

Article

# A new dialectical model of water security under climate change

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**Abstract:** The way humans use natural resources and especially freshwater, reflects their relationship with nature. It also influences the conceptual Water Resources Management (WRM) model. A historical review shows that the interplay between Humans and Nature is diachronically in constant change between two opposites: conflict and cooperation. Lessons from the past 20.000 years indicate that the WRM model is a function of two main parameters: (1) socio-economics, and (2) climate conditions. Three different Eras of the Humans-Nature relationship have been distinguished: (1) *Naturalistic*: Nature dominating Humans during the Last Glacial Period (100-10) kyr BC, (2) *Dualistic*: Nature-Humans both in cooperation and competition from 10 kyr BC to 1800 AD, and (3) *Anthropocentric*: Humans dominating Nature from 1800 AD to now. Since 2000, the Integrated WRM (IWRM) model is promoted as state-of-the-art and remains anthropocentric producing huge externalities. Its assessment during the last 20 years has given mixed results and needs to be improved. The new model we suggest is based on the dialectical tool for conflict resolution. It unifies Humans and Nature and enhances the social dimension of WRM. After identifying conflicts between stakeholders and the natural laws (eristic part), opposite objectives are unified to harmonize Humans with Nature (dialectical resolution). A case study of flood mitigation illustrates the eristic-dialectical methodology.

**Keywords:** water management; climate history; humans-nature cooperation; conflict resolution; dialectics

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## 1. Introduction

Among multiple severe environmental challenges we face today, water security under climate change is the most prevailing for humans and the future of life on our planet. According to UN Secretary-General, climate change is “the defining issue of our time” [1]. From different interpretations of the meaning of water security provided by International and UN Organizations, such as [2], we may consent that it is a goal to guarantee a sufficient quantity of freshwater of good quality for humans and nature, including plants, animals and all ecosystems under climate variability and natural disasters, such as droughts and floods. More frequent catastrophic floods and extensive droughts in different regions around the world, the flow rate reduction of big rivers, aquifer depletion, and diffuse pollution indicate that water security is today at risk for several reasons.

Firstly, a constant global population increase and overuse of freshwater resources. The curve showing the time variation of the total population on Earth is continuing to increase so that today's humanity counts almost 8 billion inhabitants. More people mean more water and food to be provided. For human subsistence, the necessary amount of water per capita is set by water utilities and the UN's recognition of water as a human right generally to 150 l/day. This is a small portion of the total quantity of water necessary to sustain life on the planet. It includes water for drinking and other human socio-economic activities, agricultural food production, and water necessary to sustain plants, animals, and all ecosystems. A rough estimation of this quantity of water per capita is up to 3000 l/day [3]. The need for this huge quantity of water becomes evident when, during periods of extended drought, big rivers are almost drying out (Yellow River in China, Colorado River in the USA, and Rhine River in Europe).

Secondly, the way humans use diachronically natural water resources. For human activities, especially for agriculture, the water used is the same freshwater shared with nature for the needs of ecosystems, plants, animals, and land vegetation. During the last 10 thousand years, extensive agricultural activities for food production have modified the natural landscape and impacted the hydrological water cycle. Vital components of the water cycle have been modified like evapotranspiration enhances rainfall was increased and infiltration that fills up aquifers decreased. Impact on water quality from intensive industrial and agricultural practices, and huge quantities of pesticides and fertilizers have produced soil degradation and diffuse pollution. Negative impacts on air, soil, and water are persisting to different degrees and make remediation efforts very difficult [4].

Thirdly, limited results produced by the global UN submits called COPs, and recently the COP27 in Sharm el-Sheikh, Egypt, 6-20 November 2022, made the progress for climate mitigation and adaptation more uncertain. Starting in 2000, different COPs aimed to reach International Agreements for reducing greenhouse gaseous emissions and reversing the carbon footprint from fossil energy sources to renewable forms of energy. As a result, the climate crisis is growing with a rise of the average global temperature of about 1.5°C, acceleration of glaciers melting, and more atmospheric instabilities. Concerning the goal of water security, modification of rainfall patterns in the hydrosphere has increased extreme floods. At the same time, droughts of extended duration and water scarcity in regions of temperate climate have threaded local economies, such as those located in South Eastern USA, and Central and Northern Europe. In the summer of 2022 for example, big rivers like the Rhine have seen their flow rate drastically reduced. Also recently, southern areas of Sweden have experienced unusual water scarcity.

To respond to these challenges and increase resilience in water security, innovative global solutions are needed [5], [6]. One powerful tool that humanity has already experienced in the past, especially in the Western World is the progress continuously made in scientific and technical innovation and the application of technical infrastructure. However, as we analyze in this paper, without a conceptual framework on how to reach global sustainable goals, the application of advanced technological solutions alone is not effective in the long term. On the contrary, although technical solutions may increase the benefits for humans, like energy and food, they could decrease renewable natural resources by creating huge environmental externalities, like pollution and loss of biodiversity. In this paper, we explore ways of enhancing water security in two steps:

- 1) Through a historical review, we investigate possible correlations between human socio-economic practices, like agriculture, industry, and cultural achievements on the one hand, and natural climate conditions on the other hand. Water-related human activities such as WRM (Water Resources Management) could be either in accordance or in conflict with natural laws, like the water cycle and climatic stability. The historical review reveals how humans have perceived their relationship to the natural environment and how ancient civilizations have been confronted with natural threats. We may learn useful lessons, not for coming back to the past, where natural and human socio-economic conditions were quite different, but for defining a conceptual model harmonizing water and environmental security with human prosperity. From the historical revision, we have concluded that Humans-Nature interaction is in constant change, oscillating during different historical periods between three different states: (a) humans being dominated by nature; (b) conflict and cooperation coexisting between the two parts, and (c) humans dominating nature.

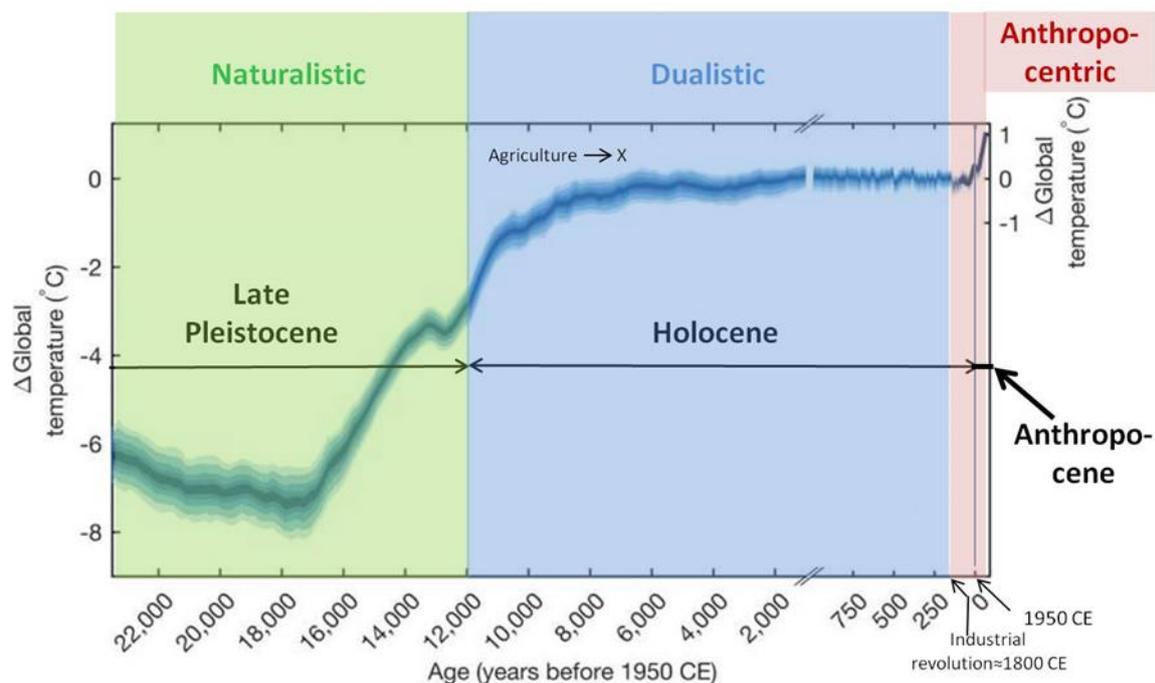
- 2) WRM practices influence water policy and governance through complex bilateral interactions between science, policy, and governance. Governance, Policy, and Science are interrelated in a complex process that may form an entity we call GPSN (Governance-Policy-Science Nexus). To understand how GPSN works in practice, WRM practices through data, knowledge, and science involving different Human-Nature interplays were identified as the main drivers of water governance. Since the year 2000, the Integrated WRM (IWRM) model is considered the state-of-the-art model for WRM. It takes into account technical, economic, social, and environmental considerations. Its application in policy, as in the case of the European Union's Water Framework Directive (EU-WFD) has produced several negative environmental impacts, such as diffuse pollution, groundwater depletion, and soil degradation. To increase resilience in water security we propose to improve the IWRM model by adding a social dimension by activating stakeholder participation. This is done in two steps:

(a) assessing conflicts between natural laws and human socio-economic activities (Eristic Analysis), and (b) resolving these conflicts dialectically (Dialectical Resolution), as it is explained in the following chapters.

## 2. Dialectical Humans-Nature interplay between conflict and cooperation

Although humans are closely related to nature and are part of it, they feel necessary to compete with natural forces to survive and improve their living conditions. This is not only for protecting themselves from natural disasters, such as floods, hurricanes, and tsunamis but also for controlling, appropriating and even mastering natural resources, such as water, food, and energy. This was obvious during the prehistoric period when humans struggled to survive in a hostile environment dominated by wild animals, floods, volcano eruptions, and low temperatures. During the era between 100 and 10 thousand years ago, a period scientists call the “Pleistocene”, they have had experienced different severe climatic hazards. As shown in Figure 1, during the Late Pleistocene, i.e. between 20 to 10 thousand years ago, our planet was dominated by low temperatures going down to  $-8^{\circ}\text{C}$ . During that period, securing life under severe climate conditions was a priority. Scientific developments and technical tools to manage natural resources, such as big rivers, and reduce impacts from floods were almost inexistent. During that period humans considered cosmic forces like the Sun [7] as Gods controlling human existence. Nature was dominating humans and therefore we may call that period “Naturalistic” (Figure 1).

After the Late Pleistocene, which was the last glacial period, the global temperature on Earth was steadily increasing to reach a constant mean value around 8000 years ago, as we can see in Figure 1. The geological age that started around 10.000 years ago has been particularly beneficial to humans and is called the “Holocene” or the “Age of Man” (Figure 1).



**Figure 1.** Humans-Nature interplay between Naturalistic, Dualistic, and Anthropocentric status during the last 24.000 years. Adapted from [8].

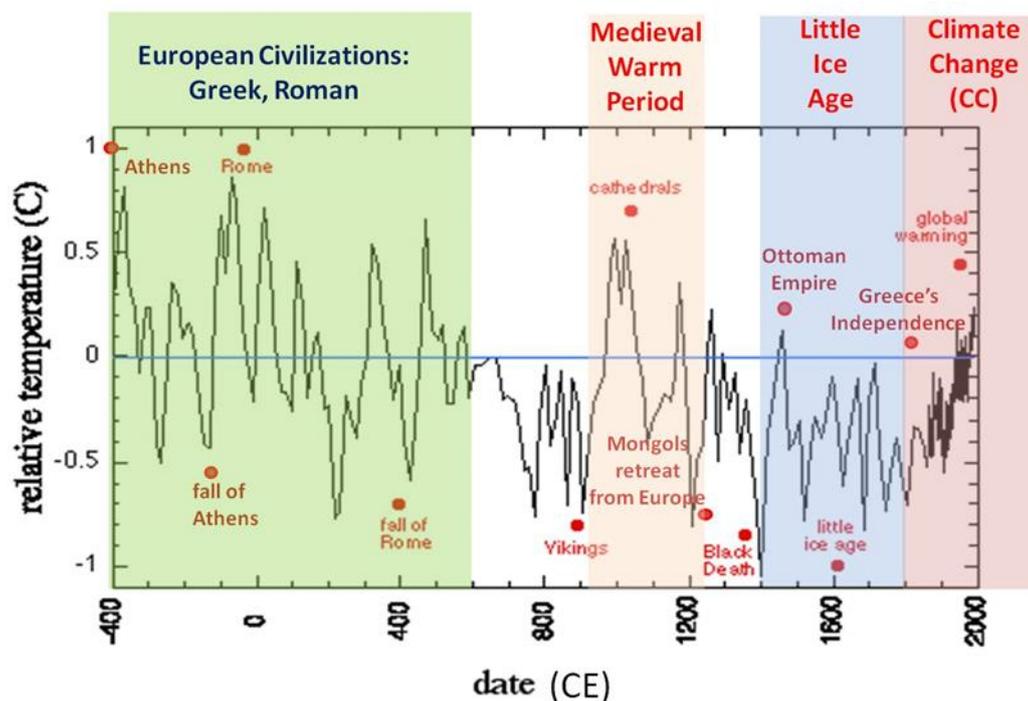
During the Holocene period, humanity started experiencing new ways of living and developing healthy socio-economic activities, especially in agriculture and trade. Social interaction and cultural progress have been facilitated by creating larger human settlements and the first important cities that flourished in places of fertile agricultural land. Extensive agriculture has been developed with large quantities of irrigation water from big rivers like the Nile in ancient Egypt, the Tigris and Euphrates in Mesopotamia (Middle-East), the Indus River valley in Asia, China, and South America. Old cities

like Babylon, located in present-day Iraq, have founded more than 4000 years ago and ancient civilizations like the Minoan [9] go back more than 3000 years. They have been developed in islands and coastal areas across the Mediterranean as nautical powers trading artifacts, potteries, and agricultural products between cultural centers like Knossos on the island of Crete and Mycenae and Pylos in the Peloponnese.

Advanced water infrastructure for drinking water supply and sanitation have been found in Knossos, Crete island, and subterranean aqueducts known as Canats for transporting groundwater by gravity, have been discovered and implemented in ancient Persia, Egypt, and China for water supply and irrigation. At the same time, the Norias of Hama, big circular hydraulic pieces of machinery were invented in the city of Hama, Syria to elevate water from the Orontes River to a higher elevation for irrigation. Norias were tall water wheels with a series of boxes collecting by circular movement water from the river and depositing it in the irrigated field located higher. There is strong evidence Norias were in operation by Romans in Syria at least by 350 CE

The time from 600 BC to 600 CE is marked by the rise and fall of the Greek and Roman civilizations in Europe. As we can see in Figure 2, there is a correlation between high temperatures and the time of big achievements of these two civilizations. In the same graph, we can observe that the fall of Athens and Rome took place in periods of low temperatures. Low temperatures are also noticed with the southern expansion of Vikings, the retreat of Mongols from Europe, and the “Black Death” pandemics (Figure 2).

From 480 BC to the year 400 BC Athens, the glorious city-state in Greece experienced the most prosperous economic and cultural growth in its history, known as the “Golden Age” of the Athenian democracy under Pericles.



**Figure 2.** Humans-Temperature interaction from 400 BC to 2000 CE. Adapted from [10].

Athens, often called the cradle of Western Civilization, has invented the democratic rule of governance, leading the city by the will of the majority of its citizens. Democracy in Athens was copied by other states at that time and until today, even with some negative symptoms related to populism and the lack of public culture, it is considered as the most prominent system of political governance. Athenian democracy enhanced the explosion of arts, such as theater, music, and poetry, the roots of scientific progress led by strong individuals like Aristotle, Plato, and Socrates. Greek philosophers were also pioneers in studying natural phenomena without referring to religious thinking and

believing in extra natural forces. The progress made in mathematics, astronomy, social sciences, and logic by the "School of Athens" and its colonies in Ionia, today's coastal Mediterranean Turkey, Sicily, and South Italy have been recorded as the fundamentals of Western science and civilization. These collective cultural achievements could not be possible without a strong military force, and a considerable naval power, that made Athens able to resist Persian invasions and build healthy economic activities of maritime trade across the Mediterranean. Its power was dominant in Greece and the Mediterranean, building colonies and strong alliances with cities located mainly in the Aegean islands, the Middle East, the Black Sea, and Southern Italy.

Concerning the use and management of water resources, the Greeks refined different techniques of ancient civilizations, such as the implementation of technical infrastructure for urban water supply and irrigation. To transport water from springs in higher elevations they were able to construct subterranean aqueducts conveying with high precision water by gravity over several miles. Well known is the Eupalinos tunnel in Samos Island [11], dated back to the 6<sup>th</sup> Century BC, and in the same period the Peisistraton subterranean aqueduct in ancient Athens, in partial operation until today. Furthermore, a well-known hydraulic device invented by the Greeks is the Archimedes hydrodynamic screw which has been used in Hellenistic Egypt from around 234 BC and is named after the Greek mathematician Archimedes. Also known as the Hero of Alexandria, a Greek mathematician and engineer, who used to live in Alexandria, Egypt where he discovered, following the Hellenistic tradition, the first steam-powered device and a wind-powered engine. The first legislation to control individual and public wells for groundwater supply in ancient Athens was promoted by Solon, around the 5<sup>th</sup> Century BC [12].

The Romans become famous for building the Roman Empire based on strong military power and special organizational skills. They have been distinguished as engineers and architects with special skills in building huge public temples and buildings, such as the Pantheon and the Coliseum in Rome. They also improved the construction of aqueducts in the form of strong bridges, made by a succession of rounded arcs to support open flow channels, able to transport to cities water over long distances [13].

In the Holocene period that started about 10.000 years ago (Figure 1) and then, during the Western European civilization from 400 BC to 500 CE, as shown in Figure 2, mild temperatures contributed to developing a more comfortable human life and modify the interrelation between humans and nature. However, the progress in arts and sciences was not sufficient or strong enough to support human efforts to dominate natural resources and domesticate wild living ecosystems. Not only in Europe but also in Asia, India, China, and South America local religions such as paganism in ancient Greece and Rome [14], and the Hindus in ancient India had considered rivers and streams as Gods. In the period of classical antiquity, humans were able to dam relatively small rivers to control and divert the flow for irrigation and protect their cultures from possible floods. They have developed a mixed relationship with nature, oscillating between friendly and adversarial. The Ilissos River in Athens is depicted as a statue of Man-God in the form of a young man on the western pavement of the Parthenon [15]. In the same period, the mythical hero Hercules is shown in Athenian potteries fighting the River Achelous, having the form of a big snake that had produced catastrophic floods in continental Greece [16].

The dual behavior of conflict and cooperation between humans and nature during the classical period can be named "Dualistic". It was continuously present during the adoption of the Christian religion in the Roman Empire and beyond it. As shown in Figure 2, during the "Middle Ages" 500-1400 CE and mainly in the "Early Modernity" 1400-1800 CE, Europe experienced a dramatic economic and cultural expansion, culminating in the collapse of the old noble regime, the French Revolution (1789) and the Industrial Revolution (1800). The idea that humans are part of nature and at the same time by developing their one culture are placed out of it was also promoted in Geneva by the French philosopher Jean-Jacques Rousseau [17].

After the years of successive industrial revolutions started in 1800, the exponential growth of sciences and technology has reinforced the human belief in the possibility of mastering natural processes on a big scale. Most of the rivers in the Western World and also in the Greater South have been modified by a succession of dams to form artificial waterways for producing hydropower. A

milestone of this human ability to dam big rivers is the construction in 1935 of the Pharaonic Hoover Dam in the Colorado River, USA [5]. The drainage of huge humid regions and shallow lakes for agricultural purposes has been called “reclamation work”, aiming to improve the quality of human life by threatening ecosystem services and reducing water resilience. Economists have named these negative environmental impacts as “externalities” and engineers thought of being able to remediate ecological disasters. We may call this human behavior “anthropocentric”, i.e. “human-centered”, restricting values to human beings. This human attitude against nature has produced a strong footprint so a group of scientists has proposed to call that period the “Anthropocene”, i.e. the era of humans (Figure 1 and [6]).

From the previous historical peregrination, we may recapitulate some lessons learned on humans-nature interaction and consequently on water security as follows:

(1) Humans, although enfolded in nature and influenced by natural processes have distinctive and unique behavior that separate them from it. To survive, they depend on natural resources, like water and food, and are subject to natural laws, such as the water cycle, natural disasters, and solar radiation. At the same time, using human capital, like labor, education, science, and technology, they can develop independently from nature their prosperity, and culture.

(2) The contradictory Humans-Nature interplay between dependence and independence, conflict and cooperation, and harmony and disharmony was the main topic of investigation by ancient and contemporary philosophers. The Pre-Socratic Greek philosopher Heraclitus first introduced the dialectical model as a tool to describe and unify the Human-Nature contradictory behavior of conflict and cooperation [18]. He was followed by well-known philosophers like Kant, Hegel, and Marx, who have promoted the dialectics of the Human-Nature interaction as a balance of power between natural forces and human capabilities through a permanent state of change [19], [20].

(3) The Heraclitean doctrine of “panta rei-everything is in constant flux” applies to nature and humans as well. As shown in Figures 1 and 2, natural climate conditions are in constant evolution and the same applies to human societies (rise and fall of human civilizations, variability of socio-economic activities).

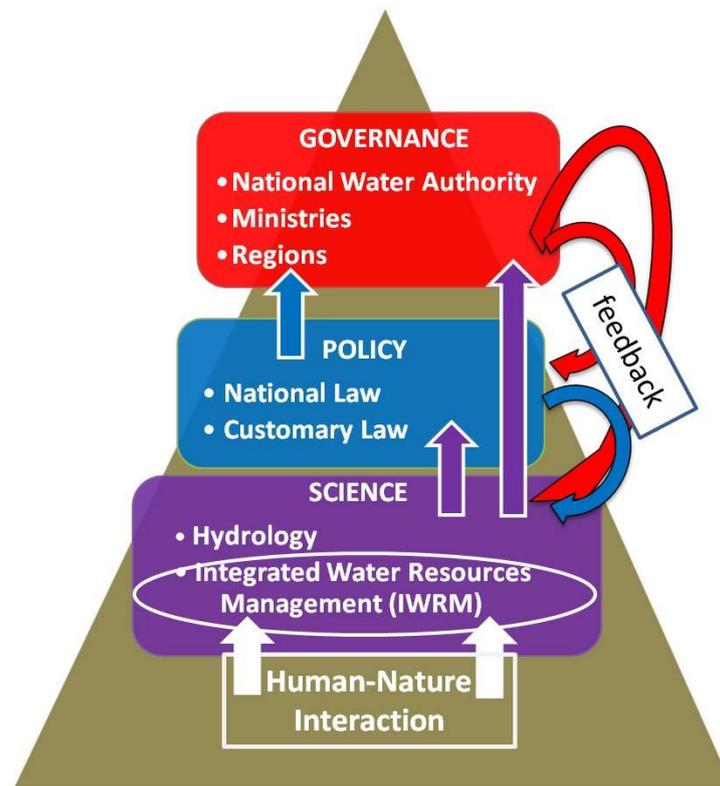
(4) Historical events many thousands of years back indicate a correlation between human processes and natural conditions in evolution. Of course, the climate is not the only variable to explain human activities, such as the rise or decline of civilizations. At times of limited technological infrastructure, the data show a strong relationship between human wealth fare and nature. During periods of low temperature and limited technological infrastructure, a decline in human achievements is reported. In the Pleistocene, shown in Figure 1 and known also as the LGP (Last Glacial Period), Nature dominated Humans (Naturalistic Era).

(5) In the early Holocene, the increase and stabilization of a warm climate facilitated the development of extensive agricultural activities (Figure 1). We also may notice during high temperatures in the late Holocene, the flourishing of European Historical Civilisations (-400 to 500), the building of Cathedrals in Western Europe during the Medieval Warm Period (900-1200), and the industrial era started in 1900 after the pre-industrial one 1850-1900 (Figure 2). On the contrary, the low temperatures recorded in the early Middle Ages (500-900) had influenced the Vikings' migration Southern and the LIP (Little Ice Period, 1400-1800) is linked with a decrease in human achievements. During the major part of the Holocene, humanity benefited from an almost warm and stable climate. However, on a smaller scale, the interplay between Nature and Humans oscillated between relatively cold and warm periods, or between conflict and cooperation. We may call this period a Dualistic Era.

(6) After the first industrial revolution in c. 1800, humans adopted an “anthropocentric” approach to nature that created huge environmental damages, including climate change. In the field of water resources, which are the common denominator for a healthy planet, it is urgent to investigate how to improve the way we use and manage this precious natural resource, which is limited and constitutes the origin of life. In other words, how a dialectical model of Human-Nature interaction can help to improve the WRM model and ensure water security and sustainable water governance under climate change.

### 3. The Governance-Policy-Science Nexus (GPSN)

Water governance can be defined in different ways including that formulated by UNDP [22], as “the range of political, social, economic, and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society”. We may resume that water governance is a socio-economic and administrative framework that for taking political decisions combines a set of laws and policy measures with a WRM model. In democratic societies, based on the rule of law political decisions are taken by the majority of elected representatives. This range of socio-economic systems forms a hierarchical complex, composite and interdisciplinary framework that is shown schematically in Figure 3.



**Figure 3.** The GPS Nexus: from Human-Nature Interaction to Hydro-Governance.

It consists of three main elements: Governance (decision-making), Policy (water laws), and Science (water management). We may call it the GPSN (Governance, Policy, Science Nexus). To ensure the rational use of water for the community, Hydro-Governance is the upper stage of three underlying and interconnected systems.

From a bottom-up approach, these are the:

- (1) Interplay between Humans and Nature, leading to a
- (2) WRM models for developing a
- (3) Policy or a water-regulation system.

In reality, Hydro-Governance is the overarching process integrating Policy and WRM into the Socio-Political and Socio-Economic domains. WRM plans that public authorities develop and address to water utilities, and all water users, incorporate indirectly the relationship humans entertain with nature. Along the complex steps in the decision-making chain for water allocation and management, WRM plans which are based on information, data, and scientific knowledge, reflect at the same time the particular interplay between humans and nature at a given historical period. In water governance, elected officials in central, regional, and local administration ask advice from water scientists on how to implement WRM plans or how to use water legislation to taking appropriate decisions. In the opposite direction, as shown in Figure 3, WRM plans and scientific information may benefit from experiences coming out from water governance and policy (feedback).

We may describe the time evolution of the WRM model as follows:

1) At a given time, WRM planning is influenced by the Human-Nature interaction and can be distinguished by the naturalistic, dualistic, and anthropocentric historical trajectory. Diachronically, the contents of water laws for policy regulation and the way water governance is exercised depend on the conceptual framework of the WRM model.

2) Since 2000, the WRM model has become gradually a systemic tool, under the title of IWRM (Integrated WRM) [23]. The IWRM model has evolved through multiple steps initiated by many UN conferences and the corresponding UN resolutions, such as:

3) In 1972, i.e. 28 years before the IWRM's completion, the UN Stockholm declaration called for environmental protection,

4) 20 years later, in 1992, the Rio UN summit adopted the need for sustainable WRM, living in harmony with Nature, together with the definition of Agenda 21 and the MDGs (Millennium Development Goals), and

5) In 2000, at the 1st WWF (World Water Forum), The Hague, the IWRM systemic model resulted in the adoption of the integrated 3Es axes of sustainability: Environmental, Economic, and Equitable WRM.

#### 4. Policy implementation of the IWRM model

The main idea of the IWRM model is that the management of water resources should address not only the quantity and quality of water for sustaining human life and maintaining all kinds of life on earth. Water is the raw material of almost all socio-economic activities, like agriculture, industry, energy production, manufacturing, and transportation. Therefore its use should take care holistically its use in different economic sectors, providing a sufficient amount of water to satisfy the demand. Furthermore, water management is a multi-disciplinary topic, involving different disciplines and many professions like engineers, dealing with water infrastructure, chemists and biologists for water quality, lawyers for water policy, economists for water pricing, and general managers at different scales. This systemic approach to water resources management is very appealing theoretically and very popular for educational activities. The IWRM model is described in detail by a series of technical reports [23], [24], produced by the Global Water Partnership (GWP), an NGO affiliated with the World Bank.

The application of the IWRM model in policy and public water regulation is complicated. After many years of experimentation in several countries, the model has resulted in partially positive results. This happened for several reasons.

Firstly, the general aim of the model implementation in the real world was very ambitious and complicated to attain. To achieve an integrated result, the model targeted not only technical and economic reliability in water management but also environmental and ecological preservation together with social fairness and social equity. However, if the techno-economic approach was feasible mainly about water infrastructure, the social and environmental sustainability have been obtained only up to a certain level.

Secondly, the theoretical relationship between the use of water resources and its allocation in different socio-economic sectors although easy to understand has been proven almost impossible to formulate. For example, it is obvious that we need to use more energy for agricultural irrigation due to water transportation or pumping; and also more water is needed for maximizing agricultural food production. However, in the mathematical frame of multi-objective decision-making, an optimum solution minimizing water and energy consumption while maximizing food production is impossible to obtain. Instead of an optimum solution, multiple feasible alternatives are possible; any choice between them depends on our preferences, either economical or environmental. An important attempt to simplify the complexity of the IWRM model is the focus on three main natural resources, i.e. water, energy, and food. Because these three elements are interrelated in a complex way, the model was named Water-Energy-Food Nexus. If the model is used without special attention to water consumption, water security can be compromised [21].

Thirdly, the organizational setup for implementing the IWRM or the Nexus model was missing. The main advantage of the integrated approach was to profit from synergies between activities in different sectors, save natural resources, and achieve sustainable solutions. However, common administrative systems have a long tradition of working in silos. For example, governments distribute socio-economic responsibilities in ministries, dealing with particular sectors, e.g. ministries of agriculture, energy, and environment. Although in many countries the environment is associated with the energy sector, some attempts to combine agriculture, energy, and environmental issues have failed due to inadequate coordination between the three sectors and lack of collaborative skills.

The first serious political effort to translate the IWRM model into a policy document was the adoption by the European Parliament in 2000 of the Water Framework Directive (EU-WFD) 60/2000/EC [25]. Because Europe is not a Federal Country but a Union of Independent Member-States the Directives issued by the European Commission and adopted by the European Parliament do have not the form of federal laws. However, there is an obligation of all Member-States to incorporate them into the National Law. Based on the subsidiarity principle, every Member-State could adapt the directive following national particular conditions, but failure to adopt the main principles of the Directive could bring the Member-State to the European Court. Severe fines can be imposed by the Court in case of non-compliance by the Member-State.

The EU/WFD has been the compromise between different professional lobbies, NGOs, ecologists, scientific associations, and the European Parliament. The main principles and guidelines of the directive can be resumed as follows:

- 1) Water Resources Management and water allocation in different socio-economic sectors should take place at the River Basin scale
- 2) National authorities should nominate the River Basin Organizations (RBOs) covering all national and transnational river basins or groups of them, called Hydrological Districts.
- 3) RBOs are responsible for assessing the hydrological, chemical, and ecological characteristics of the water bodies, including rivers, lakes, and aquifers
- 4) Based on the status of the water bodies, and the needs for water of various socio-economic sectors, RBOs should develop the River Basin Management Plans (RBMPs), to be revised every 6 years by collecting additional data and improving the National Monitoring System.
- 5) In case of ecological problems and water scarcity, RBOs should propose a Program of Measures (PoMs) aiming to restore any environmental degradation.
- 6) An economic evaluation based on the cost recovery of water services should be developed for evaluating the water cost for different uses and fixing the water tarification.
- 7) Extensive public consultations should take place for correcting and adopting the RBMPs and the PoMs.

Almost 20 years after the implementation of the EU-WFD by its Member-States, in 2019 the European Commission started an extensive review among all Member-States on the obtained results. More particularly, the fitting for-purpose evaluation has focused on the relevance, effectiveness, efficiency and the European added value of the Directive [26]. In the Directive, the year 2015 has been targeted as the year to obtain a “good” environmental state of all European water bodies. A “good” state is defined as an acceptable chemical and ecological status for surface water and the same for the quantitative and chemical state of groundwater. As this time has not been obtained in 2015, after the assessment it was extended to 2027. The results of the fitness check show that less than half of the EU’s water bodies were in good ecological status. In Greece, 30% of the rivers and 80% of the lakes have failed to have a good ecological status.

Officially, these results have been attributed not to the contents and the methodology recommended by the Directive but to the delays caused by the Member-States in implementing it. Different causes of such delays have been noticed, such as lack of sufficient funding, weak water governance, and lack of coordination between economic sectors like agriculture, energy, and transport that impact heavily the water environment.

In our opinion, the main reason for not attending the Directive’s goal by 2015 and most probably by the new time horizon of 2027 is more fundamental and linked to the anthropocentric character of the IWRM model is the theoretical support of the Directive.

## 5. The dialectical model of water security

Revisiting Figure 3, we realize that the interaction between humans and nature is the main driver regulating the efficiency of the WRM model and influencing water policy and governance. From the previous historical revision of the WRM metabolism throughout different eras and various socio-economic and climate conditions, we have learned that the WRM model is in constant evolution: it takes different formulations depending on the balance of power between human societies and natural forces and is impacting not only its internal structure but also the diachronic water policy and governance (Figure 3).

From the historical review, we can resume the following:

(1) During the pre-historic era of the Late-Pleistocene, the Human-Water relationship used to be Nature-Dominated or *Naturalistic* (Figure 1);

(2) In historical, the Middle-Ages and Early-Modern times, it was changed to *Dualistic*, i.e. separating Humans from Nature, although the contraries co-existed (conflict and Cooperation) (Figure 2);

(3) During the successive ages of industrial revolutions until recently, it became Man-Dominating or *Anthropocentric* (Figures 1 and 2), and

(4) Since the year 2000, in the state-of-the-art IWRM model it remains *Anthropocentric* and *Technocratic*. The main drawback of the anthropocentric approach is that it generates negative environmental impacts or externalities that in the Anthropocene period became excessive, including climate change (Figures 1 and 2).

In the IWRM model and other recommendations of the UN and Civil Society Organizations, ecological issues for environmental sustainability are mainly defined as goals and targets. They also include indicators aiming to assess the progress made in attaining the goals. In the EU/WFD, specific monitoring activities are described aiming to classify the ecological status of surface and groundwater bodies. Five main water quality classes are distinguished, such as High, Good, Moderate, Bad, and Poor with the ultimate goal to obtain the “good” status of all European waters. However, the WFD was unable to achieve completely its goal, mainly due to its anthropocentric formulation.

The technocratic view of the IWRM model and the EU/WFD is based on the underlying assumption that humans can manipulate nature positively or negatively by producing negligible collateral environmental damage. As it is described in more detail by [5] (pp. 1145-1146), the methodology consists of the following steps: After exercising environmental pressures from different socio-economic activities, like agriculture and industry producing pollution to the natural environment and loss of biodiversity, the model assumes that it is possible to restore a “good” environmental status by applying a Program of Measures (PoMs) of usually high cost. Although the need of reformulating the WFD was recognized, because of the validity of its environmental objectives a new deadline for reaching its goal has been extended beyond 2027.

Goals and targets aiming to achieve sustainability are also described in detail in the 2030 Agenda for Sustainable Development, adopted in New York in September 2015 [27]. Enumerating 17 SDGs (Sustainable Development Goals) and 169 targets, the new UN Agenda demonstrates its ambition to achieve environmental sustainability by 2030. Concerning the SDG.6 on Clean Water and Sanitation, 6 different targets with 10 indicators are described: 6.1 Drinking Water, 6.2 WASH (Water and Sanitation Hygiene), 6.3 Wastewater and Water Quality, 6.4 Water Use and Water Scarcity, 6.5 Integrated WRM and Transboundary Surface and Groundwaters, and 6.6 Water Ecosystems.

Although setting ambitious goals and targets is important, more crucial is to set up the framework and describe the steps to follow to achieve them. The experience we have from the past is that the time frame for reaching goals is usually not achieved. Different reasons and new interpretations of data are given to explain why that happened. For example, the 1992 Rio Declaration, Agenda 21 setting the Millennium Development Goals (MDGs) to be achieved by the year 2015, has given mixed results and was revised in 2015 by the SDGs. The main reason for this UN inefficiency is the fact that the diversity of the UN Member States makes the needed abstraction and standardization of a common action plan very difficult. Concerning the fate of SDG 6.5 on IWRM, it is anticipated that its mid-

term review in NY, March 22-24, 2023 will have as in the case of the EU/WFD only partial good results.

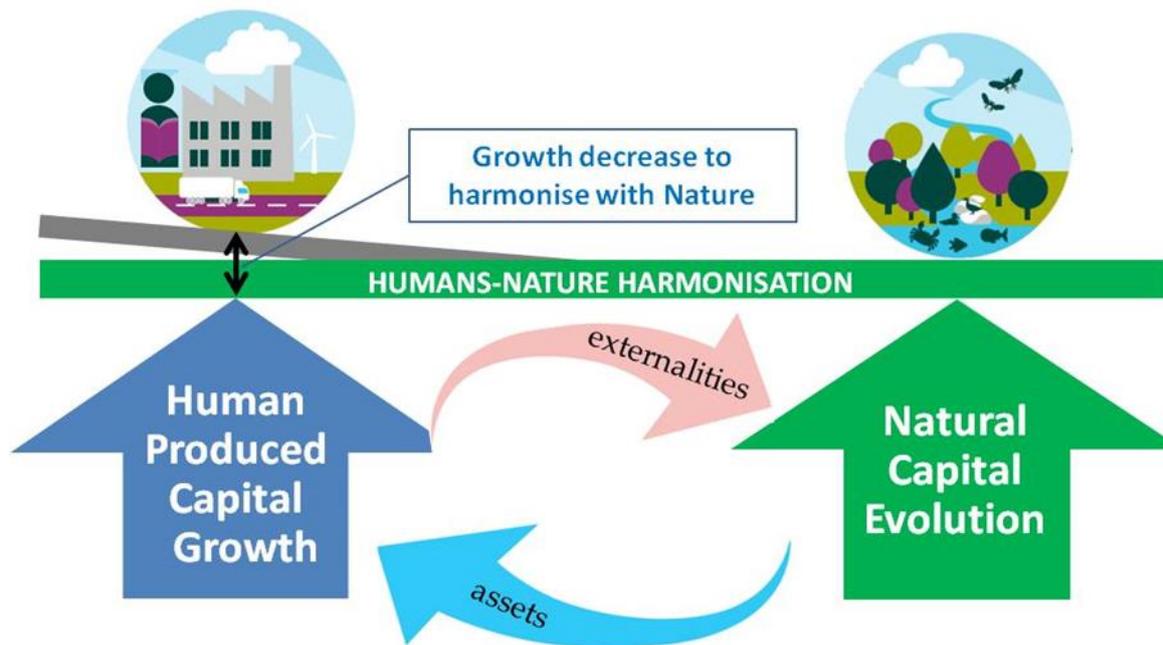
To reduce environmental pressures and limit externalities up to acceptable levels, it is necessary to redefine the conceptual WRM framework and the underlying theory based on a revised Humans-Nature relationship. The solution is not to come back to older models of naturalistic or dualistic view but to articulate a new conceptual relationship and underlying theoretical and methodological approach. Two recent approaches have initiated a revival of interest. These are (a) the so-called NBs (Nature-based solutions), and (b) the upscaling of ancestral THT (Traditional Hydro-technologies).

An interesting discussion has been recently animated in the specialized literature concerning the use of NBs as a new WRM model. First coined during the 2016 World Conservation Congress organized by the IUCN (International Union for Conservation of Nature) [28], NBs were defined as “actions to protect, sustainably manage and restore natural and modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits”. In recent times, several initiatives from civil society have emphasized the need of introducing NBs for protecting urban ecosystems and water streams for ecological reasons, climate change adaptation, and to increase biodiversity and the quality of life [29].

In Athens, Greece, a strong debate has been initiated between local authorities, professional organizations, and NGOs for protecting and stabilizing the banks of urban streams with the use of NBs, like plants and bio-engineering materials. Ecological Associations went to the Greek Supreme Court of Justice and won against local authorities and public contractors who used to protect against floods and stabilize open water streams with concrete material or stone-made gabions. NBs can be used as an alternative in the case of small water streams like those that have survived in Athens. The aim is to increase green areas, protect ecological services and integrate water areas into the urban landscape. However, if NBs are efficient on a small scale, upscaling them is questionable for security and their application cannot be considered a panacea.

More recently, in connection with NBs and climate adaptation, traditional ancestral hydro-technologies, and tribal water management techniques have regained the public interest [30]. During the recent Int. Conference on Ancestral Hydro-Technologies, Barcelona, Spain, 16-17 Febr. 2023, many case studies on THT (Traditional Hydro-Technologies) have been presented, especially from Spain, France, Greece, and South and Latin America. These are mostly local, low-energy, and environmentally friendly technologies for water saving, urban water supply in arid climates, flood protection, and adaptation to droughts [31]. The organizers have concluded that because THTs have low energy, resources, and carbon footprint, they are important NBs. By integrating the Water-Energy-Food-Nexus they could contribute to achieving the SDGs (Sustainable Development Goals). However, the main drawback of THTs is the social context in which they have been efficient. The actual socio-economic environment is quite different from the historic rural societies that make the return to the past a utopia rather than an innovative solution adapted to the modern world for facing actual environmental challenges.

Before introducing the dialectical model for WRM in the Anthropocene Era, it is interesting to discuss briefly the economic dimension of the WRM process. The balance of power between Humans and Nature can be evaluated and compared in monetary terms [32]. At different time and space scales, we may distinguish between (a) natural capital, (b) human capital, and (c) produced capital. Human societies use natural assets that can be renewable, like water, forests, crops, solar and wind energy, and non-renewable, such as oil and gas stock on the planet. Hopefully, renewable natural capital is regenerated in the biosphere by natural and complex biochemical processes and ecosystem services. For example, freshwater resources are recycled through the hydrological cycle, and forests are naturally regenerated. Natural capital has long been considered for granted and used as free. However, when humans return to nature pollution at a rate that the Earth cannot recover, natural assets are threatened and social economies too (Figure 4).



**Figure 4.** Humans-Nature capital inequality and possible harmonization (adapted from [32]).

Humans use natural capital in terms of goods and ecological services to produce income, such as water supply and sanitation, housing, transportation, and infrastructure. This is the produced capital through different tools related to education, labor, and technological innovation. By increasing this capital, humans return to nature, what economists call externalities that threatens the natural capital (Figure 4).

According to [32], the economic estimation during the period 1992-2014 indicates that the globally produced capital per head has increased by 100% while the value of the natural capital per head declined by 40%. This capital inequality as shown in Figure 4, is the consequence of the way we continue to use and manage our natural resources. If we don't eliminate the reason that produces this inequality, for obtaining the harmonization between human development and natural capital, two solutions are possible:

- (a) Consent to decrease the level of our socioeconomic conditions, or
- (b) Increase the natural capital with human interventions, like plantation of new trees, cleaning our rivers and lakes, and changing our agricultural practices. Decreasing social growth and human welfare means a reduction of our actual GDP (Gross Domestic Product) which is socially unacceptable. On the other side, increasing the natural capital by restoration and conservation needs many generations time and is very difficult to be implemented socially, especially in the Greater South.

Considering the framework of the new model after our previous reflection, the following criteria could be mentioned:

- a) Preserving on the one hand human socio-economic growth, including human aspirations for a better and equitable life, and on the other hand, nature's evolution, including ecosystems conservation/rehabilitation and climate change adaptation/mitigation
- b) Considering the balance of power between Humans and Nature pragmatically as a unity of two opposites that are conflict and cooperation
- c) Analyzing conflicts with nature and resolving them in a unifying framework as conflicts between Human socioeconomic activities and Natural Laws.
- d) Resolving the above conflicts dialectically by unifying the opposites (human benefits versus environmental threats) to reduce or eliminate externalities.

The eristic-dialectical model has been first formulated philosophically by Heraclitus [18], fully adopted in the 19th Century by the German philosopher Hegel [18], [34] and served as the basis of the dialectical materialistic theory of Karl Marx and Friedrich Engels. The model we suggest for improving IWRM is based on a dynamic, open-ended method [33] that avoids a monistic

approach, if it was based on a specific discipline such as technical, social, or physical. The dialectical model we describe step by step hereafter unifies positive and negative effects by exchanging contradictory arguments [20] to find the best solution (dialectical logic), away from one-dimensional views, such as technocratic, anthropocentric, naturalistic, traditionalistic, realistic, feministic, or liberalistic. It is based on the following natural and epistemic principles, emerging from data, observations, and a common logical experience:

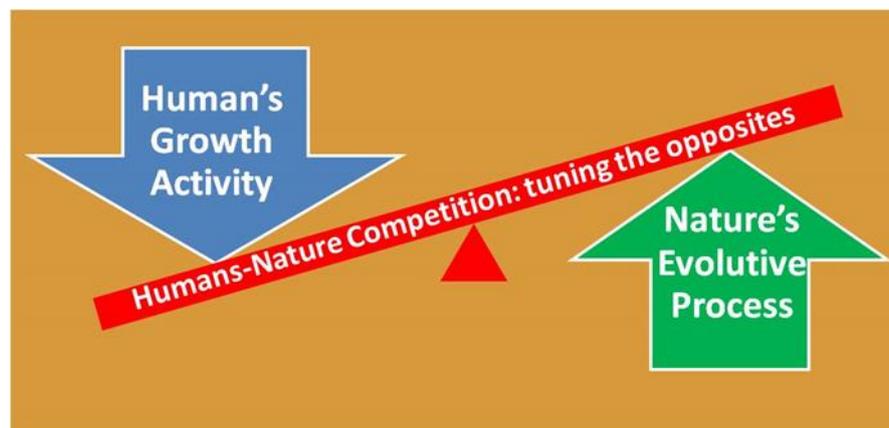
- Change in Nature and Humans is constant and inevitable: according to Heraclitus all are in flux (“panta rei”)
- Conflict is universal and positive; it is “the father of everything” (Heraclitus)
- Humans and Nature being distinctive and interconnected are at the same time fighting and cooperating (dialectical principle of the unity of opposites)
- Unifying the opposites can generate sustainability and lead to a harmonic symbiosis between the socio-economic interests of humans and the natural/hydrological laws that control the environmental processes.

To understand the process, Heraclitus gave two simple examples:

(1) To obtain the best melody from a violin or a lyre we should tune its strings by turning the pegs in a way that the tension on a string becomes equal and opposite to the force on the pegs.

(2) A bow becomes functional and a weapon of death when the tension on its resistant string is equal and opposite to the pressure that is applied to the bow.

Another simple example of an eristic-dialectical IWRM model (EDIWRM) is the building of a dam on a river for electricity production. Most of the time, this kind of technical infrastructure aims to obtain safe structural reliability and minimize construction and operation costs. The dimensions of the dam and the turbine machinery are designed for maximizing energy production. This anthropocentric model faces environmental consequences such as the blocking of fisheries traveling upstream from the dam which is considered as externalities or collateral damages (Figure 5).



**Figure 5.** Dialectical Humans-Nature conflict resolution by tuning the opposites.

An eristic-dialectical approach recognizes first the conflict between damming the river and the hydraulic and ecological laws of free river flow and fisheries migration. The dialectical solution is to unify the two contraries (1) electricity production for humans, and (2) fisheries-free migration upstream. In Europe and the USA special design of dams and turbines allow fisheries like salmon to travel through the dam and continue their journey on the river.

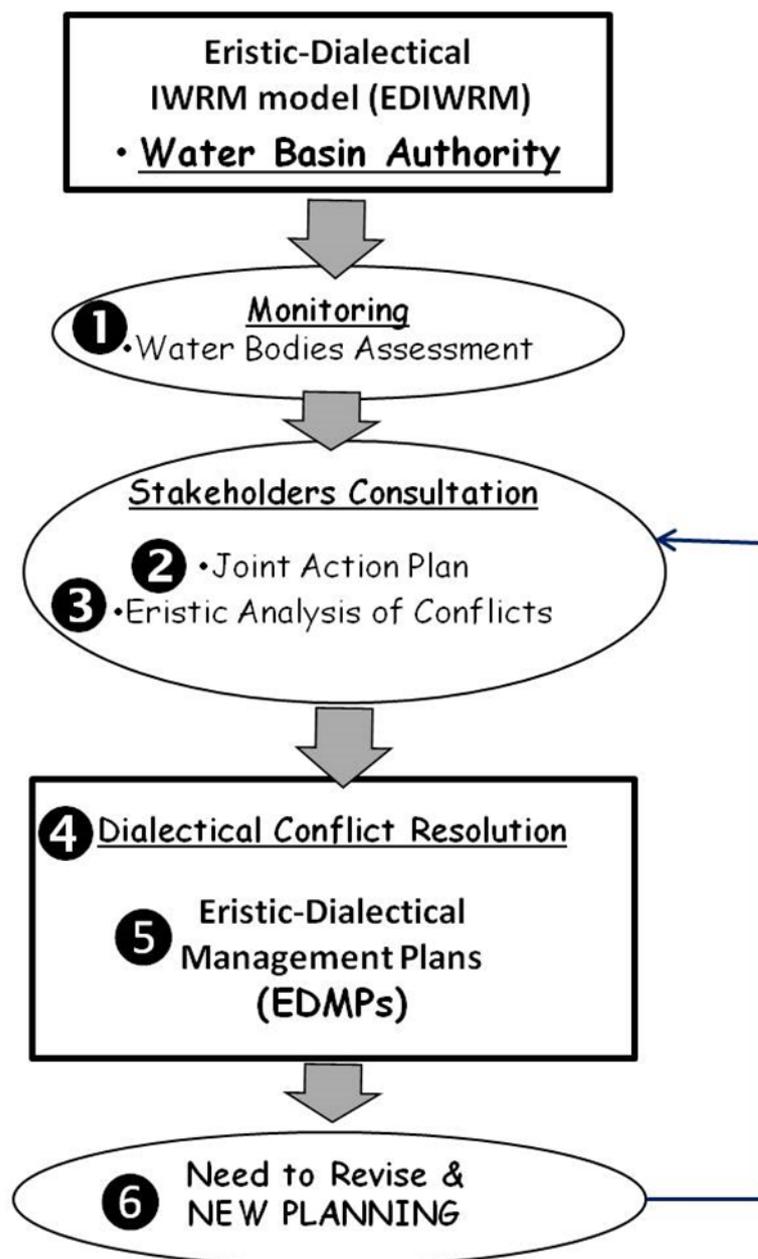
This simple case illustrates the fact that the EDIWRM model is not based on a compromise between alternative technical solutions aiming to minimize externalities but is a harmonic symbiosis between humans and nature by unifying the opposites: energy production for humans and free migration for fisheries. This kind of balance between two opposite forces is shown schematically in Figure 5.

The Eristic-Dialectical model of IWRM can be applied in more complicated cases, including the Integrated Flood Management (EDIFM) that is illustrated in the case study, adopted by GWR in its

Toolbox [36]. The successive steps to follow for the EDIWRM implementation are shown in Figure 6 and can be described as follows:

- (1) Setting the scene by detecting all surface and groundwater bodies at the watershed scale. Monitoring water bodies to determine their physical, chemical, and ecological status.
- (2) Stakeholders consultation for developing a Joint Action Plan (JAP)
- (3) Eristic Analysis of Conflicts between stakeholders and the natural laws
- (4) Dialectical Conflict Resolution between human different activities and the natural laws
- (5) Establishing Eristic-Dialectical Integrated Management Plans
- (6) Revision and new planning.

The case study of a dialectical flood management that follows, illustrates the applicability of the new model for mitigating the flood risk in urban areas.

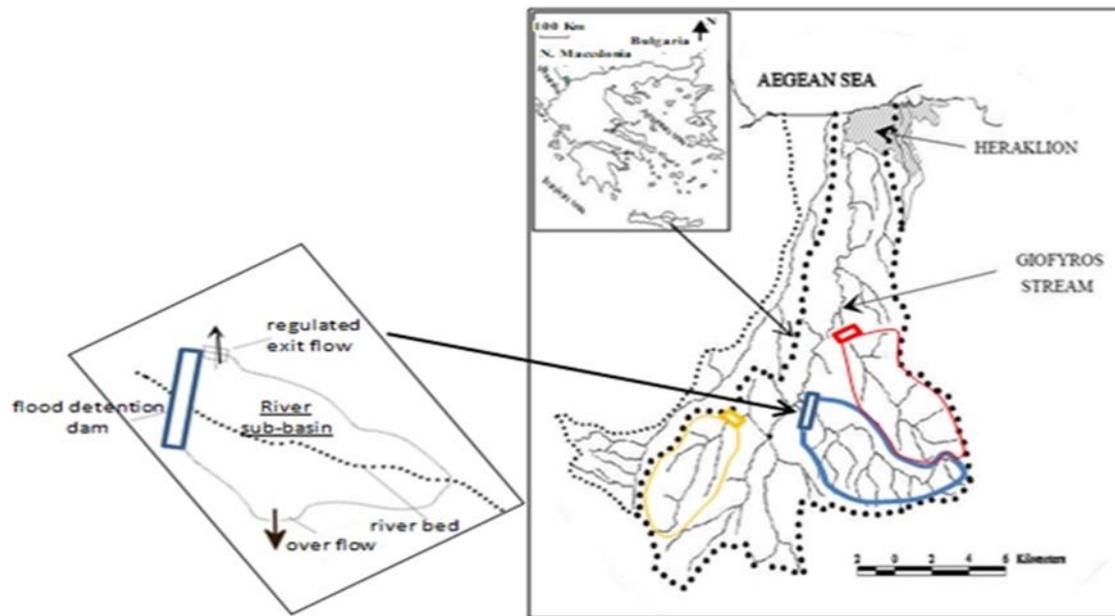


**Figure 6.** Steps for application of the EDIWRM (Eristic-Dialectical IWRM) model.

#### 6. A case study of eristic-dialectical integrated flood management (EDIFM) [35, 36]

In recent years, on Crete Island, Greece, floods have become frequent and catastrophic under climate change. In the case of the Giofyros River flowing through the city of Heraklion (Figure 7), to

complement an Integrated Flood Management (IFM) plan, a social component has been added. The new model is based on conflict resolution between human activities and the hydrological/hydraulic/natural laws. The model uses the fact that historically, water-human interactions have been and remain contradictory, i.e. at the same time conflicting (urban use of the flood plain) and cooperative (developing green areas around the river). To increase flood security, firstly the conflicts were assessed and analyzed; and secondly, by unifying the opposite nature-human interactions, a dialectic flood-resilient solution was obtained. It has been proven to be resilient until today to newer flood hazards.



**Figure 7.** Location of the Giofyros River Basin and flood detention reservoirs upstream.

### *Summary description*

Following the steps indicated in Figure 6, the new Eristic-Dialectical Integrated Flood Management (EDIFM) model was implemented as follows

#### (1) Assessment of the initial situation

The Regional Agency for the Development of Eastern Crete (OANAK) located in the city of Heraklion was responsible together with the city's local authorities to develop an Integrated Flood Management Plan (IFP), after a catastrophic flood that took place on January 1994 [35], [36]. OANAK invited the expert team from the Aristotle University of Thessaloniki, led by Prof. J. Ganoulis to assess the situation and establish an Integrated Flood Risk Management (IFM) Plan.

#### (2) A Joint Action Plan (JAP) with local stakeholders

The main water users and responsible authorities have been identified among citizens who had lost their property during the 94's historical flood, the OANAK, and the city's elected authorities. The main purpose of the JAP was to identify not only natural hazards but also how humans have conflicted with nature by occupying part of the river bed to develop their properties. The consultation aimed to define the natural conditions generating floods, i.e. the river's boundaries with variable flow rates, the hydrological and solid transport characteristics of the river, and the marine coastal currents near its delta that are influenced by Coriolis forces.

#### (3) Eristic Analysis of Conflicts (EAC)

In the EAC process, conflicts were identified between the land use for urban interests across the river and the river's bed extension for different return periods of flooding. The river's boundaries have been identified for a 20 years return period. To resolve conflicts of land use and other violations of natural laws, the hydrological characteristics, such as the hydraulic conductivity of the river for different rainfall intensities, the transportation capacity of solid and suspended material, and the coastal currents near the mouth of the river have been analyzed. As a result, humans were identified

to violate the river's bed flood boundaries and as an exchange, the river used to flood urban areas up from a certain flow rate with negative consequences to human property.

#### (4) Dialectical Conflict Resolution (DCR)

##### *Natural Laws*

The hydraulic and hydrological investigation at the basin scale has produced the following results:

- *The Hydraulic Law*: under the existing river's bed characteristics, the flow capacity without flooding the urban area was 300 m<sup>3</sup>/s for a T=20 years return period. For higher flow rates water overflows the river and produces urban floods [35].
- *The Coriolis Forces*: because of the Earth's rotation in case of low tidal forces, like in the Mediterranean Sea, the river deltas show most of the time a dextral deviation of the river's mouth. This is the case in the Northern Hemisphere, while the opposite deviation may occur in the Southern Hemisphere [36].

##### *Conflict resolution*

(a) The dialectical model for resolving conflicts is based on the unification of contraries, which in our case are: (1) humans occupying part of the river's bed, violating the hydraulic and hydrological laws and increasing their proper benefits, and (2) the river responding by inundating their property when the flood water exceeds the river's flow capacity. The best solution is to retain upstream not all the volume of the flood but only the volume of the peak floodwater, i.e. the volume of water that exceeds the flow capacity of the river. In harmony with natural laws, the dialectical solution in the Giofyros basin has provided a series of flood detention reservoirs, i.e. small artificial lakes with an outlet pipe up to a certain level. In the detention reservoirs only the peak flood volume is stored, the rest of the flood is safely directed into the sea (Figure 7).

(b) To facilitate and reinforce the dextral deviation of the Coriolis Forces around the mouth of the river, an inclined jetty has been constructed facilitating the solid transportation into the sea and reducing the maintenance cost for cleaning the river bed (Figure 8).



**Figure 8.** The jetty for a Coriolis dextral deviation of the Giofyros mouth.

### *Lessons Learned*

#### Activating stakeholders

Increase flood resilience by adding a social component to the IFM model. This has been achieved by the Eristic-Dialectical EDIFM model that proceeds in two steps (1) assessing conflicts between stakeholders and natural/hydrological/hydraulic laws and (2) resolving these conflicts by unifying opposite issues to obtain environmental sustainability.

#### Flood detention reservoirs

Flood resilience at the watershed level is increasing by retaining only the peak of the flood instead of storing its total volume. Flood detention reservoirs are adequately designed among the river's sub-catchments to avoid the accumulation of tributary flows that may cause an overflow downstream. Water volumes stored in detention reservoirs can be used for irrigation.

#### Solid transportation by Coriolis forces

Coriolis forces were used to facilitate solid transportation from the river's mouth into the sea. This can be achieved by preserving the natural dextral flow deviation with an inclining jetty. The inertial forces prevent possible obstruction of the river's mouth and reduce maintenance costs. This is illustrated in the case study and was proven reliable.

#### Keep urban streams uncovered

Urban water streams, such as the Giofyros River, can enhance green areas, reduce temperature increase due to climate change and absorb air pollution. Public authorities use to cover water streams because of the lack of water flow in summer and the activation of garbage and mosquito colonies. Flood detention reservoirs can provide sufficient water to sustain summer ecological flows.

#### Flood Governance

Hydro-Governance is the integration of water management and policy in the political field. It is exercised at different levels, such as National, Regional, and Local. Flood Governance at the local level, consisting of the city elected authorities, the public Organism for water management (OANAK), and the University team as scientific advisor, was proven very efficient in practice.

## **7. Conclusions**

At times of climate crisis, water security can be achieved by establishing effective Water Governance that can lead to water security. The analysis of the GPS (Governance-Policy-Science) Nexus presented in this paper indicates that the best way for improving Hydro-Governance is to revise dialectically the existing IWRM model (scientific approach) and reinforce its communication to law experts (Policy) and decision-makers (Governance).

The historical review of the human-water interaction shows that the state-of-the-art IWRM is anthropocentric and technical-oriented. This is also included in the IWRM model and continues to produce huge environmental externalities including climate change. We suggest increasing its role of social dimension by adopting the Eristic-Dialectical model of conflict resolution of stakeholders' socioeconomic interests with the natural laws (Figure 9). Dialectics is an open methodology for assessing the unity of opposites between Humans and Nature, i.e. the unity of conflict and cooperation. It proceeds by exchanging logical arguments in a dynamic multi-disciplinary framework away from ideological approaches, such as technical, neo-liberalistic, or capitalistic.



**Figure 9.** The Eristic-Dialectical model of sustainable conflict resolution.

**Conflicts of Interest:** The author declares no conflict of interest.

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