly referenced in spatial, tourism, agriculture, energy, and transport planning, so that groundwater vulnerability is consistently addressed across sectors.

Cross sectoral integration is essential to strengthen resilience, ensure coherent land use management, and protect groundwater dependent ecosystems. Spatial planning should ensure that SPZ and vulnerability layers have direct planning relevance in zoning, building permits, and strategic environmental assessments: Tourism, agriculture, energy, hydropower, and public health regulations should adapt their licensing, operational standards, and compliance measures to reflect these planning requirements.

Financial instruments must prioritize investments that reduce groundwater risk, including sanitation upgrades, leakage control, and monitoring infrastructure. Eligibility criteria and scoring systems shall reflect these priorities to ensure public finance supports protective measures.

Socio-economic measures are critical. Rural sanitation must be upgraded, tourism pressures managed, waste controlled, and drinking-water security reinforced. Agriculture should adopt practices compatible with karst vulnerability, while economic incentives and targeted financing should focus on high-risk areas. Public awareness and community engagement are essential to strengthen stewardship.

Monitoring and data management must be harmonized and expanded. A shared conceptual model, common protocols, and interoperable data exchange will provide a reliable evidence base. Automatic monitoring, risk-based approaches, and capacity building will improve early detection and response. Transparency must be ensured through accessible results and public communication.

Cross-border cooperation must be stable and structured. A permanent coordination mechanism should oversee dialogue, monitoring, and joint responses. Shared standards for sanitation, harmonized tourism requirements, rapid emergency communication, and inclusive stakeholder engagement will ensure resilience.

8.2 Strategic Priorities for Groundwater Governance in TBA Neretva

Groundwater in the TBA Neretva is a vital karst resource, highly vulnerable to contamination and essential for drinking water, ecosystems, and socioeconomic development. Strategic priorities should be established jointly by Bosnia and Herzegovina and Croatia, aligned with EU legislation, national River Basin Management Plans, and bilateral agreements. The following four priorities define the strategic focus for Bosnia and Herzegovina and Croatia in safeguarding this shared aquifer:

1. Groundwater Governance and Legal Alignment between Croatia and Bosnia and Herzegovina
   This priority emphasizes harmonized legal and institutional frameworks, mutual recognition of sanitary protection zones, and strengthened roles for the Joint Water Management Commission. It ensures that governance reflects socio economic realities, institutional capacities, and future demand projections, while the adapted bilateral Water Management Agreement between Bosnia and Herzegovina and Croatia provides the binding foundation for transboundary coordination and long-term sustainability.

2. Resource Assessment, Monitoring, and Risk Evaluation

   This priority establishes a harmonized methodology for assessing groundwater reserves, supported by aquifer characterization and vulnerability mapping. It also includes harmonized monitoring networks, shared data platforms, and standardized criteria for evaluating groundwater and ecosystem status, providing the scientific basis for sustainable and equitable use.

3. Protection and Remediation

   This priority highlights preventive measures such as vulnerability and risk mapping, harmonized sanitary protection zones, and land use controls to safeguard drinking water sources. It also addresses contamination risks, including microbiological and PCB pollution, through targeted remediation and coordinated transboundary oversight.

4. Implementation, Transparency, and Adaptive Management

   This priority defines performance indicators, reporting procedures, and review cycles to ensure transparency and stakeholder involvement. It promotes adaptive management of the Joint Action Program, linking financial instruments and community participation to long term sustainability.

8. Annexes

8.1 List of References

I. Policy, Legal and Regulatory Framework in Croatia

1. Agriculture Strategy of the Republic of Croatia until 2030, Official Gazette No. 26/2022.
2. Environmental Protection Act, Official Gazette No. 80/2013, 153/2013, 78/2015, 12/2018, 118/2018.
3. Forest Act, Official Gazette No. 68/2018, 115/2018, 98/2019, 32/2020, 145/2020, 101/2023, 36/2024.
4. Nature Protection Act, Official Gazette No. 80/2013, 15/2018, 14/2019, 127/2019, 155/2023.
5. Regulation on Emission Limit Values for Wastewater, Official Gazette No. 26/2020.
6. Regulation on Water Quality Standards, Official Gazette No. 96/2019, 20/2023, 50/2023.
7. Regulation on Water Service Pricing Methodology, Official Gazette No. 70/2023.
8. River Basin Management Plan of the Republic of Croatia until 2027, Official Gazette No. 84/2023.
9. Rulebook on Conditions for Establishing Sanitary Protection Zones of Water Sources, Official Gazette No. 66/2011, 47/2013.

10. Rulebook on Conformity Parameters, Analytical Methods, and Monitoring of Water Intended for Human Consumption, Official Gazette No. 64/2023, 88/2023.
11. Rulebook on Technical Requirements for Drainage Structures, Official Gazette No. 3/2011.
12. Rulebook on the Issuance of Water Acts, Official Gazette No. 9/2020, 39/2022.
13. Spatial Development Strategy of the Republic of Croatia, Official Gazette No. 106/2017.
14. Sustainable Tourism Development Strategy of the Republic of Croatia until 2030, Official Gazette No. 2/2023.
15. Transport Development Strategy of the Republic of Croatia 2017–2030, Official Gazette No. 84/2017.
16. Waste Management Act, Official Gazette No. 84/2021.
17. Waste Management Plan of the Republic of Croatia for the Period 2023–2028, Official Gazette No. 84/2023.
18. Water Act, Official Gazette No. 66/2019, 84/2021, 47/2023.
19. Water for Human Consumption Act, Official Gazette No. 30/2023.
20. Water Management Financing Act, Official Gazette No. 153/2009, 90/2011, 56/2013, 154/2014, 119/2015, 120/2016, 127/2017, 66/2019, 36/2024.
21. Water Management Strategy of the Republic of Croatia, Official Gazette No. 91/2008.
22. Water Services Act, Official Gazette No. 66/2019, 84/2021, 47/2023, 110/2024.

II. Policy, Legal and Regulatory Framework in Bosnia and Herzegovina

1. Agriculture and Rural Development Strategy of the Federation of Bosnia and Herzegovina 2021–2027, Official Gazette of the Federation of BiH No. 52/24.
2. Agriculture and Rural Development Strategy of the Republic of Srpska 2021–2027, Official Gazette of RS No. 123/21.
3. Decision on the Characterization of Surface and Groundwater, Reference Conditions and Parameters for Assessing the Status of Water, and Water Monitoring, Official Gazette of the Federation of BiH No. 1/14.
4. Energy Development Strategy of the Federation of Bosnia and Herzegovina until 2035, Official Gazette of the Federation of BiH No. 28/20 (2020).
5. Energy Development Strategy of the Republic of Srpska until 2035, Official Gazette of RS No. 49/09.
6. Environmental Protection Strategy of the Republic of Srpska 2022–2032, Official Gazette of RS No. 96/22.
7. Law on Spatial Planning and Construction of the Republic of Srpska, Official Gazette of RS No. 40/13.
8. Law on Spatial Planning and Land Use of the Federation of Bosnia and Herzegovina, Official Gazette of the Federation of BiH Nos. 2/06, 72/07, 32/08, 4/10, 13/10, 45/10, 85/21, 92/21, 72/24.
9. Regulation on Amendments and Supplements to the Regulation on Conditions for Discharge of Wastewater into the Environment and Public Sewerage Systems, Official Gazette of the Federation of BiH No. 01/24.

10. Regulation on the Characterization of Surface and Groundwater, Reference Conditions and Parameters for Assessing Water Status and Monitoring, Official Gazette of RS No. 1/14.
11. Regulation on the Classification of Waters and Categorization of Watercourses, Official Gazette of FBiH No. 18/99.
12. Regulation on the Classification of Waters and Categorization of Watercourses, Official Gazette of RS No. 42/01.
13. River Basin Management Plan for the Adriatic Sea Basin in the Federation of Bosnia and Herzegovina (2022–2027).
14. River Basin Management Plan for the Sava River Basin in RS 2016–2021, Official Gazette of RS.
15. River Basin Management Plan for the Sava River Basin in the Federation of Bosnia and Herzegovina (2022–2027).
16. River Basin Management Plan for the Trebišnjica/Adriatic Basin in RS 2016–2021, Official Gazette of RS.
17. Rulebook on Conditions for Discharge of Wastewater into Public Sewerage Systems.
18. Rulebook on Conditions for Discharge of Wastewater into Surface Waters, Official Gazette of RS No. 44/01.
19. Rulebook on Determining Areas Prone to Eutrophication and Sensitive to Nitrates, Official Gazette of the Federation of BiH No. 71/09.
20. Rulebook on Measures of Protection, Method of Determining and Maintaining Sanitary Protection Zones of Water Sources and Facilities, Official Gazette of RS No. 7/03.
21. Rulebook on Monitoring in Areas Prone to Eutrophication and Sensitive to Nitrates, Official Gazette of the Federation of BiH No. 71/09.
22. Rulebook on Monitoring of Surface and Groundwater (FBiH), Official Gazette of the Federation of BiH No. 71/09.
23. Rulebook on the Method of Determining Conditions for Establishing Sanitary Protection Zones and Protective Measures for Water Sources for Public Water Supply of the Population, Official Gazette of the Federation of BiH No. 88/12.
24. Rulebook on the Treatment and Drainage of Wastewater for Urban Areas and Settlements without Public Sewerage Systems, Official Gazette of RS No. 68/01.
25. Tourism Development Strategy of the Federation of Bosnia and Herzegovina 2022–2027, Official Gazette of the Federation of BiH No. 88/23.
26. Tourism Development Strategy of the Republic of Srpska 2021–2027, Official Gazette of RS No. 119/21.
27. Water Management Strategy of the Federation of Bosnia and Herzegovina 2022–2032, Official Gazette of the Federation of BiH No. 9/23.
28. Water Management Strategy of the Republic of Srpska, Government of RS, 2012.
29. Water Strategy of the Federation of BiH, Government of FBiH, 2012.

III. Reports, Studies, Papers, Guidelines, Regional Plans and Strategies

1. Food and Agriculture Organization of the United Nations (FAO) (2011): Guide to Good Hygiene Practices for Small-scale Livestock Farming, Rome.

2. DIKTAS Country Report – Bosnia and Herzegovina**,** 2012.
3. DIKTAS Country Report – Croatia, 2012.
4. UNESCO / IHP – GEF (2015): DIKTAS Phase I – National Report: Bosnia and Herzegovina. Assessment of water use, pressures and pollution sources in the TBA Neretva.
5. UNESCO / International Hydrological Programme (IHP) – GEF (2015): Governance of Groundwater Resources in Transboundary Aquifers (GGRETA) – Phase I: Transboundary Diagnostic Analysis (TDA), Paris: UNESCO.
6. Agency for Statistics of Bosnia and Herzegovina (2016): 2013 Population Census – Final Results, Sarajevo.
7. UNESCO / International Hydrological Programme (IHP) – GEF (2016): Strategic Action Programme (SAP) for the Governance of Transboundary Aquifers, Paris: UNESCO.
8. FAO, UNESCO-IHP, IAH, GEF (2016): Global Framework for Action (FFA) to achieve the Vision on Groundwater Governance, the final output of the Project "Groundwater Governance — A Global Framework for Action".
9. World Health Organization (2017): Guidelines for Drinking-water Quality (4th edition), Geneva.
10. European Environment Agency (2018): CORINE Land Cover – Bosnia and Herzegovina and Croatia, Copenhagen.
11. International Commission for the Protection of the Danube River (ICPDR) (2021): Danube River Basin Management Plan – Update 2021, Vienna.
12. Croatian Bureau of Statistics (2022): 2021 Population Census – Final Results, Zagreb
13. UNESCO / International Hydrological Programme (IHP) – GEF (2023): GGRETA Phase II (DIKTAS II): Project Documentation and Methodological Guidance, Paris: UNESCO (internal project documentation).
14. DIKTAS-2 Working Group Records and Regional Diagnostic, UNESCO-IHP, 2023–2024
15. Stakeholder Awareness Activities under DIKTAS-2 BiH**,** WWF Adria & Center for the Environment, 2024.
16. Expert inputs and stakeholder consultations (2024–2025): Contributions from sectoral experts on socio-economic conditions, groundwater use, sanitation, gender considerations and stakeholder engagement within the DIKTAS II project framework.
17. Global Environment Facility (GEF): Transboundary Diagnostic Analysis (TDA) Methodology. GEF International Waters Programme, Washington, D.C.
18. United Nations Educational, Scientific and Cultural Organization (UNESCO) – International Hydrological Programme (IHP): Transboundary Aquifers of the World: Map and Methodology. UNESCO-IGRAC, Paris, United Nations Development Programme (UNDP).
19. DIKTAS Phase I and Phase II Project Documentation, UNDP, Sarajevo / Zagreb.

IV. International and Bilateral Contracts and Agreements

1. Barcelona Convention – Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (1976, revised 1995).
2. Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Helsinki, 1992.
3. Convention on the Transboundary Effects of Industrial Accidents, Helsinki, 1992.
4. Convention on Cooperation for the Protection and Sustainable Use of the Danube River, Sofia, 1994.
5. Contract between the Government of the Republic of Croatia and the Government of Bosnia and Herzegovina on Water Management Relations, Dubrovnik, 1996.
6. Framework Agreement on the Sava River Basin, Kranjska Gora, 2002.

8.2 Stakeholder Lists

CROATIA			
Stakeholder group	**Key Actors**	**Mandates / Roles**	**Relevance to Groundwater**
National Authorities	Ministry of Environmental Protection and Green Transition; Ministry of Agriculture	Water policy, groundwater protection standards, agriculture regulation	High – sets regulatory framework
Water Management Institutions	Croatian Waters (Hrvatske vode)	Monitoring, abstraction permits, enforcement, protection zones	Very High – core technical authority
County Governments	Dubrovnik Neretva County	Spatial planning, environmental oversight	High influences recharge zones
Municipalities	Metković, Opuzen, Ploče, rural municipalities	Local planning, sanitation, inspections, waste management	High local control over diffuse pressures
Public Water Utilities	Local water utilities	Drinking water abstraction and supply	High dependent on groundwater quality
Agriculture Stakeholders	Farmers, cooperatives, agribusiness operators	Irrigation, fertilizer and pesticide use	Very High dominant groundwater users
Waste Management Services	Municipal service providers	Waste collection & disposal	Medium – prevent illegal dumping
Tourism Stakeholders	Agri tourism providers, small accommodation	Seasonal water use, wastewater generation	Medium localized pressure

CROATIA			
Stakeholder group	**Key Actors**	**Mandates / Roles**	**Relevance to Groundwater**
Civil Society	Local NGOs, community associations	Awareness, reporting, advocacy	Medium – support monitoring and engagement
Local Communities	Rural settlements, farming households	Household sanitation and land use practices	High diffuse impact

BOSNIA AND HERZEGOVINA			
Stakeholder group	**Key Actors**	**Mandates / Roles**	**Relevance to Groundwater**
Entity Authorities	FBiH Ministry of Agriculture, Water Management and Forestry	Water governance, regulation, permitting	High – defines policy & oversight
Cantonal Authorities	Herzegovina Neretva Canton	Environment, spatial planning, communal services	High – strong operational influence
Municipal Authorities	Konjic, Jablanica, Mostar	Spatial planning, wastewater, inspections	High – manages urban/peri-urban pressure
Public Water Utilities	Vodovod Mostar; local utilities	Groundwater abstraction and supply	Very high – critical dependency
Energy Sector	Hydropower operators	Flow regulation, reservoir management	High indirect influence on groundwater
Industry	Small manufacturers and processors	Water use and wastewater discharge	Medium localized risks
Protected Area Authorities	Nature protection bodies	Conservation and visitor management	Medium potential protection leverage

BOSNIA AND HERZEGOVINA			
Stakeholder group	**Key Actors**	**Mandates / Roles**	**Relevance to Groundwater**
Tourism Stakeholders	Rafting operators, hotels, restaurants	Seasonal water use and wastewater loads	Medium to high seasonal pressure
Agriculture Stakeholders	Farmers and livestock holders	Irrigation and manure management	Medium – diffuse pollution risk
Civil Society & NGOs	Environmental NGOs, youth groups	Monitoring, awareness, advocacy	Medium – strong local engagement
Local Communities	Urban and rural residents	Daily sanitation and land use behaviour	High cumulative impact
Research & Academia	Universities, hydrologists	Data, studies, assessments	Medium – evidence base

CROSS-BORDER COORDINATION ROLES – TBA NERETVA				
Actor / Institution	**Country**	**Mandate in National System**	**Role in Cross-Border Cooperation**	**Priority Coordination Functions**
Croatian Waters (Hrvatske vode)	Croatia	Groundwater monitoring, abstraction control, protection zones, WFD/GWD compliance	Core technical counterpart to BiH water institutions	Joint monitoring design Data harmonization Groundwater quality assessment Early warning & incident communication
Public Water Utilities (Mostar, Konjic, Jablanica)	Bosnia and Herzegovina	Groundwater abstraction and public water supply	Key upstream and midstream operational actors	Sharing abstraction and quality data Joint risk assessment Emergency response coordination
Ministry of Environmental	Croatia	National water/waste/environment policy	Strategic-level coordination, legislative alignment	Legal harmonisation Transboundary agreements

CROSS-BORDER COORDINATION ROLES – TBA NERETVA				
Actor / Institution	**Country**	**Mandate in National System**	**Role in Cross-Border Cooperation**	**Priority Coordination Functions**
Protection and Green Transition				Strategic guidance
FBiH Ministry of Agriculture, Water Management and Forestry	Bosnia and Herzegovina	Water governance, permitting, regulation	Strategic coordination and regulatory alignment	Harmonising standards Coordinating permits affecting transboundary zones
Herzegovina Neretva Canton	Bosnia and Herzegovina	Environment, spatial planning, communal services	Operational coordination with Croatian county authorities	Land use alignment Sanitation priorities Hotspot mapping
Dubrovnik Neretva County	Croatia	Spatial planning and environmental oversight	Downstream operational partner	Coordination on agricultural pressure Sanitation planning Awareness initiatives
Municipalities (Mostar, Konjic, Jablanica, Metković, Opuzen, Ploče)	HR & BiH	Local sanitation, wastewater management, inspections	Front line implementation actors	Local incident reporting Sanitation improvements Community engagement
Hydropower Operators	Bosnia and Herzegovina	Energy generation and river regulation	Indirect but influential transboundary actors	Flow regime coordination Information sharing on operational changes
Agricultural Authorities and Cooperatives	HR & BiH	Irrigation management and agricultural support	Sector specific coordination	Irrigation efficiency Nutrient management Salinization risk reduction
Environmental NGOs and Civil Society	HR & BiH	Awareness raising, monitoring, advocacy	Informal facilitators of cooperation	Reporting pollution hotspots Public awareness Trust building
Research & Academic Institutions	HR & BiH	Hydrology, karst research, data analysis	Technical support to cooperation	Joint studies

CROSS-BORDER COORDINATION ROLES – TBA NERETVA				
Actor / Institution	**Country**	**Mandate in National System**	**Role in Cross-Border Cooperation**	**Priority Coordination Functions**
				Data interpretation Methodology alignment
UNESCO / DIKTAS II Partners	International	Coordination of project activities, facilitation	Catalytic role in formalising cooperation frameworks	Supporting joint platforms, tools, reporting, and dialogue mechanisms