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Water Quality Trading
A Solution to the Eutrophication of Waterbodies?

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 01.06.2017

Affidavit

I, **BEATRICE FANTACCI**, hereby declare

1. that I am the sole author of the present Master's Thesis, "WATER QUALITY TRADING: A SOLUTION TO THE EUTROPHICATION OF WATERBODIES? ", 79 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

Eutrophication is serious threat for waterbodies it menaces the health of the environment and of human beings. Water quality trading (WQT) has been identified by the U.S. Environmental Protection Agency as a cost-effective solution for this issue. It is a market based approach that involves the exchange of nutrient pollution credits or allocations between sources.

The objective of this thesis is to assess WQT, namely its benefits and challenges, through a combination of theoretical and practical analysis. The theoretical analysis highlights the legal aspects and design features that are relevant for the establishment of an efficient water quality trading program. Moreover, if these elements are appropriately addressed WQT can theoretically guarantee environmental, economic and social advantages compared to command and control approaches. The practical analysis comprises the presentation of two case studies and a compared analysis of the two. The case studies are on the Chesapeake Bay and on the Danube River Basin (DRB). Both waterbodies have eutrophication issues and are extremely vast, but the former has introduced a WQT program, at the beginning of the century, whereas no nutrient trading program has ever been established in the DRB. This combined approach of theoretical and practical analysis allows to understand if WQT could be a cost-effective solution for the eutrophication of the north-western Black Sea.

The outcome of the thesis is that due to the recent commencement of nutrient trading programs it is not possible to provide quantitative proof that WQT are more cost-efficient than command and control programs. Furthermore, without evidence of the greater efficiency of these tools, it is not likely that they will be introduced in the Danube region given the difficulty in gaining political acceptance; the large investment that the initiation of such program would require; the complexity of the introduction of trading programs in such a wide transnational basin and, finally, because the policies that are already in place already require very stringent regulations on the emissions of sources for the riparian countries.

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List of Abbreviations

Apex	Agricultural Policy/Environmental Extender model
BAU	Business as usual
BMP	Best management practices
CWA	Clean Water Act
DRB	Danube river basin
DRPC	Danube River Protection Convention
EPA	Environmental Protection Agency
FLC	Federal Leadership Committee for the Chesapeake Bay
GIS	Geographical Information System
ICPDR	International Commission for the Protection of the Danube River
IPPC	Integrated Pollution Prevention and Control Directive
LA	Load Allocations
MONERIS	Modelling Nutrient Emissions in River Systems
MOS	Margin of Safety
N	Nitrogen
NRCS	Natural Resource Conservation Society
NTT	Nutrient Tracking Tool
NWBS	North-Western Black Sea
P	Phosphorus
P.e.	Population Equivalent
TMDL	Total Maximum Daily Load
TN	Total nitrogen
TP	Total phosphorus
USDA	United States Department of Agriculture
VNCEA	Virginia Nutrient Credit Exchange Association
WAM	Watershed Assessment Model
WFD	Water Framework Directive
WLA	Waste Load Allocations
WQT	Water quality trading
WWTP	Waste water treatment plant

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1. Introduction

Eutrophication is an ever-growing threat for waterbodies, thus the attention of policy makers and researchers has turned towards water quality trading (WQT), which is widely considered to be a cost-effective solution for this issue by many American researchers and by the United States' Environmental Protection Agency.[1] WQT is a market-based approach that can reduce nutrient loads in a waterbody allowing to meet the water quality standards. Several countries have already applied permit trading for the resolution of environmental issues, for example in European Union the Emission Trading System has been implemented in 2005, and has proven to be a worthwhile tool for the reduction of greenhouse gas emissions.

Since the introduction of WQT programs in the United States, many experts assessed the economic feasibility and potential efficiencies in reducing nutrient pollution.[2] As the programs started to be implemented, the limits and complications started to emerge, and with these the first critics.[3] Nonetheless, researchers have produce an extensive literature reviewing the WQT programs in existence[4] and in listing the design options available. These may be used by policy makers when deciding on the appropriate elements to insert in their program that best fit the needs of the specific location.[5]

The last decade has seen a rapid development of water quality trading in a vast number of watersheds worldwide. A recent study conducted by the World Resources

[1] World Resources Institute and USDA Office of Environmental Markets, "Comparison and Effectiveness of Chesapeake Bay Nutrient Trading Program Policies.", Environmental Protection Agency, "Water Quality Trading Policy: Issuance of Final Policy."
[2] Shortle, "Economics and Environmental Markets: Lessons Form Water-Quality Trading"; Shortle et al., "Building Capacity to Analyse the Economic Impacts of Nutrient Trading and Other Policy Approaches for Reducing Agriculture's Nutrient Discharge into the Chesapeake Bay Watershed"; Faeth, "Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality."
[3] King and Kuch, "Will Nutrient Credit Trading Ever Work: An Assessment of Supply and Demand Problems and Institutional Obstacles"; Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems"; Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."
[4] Pharino, *Sustainable Water Quality Management Policy. The Role of Trading: The U.S. Experience*; Greenhalgh and Selman, "Comparing Water Quality Trading Programs: What Lessons Are There to Learn?"; Selman et al., "Water Quality Trading Programs: An International Overview"; Breetz et al., "Water Quality Trading an Offset Initiatives in the U.S.A Comprehensive Survey"; Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."
[5]Williamette Partnership, World Resources Institute, National Network on Water Quality Trading, "Building a Water Quality Trading Program: Options and Considerations"; Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading.".

Institute reports that there are approximately 57 WQT programs worldwide.[6] The United States of America are the pioneers of WQT they launched their first program in the 1980's: The Fox River point-point source effluent trading.[7] Today, 51 of the 57 programs commenced globally, are in the United States. Even though WQT programs have been operating for as long as air pollution trading programs and have been widely carried out in America, they have never been implemented in the Europe.

The purpose of this thesis is to study water quality trading theory and to investigate how this has been applied in the Chesapeake Bay, in the United States, and how hypothetically it could be applied in the Danube River Basin (DRB) for the solution of eutrophication issues in the North-western Black Sea. The decision of presenting the Chesapeake Bay region and the DRB is motivated by the similarities of these two areas. Even though these areas belong to two different continents, they are alike in that the North-western Black Sea and the Chesapeake Bay both receive waters that are under the control of various jurisdictions. Thus, they face comparable challenges. Therefore, my research questions are:

-Is water quality trading an effective measure to reduce nutrient pollution?

- Are there examples of successful application of WQT?

- What may be the challenges associated with water quality trading programs?

- If implemented in the Danube region would it be a cost-effective way to reach quality targets?

To answer these questions the thesis is be structured in four research chapters. After defining the methodology, I present an overview of rivers and river pollutants to provide an understanding of how nutrient trading relates to these and why it is needed. In this chapter, I describe the main features of rivers that determine the behaviour of pollutants. Furthermore, I identify point sources and non-point sources of pollution, the pathways that the pollutants follow once they are emitted by a source, and the various pollutants that affect the health of a river system. Chapter 4 introduces the main topic of the thesis, water quality trading. I provide the definition of WQT, then the fundamental rules for the functioning of the program are illustrated followed by an assessment of the benefits and challenges associated with these programs. The chapters that follow are dedicated to the two case studies. Chapter 5, describes the Chesapeake Bay, its eutrophication issues and the legal and technical issues of the nutrient trading programs

[6] Selman et al., "Water Quality Trading Programs: An International Overview."
[7] Kieser and Feng Fang, "Water Quality Trading in the United States."

set in in the region. The Danube River Basin case study, illustrates the health issues of the river body and provides the existing legislation for the control of water quality in the Danube region. Finally, the thesis analyses the feasibility and the challenges connected to the introduction of nutrient trading in the Danube River Basin through chapter 7 that provides a comparative analysis between the two case studies and the final considerations.

This thesis provides an understanding of water quality trading practices. As a broad qualitative research this study presents the possible benefits and disadvantages, both environmental and economic, of water quality trading programs. Moreover, it highlights how the DRB needs a sustainable water management practice to avoid further harm on the environment and how WQT can be an alternative worth taking into consideration.

2. Materials and Methods

The methodological approach taken in this study is a mixed methodology based on literature research, the presentation of two case studies and comparative analysis. The data for this study were collected using existing literature on the topic from international organizations, governmental agencies and legal papers. The main sources gathered and evaluated are technical papers, as well as scientific books and journals. By reviewing literature from governmental institutions, international organizations along with internet sources, I will attempt to convey a deeper understanding of the case studies and their background.

Among the vast literature on the topic few documents and authors played a fundamental role for the drafting of the present dissertation. Tietenberg's works provide a comprehensive understanding of how economic approaches can be applied for environmental issues.[1] Market approaches are largely used for solving environmental matters, their implementation is recent but the discussion on the topic has a long history. Tietenberg, explains not only, the history of the introduction of environmental trading programs and the various oppositions that it faced, but also the rules to followed so that natural resources can be considered goods that can be exchanged on the market. The World Resources Institute (WRI), developed an overview of the WQT programs that have been implemented worldwide.[2] This wide-ranging survey, offers an understanding of how the programs follow the same mechanisms but present features that are very distinct because they are forged *ad hoc* to suit the needs of the specific location and they reflect the input of the stakeholders involved. To integrate, the general outline that is presented in the documents of the WRI, the papers of Ribaudo and Gottlieb (2011) and Woodward and Kaiser, clarify how WQT programs work in practice and what are the main structures that they can assume.[3] Moreover, Corrales et al. (2013), summarises the benefits and challenges of nutrient trading programs.[4]

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[1] Tietenberg, "Tradable Permit Approaches to Pollution Control: Faustian Bargain or Paradise Regained?"; Tietenberg and Lewis, *Environmental and Natural Resource Economics*; Tietenberg, *Emission Trading Programs: Implementation and Evolution*; Tietenberg, *Emission Trading Programs: Theory and Design*.

[2] Selman et al., "Water Quality Trading Programs: An International Overview"; World Resources Institute and USDA Office of Environmental Markets, "Comparison and Effectiveness of Chesapeake Bay Nutrient Trading Program Policies."

[3] Ribaudo and Gottlieb, "Point-Nonpoint Trading- Can It Work?"; Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."

[4] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."

The case study on the Chesapeake Bay, is supported by information that I retrieved from the websites, and the related documents, of the Chesapeake Bay Program and the Chesapeake Bay Foundation.[5] The latter, is an NGO founded in 1967, which has the goal of protecting and saving the Chesapeake Bay. The second case study, on the feasibility of introducing WQT in the DRB, is largely influenced by the Danube Regional Project developed by the UNDP and GEF.[6]

The overall structure of this thesis takes the form of eight chapters, including the introduction and this methodological chapter. The chapters are divided in two sections, if the initial part of the thesis focuses on the theoretic background of water quality trading, the second part aims at providing an empirical illustration of how water quality trading has been applied or has failed to be applied. The first case study demonstrate how water quality trading has been used in the Chesapeake Bay and the second case study presents the elements that have to be considered when analysing the possibility of introducing a nutrient trading program in the Danube region. This approach allows to answer the research questions. Chapter 4 answers the question if water quality trading is an effective measure to reduce nutrient pollution. The chapter highlights how the market based instrument may be used to reach water quality goals and how some researchers defend the position that these goals can be achieved in a cost-effective manner. Then it presents the social, environmental and economic benefits, and the possible challenges that result from introducing a trading mechanism to solve eutrophication issues, which have been identified by the scholars.[7] The research question concerning the existence of successful nutrient trading programs finds its resolution in the Chesapeake Bay case study. This case study highlights how nutrient trading program was implemented in the region but how due to its young life, it is hard to give a judgement on its actual success. The thesis concludes with a comparative analysis, which will be based both on a qualitative and quantitative research which combined with the final considerations allow to solve the final research question: if the introduction of WQT in the DRB would be a cost-effective solution to eutrophication issues.

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[5] Chesapeake Bay Program, http://www.chesapeakebay.net/; Chesapeake Bay Foundation, http://www.cbf.org/.

[6] United Nations Office of Project Services, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction"; United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."

[7] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."

3. Rivers and River Pollutants

Eutrophication has affected 532 coastal areas worldwide and researchers have become increasingly interested in finding an effective solution to this issue.[1] This phenomenon is defined as the over-enrichment of waterbodies with nutrients, namely, nitrogen and phosphorous. These nutrients originate in various ways including agriculture, households, industries, transportation and infrastructure and abandoned mines. They can then be directly introduced into the waterbodies or they may follow different pathways and then finally be released into the aquatic environment. The effects of eutrophication are well known, nutrient over-enrichment affects rivers, lakes, estuaries and ecosystems and can lead to excessive and sometimes toxic algal bloom, loss of natural habitats, variations in marine biodiversity and depletion of dissolved oxygen, with the consequent die-off of marine life. Additionally, it can result, in the most extreme cases, in the formation of hypoxic areas or “dead zones” such as it happened in the 1980’s and in the 1990 in the Black Sea in Eastern Europe and the Chesapeake Bay, which lies inland form the Atlantic Ocean.

The focus of the thesis is on waterbodies in general, nonetheless, this chapter will focus on rivers, as these are carry nutrients to the river mouth, meaning a larger river, a reservoir, a lake or the ocean. In this chapter I provide a brief introduction on the main elements of rivers that must be taken into consideration when dealing with nutrient pollution and with water quality trading design. Then I define the different sources of pollution followed by the description of the pathways of pollutants to the waterbodies. This section is important because in the current literature, there is a lot of confusion on the identification of sources, which are often confused with the pathways. To conclude I list which are the main river pollutants with an emphasis on nutrient pollution.

1.1. Brief Introduction on Rivers

Rivers are life, even if they account for just 1% of fresh waters have been essential for life on earth ever since life began, providing among others drinking water for humans and animals, natural habitat and biotopes.[2] In this section I illustrate some important characteristics of rivers that have are essential when dealing with water pollution. Then, the natural and urban water cycle will be explained to clear where the

[1] Selman et al., “Water Quality Trading Programs: An International Overview.”
[2] Perlman, “Earth’s Water: Rivers and Streams.”

pollution originates and to highlight the consequences of anthropogenic modification of rivers.

Rivers are flowing water bodies and are a renewable resource. The flow of a river proceeds from upstream to downstream, accordingly this unidirectional flow determines the trail of effluents. The flow allows the pollutants to distribute along the river basin thus the initial high concentration of pollutants in the point of discharge can be diluted. Nonetheless, beyond a certain threshold pollutants can accumulate or can damage the waterbodies (as nutrients). When addressing quality permit trading the problem of the points of high pollution concentration, the hot spots, must be taken into consideration in the design of the water quality market.[3] Other factors that influence the assimilative capacity of a rivers are the variations in flow, temperature and water levels. Flow rates are not constant and can change over time, and rivers have different water levels as well as fluctuating temperature levels at different times of the day that determine varying assimilative capacities for pollutants.[4] As mentioned, rivers are a renewable resource, meaning that regenerate at a faster pace than the rate of their consumption. The term renewable is liked to specific special and temporal criteria, usually a year or a geographic unit. It should be born in mind that rivers are not endless and thus these natural renewable resources should be carefully managed to avoid exceeding the local capacity to replenish them. This change may happen only in the long term, being a combination of the ambient surface-water, groundwater and soil moisture factors. [5]

Rivers are extensively used by people, with activities in in-situ and ex-situ. In-situ activities are various and can include leisure, fishery and aquatic culture and washing. As for ex-situ activities, the most important are the collection of water for drinking, irrigation, water supply, technical application (as hydropower stations or in condensers of other power plants and for domestic use in washing machines and dishwashers) and for industrial use.

The natural water cycle begins in the boundary layer, the lowest layer of the atmosphere, solar radiation is the motor that generates the processes of evaporation and evapotranspiration (for example from the leaves of a plant). The evaporated water condenses forming clouds that reverse the water back down on the surface of the Earth

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[3] This will be further discussed in Chapter 4.
[4] Keudel, "Water Quality Trading: Theoretical and Practical Approaches."
[5] Kreuzinger, "Water Availability."

through snow and rain. In this natural cycle rivers are formed by the convergence of surface waters. Surface water comes from rain, emerges from springs or melts from the snow and glaciers on the mountains. The water runoffs then meet where the land slopes are lowest, forming streams, brooks, or creeks. These small water courses then form a river, whose water eventually mixes into a lake or the ocean. A river and its tributaries cross the land that takes the name of watershed or drainage basin.[6] There is a constant interaction between surface water and ground water. Through infiltration surface water is filtrated into groundwater, oppositely groundwater emerges to the surface via springs.

Landscapes are shaped by rivers but human intervention has limited the meandering of rivers with the construction of dams and with river deviations. The modification of the river course and the construction of dams allows people ameliorate agriculture, solve water shortages and constrict dams that can serve to produce energy. Nonetheless, human intervention on natural resources always has its downsides, as the modification of the habitat. [7] People not only modify the river courses to satisfy their needs affecting the system’s natural course, they also affect the natural ecosystems when they introduce substances that alter the natural environment. Rivers pass by cities in which water is used and then reintroduced into the waterbody, this is called urban water cycle. Surface and ground waters are used by the population for municipal, industrial and agricultural purposes. The wastewaters and storm waters are then cleaned in the sewage and in the waste water treatment plants. During the urban water cycle pollutants from industries and nutrients from households can be introduced into the river basin. Developed countries all around the world have developed new technologies and ways to clean up the water pollution. Nonetheless, the most efficient mechanism is the prevention of pollution rather than clean up mechanisms that can be very expensive and unfeasible. In Europe in the 90 a campaign to reduce the presence of phosphorus in detergents leas to a large decrease in nutrient pollution in waterbodies. Nonetheless, in general prevention of nutrient pollution in some cases can be impossible (household discharged water).

I underlined, rivers have a variable but constant flow thus pollutants can disperse throughout the waterbody but beyond a certain threshold, pollutants, like sediments can accumulate, and others like nutrients can harm the waterbody leading to eutrophication. The latter explains how hypoxic areas are formed. Furthermore, I described how the

[6] Withgott and Laposata, *Envrionment: The Science Behind the Stories*, chap. 15.
[7] Ibid., 411.

origin of rivers and of the pathways of some pollutants can explained by the natural water cycle. Agriculture surface runoffs are the means through which fertilizers, rich of nutrients, enter rivers. These are the most important sources of phosphorus pollution in watersheds. The urban water cycle, instead, explains the point source discharge of nutrients in water bodies. Having underlined the key elements of rivers that a reader must keep in mind when analysing water quality trading, I now explain where the pollution comes from: which are the sources of pollution.

1.2. Sources of Pollution

The sources of pollution are all the activities and processes that are responsible for the input of pollutants into the environment.[8] This definition includes also natural sources, but, for the focus of this thesis, only the anthropogenic sources will be assessed. When addressing sources of pollution, we can identify two distinct sources: point-sources and non-point sources (or diffuse sources). Point sources are characterized by the discharge of pollutants in an identifiable and fixed point in the river and can be easily measured. This means that the attribution of an individual accountability for the pollution is feasible. The most important ones are industries (that do not have a treatment plant), households, mining sites and natural background. In contrast, non-point sources are smaller or scattered sources that release pollutants into the soil, the air or into the water. These include agricultural areas, natural background like forests and atmospheric deposition. Consequently, not deriving from a precisely identifiable spot and being more variable in time makes it is difficult and extremely costly to trace the pollution to a specific parcel or land use activity and to measure the amount of pollution deriving from that source. For this reason, often diffuse sources of pollution remain unregulated. Nonetheless, these sources have to be taken into consideration when addressing the pollution of a river. The table below illustrates in more detail the variety of point sources and non-point sources and the pollutants that they release into the waterbodies.

[8] European Commission, "Guidance Document No. 28: Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances."

Table 3-1. List of the major point sources and non-point sources of pollutants to surface waters, ground waters and sediments.

Sources	Explanation	Types of contaminants
Point sources		
Industries	Direct discharges from chemical manufactures, pulp and paper mills, food producers, textile manufacturers	Organochlorines, metals, nutrients
Transportation and construction material	Consumed tires, emissions from vehicles and other means of transport, degradation of construction material	Nutrients, metals
Abandoned or historic mining sites[9]	Mining of minerals (like apatite containing phosphorus)	Metals, acidity, nutrients
Nonpoint sources		
Agriculture	Chemical fertilizers, pastures, manure	Nutrients, pesticides, sediments, pathogens
Forests	Forest natural fall, logging, crops, road construction	Sedimentation
Atmospheric depositions	Various sources, including, municipal incinerators, pesticides, emissions from industrial stacks, fixation of nitrogen	Persistent organic pollutants, metals, nitrogen
Constriction sites	Construction material	Nutrients, sediments

[9] The operating mining sites are all equipped with waste water treatment facilities.

Having illustrated in general the distinction between point sources and non-point sources, now, I analyse which are the sources and pathways of nutrient pollution in the Chesapeake Bay and in the Danube River Basin. The following graphs illustrate which are the sources and pathways of nitrogen (N) loads and phosphorus (P) loads both in the Chesapeake Bay and in the Danube River Basin (hereinafter DRB) in 2015. The pollution loads in the Chesapeake Bay were measured using waste water discharge data reported by watershed jurisdiction and the Chesapeake Bay Program's Watershed Model. MONERIS model was applied in the case of the DRB for the quantification of nutrient pollution in the river system.

In both waterbodies, the quantity of nitrogen loads is more significant compared to phosphorous loads. Namely, in the total nitrogen load Chesapeake Bay, in kg/ha*a, is 6.61 compared to 0.417 [kg/ha*a] of phosphorus, similarly in the DRB the total nitrogen load was 7.5 [kg/ha*a] (605kt/a) and the phosphorus load was 0.48 [kg/ha*a] (38.5kt/a).[10] In both cases the amount of nitrogen is around 15 times larger than the amount of phosphorus. These results highlight that practices and technology to remove nitrogen are extremely relevant in order to prevent additional harm to the environment. The graphs highlight how nitrogen is mainly introduced into the environment through agricultural activities (manure, fertilizers, etc.). In the Chesapeake Bay 2.96 [kg/ha*a] of nitrogen were emitted from agriculture (53% of the total nitrogen load) and in the DRB the agricultural nitrogen emission that reached the surface waters added up to 2.96 [kg/ha*a] (51% of the total nitrogen load). In general, the N and P that reach the Chesapeake Bay and the DRB originate from agricultural and urban areas, from households and industries and from background and deposition.

The trends of P emission differ between the Chesapeake Bay and the DRB. In the Chesapeake Bay P mainly originates from a diffuse source: agricultural activities that contributes 56% of the total P emission. Instead, in the DRB no source dominates the others in general P comes from industries and households followed by urban and agricultural areas and finally form deposition and background.

[10] ICPDR and IKSD, "The Danube River Basin District Management Plan."

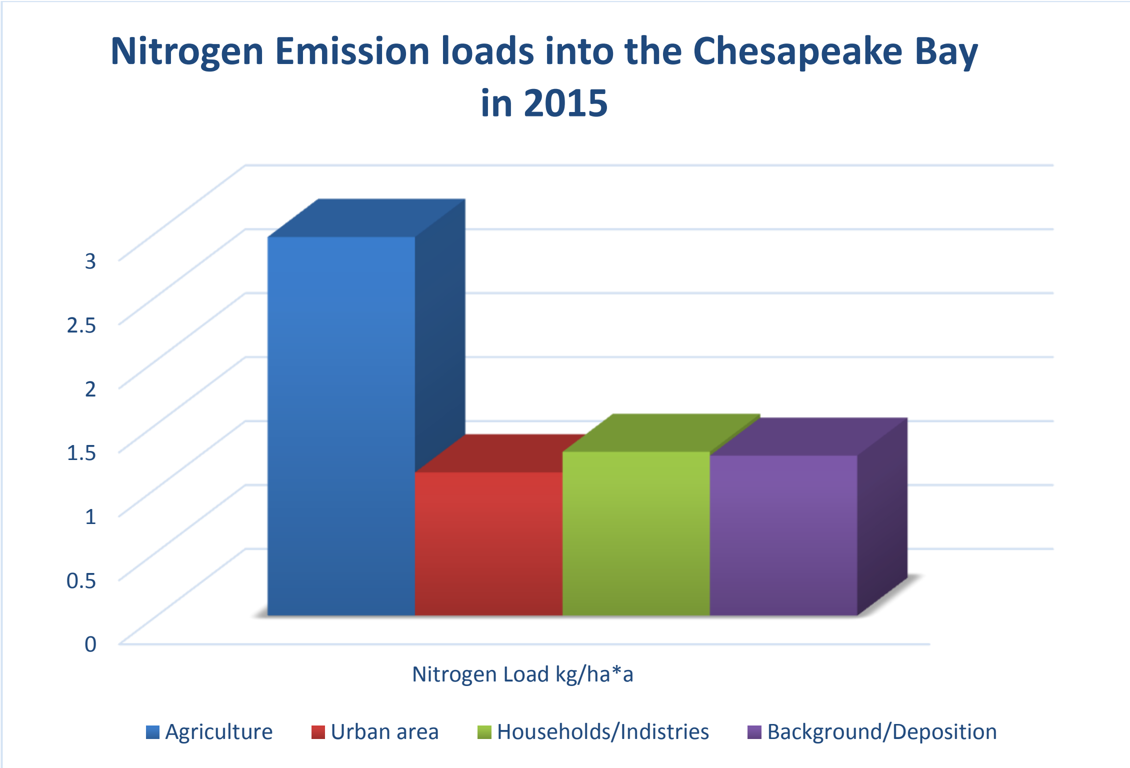

Figure 3-1.Sources and pathways of nitrogen loads into the Chesapeake Bay in 2015.[11]

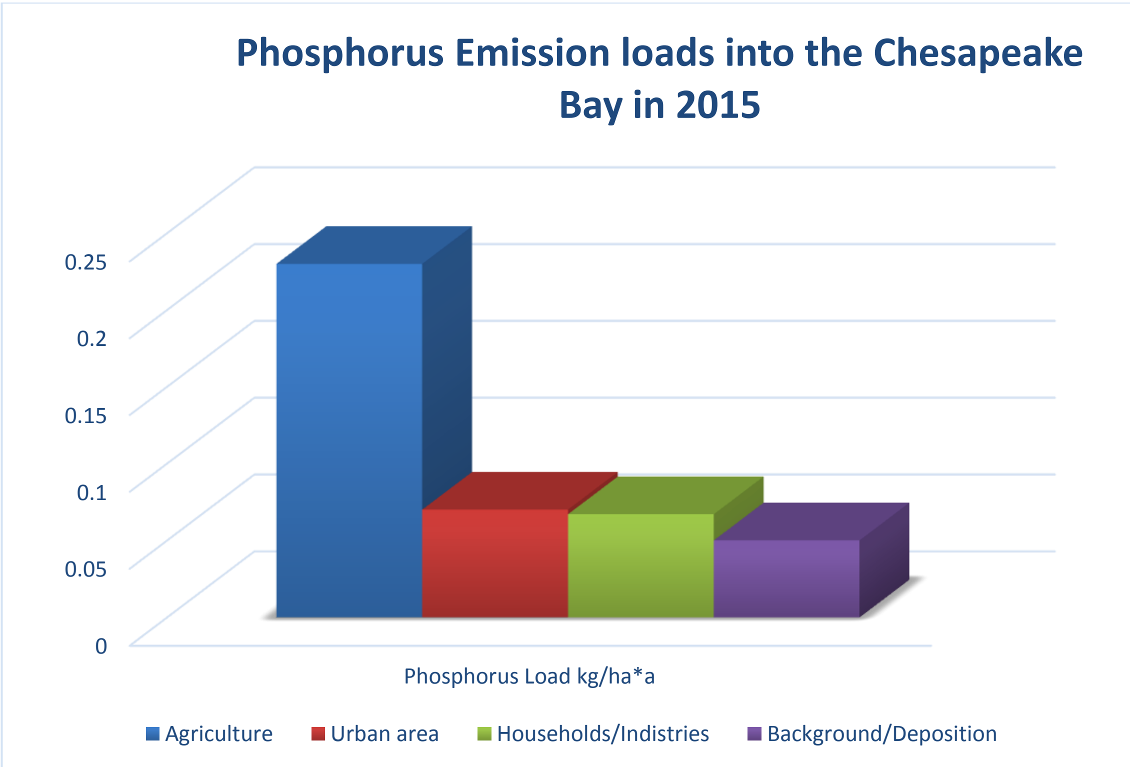

Figure 3-2. Sources and pathways of phosphorus loads into the Chesapeake Bay in 2015.[12]

[11] U.S. Environmental Protection Agency, "Reducing Nitrogen Pollution."
[12] U.S. Environmental Protection Agency, "Reducing Phosphorus Pollution."

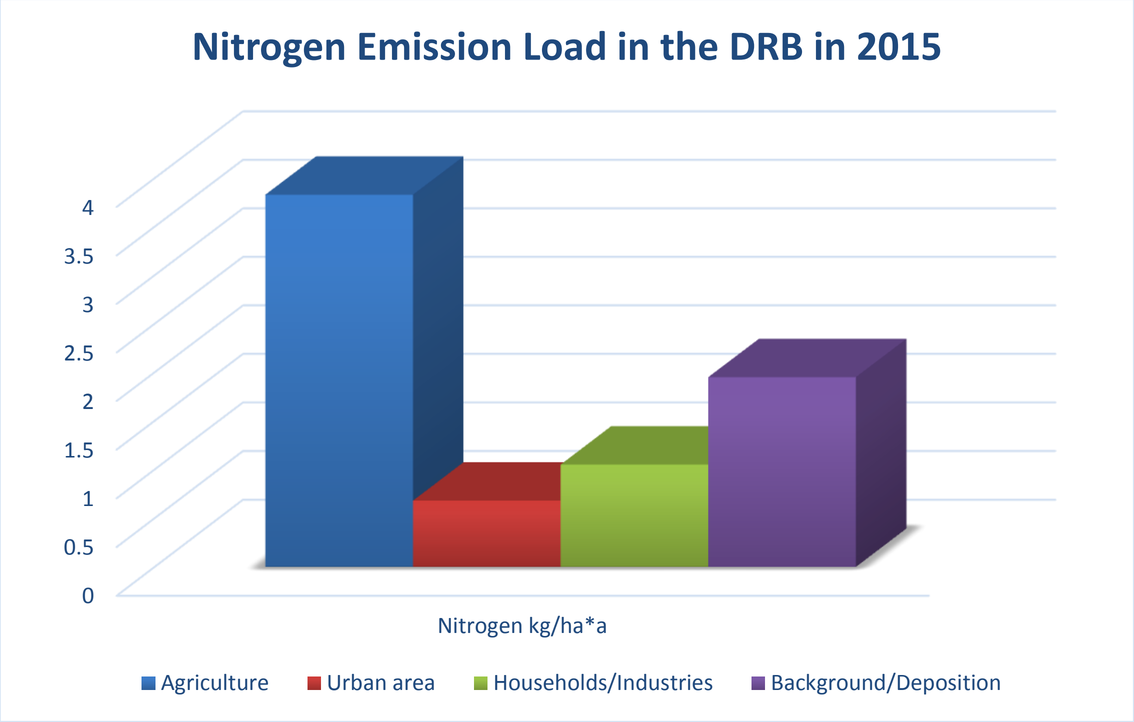

Figure 3-3. Sources and pathways of nitrogen load in the Danube River Basin in 2015.[13]

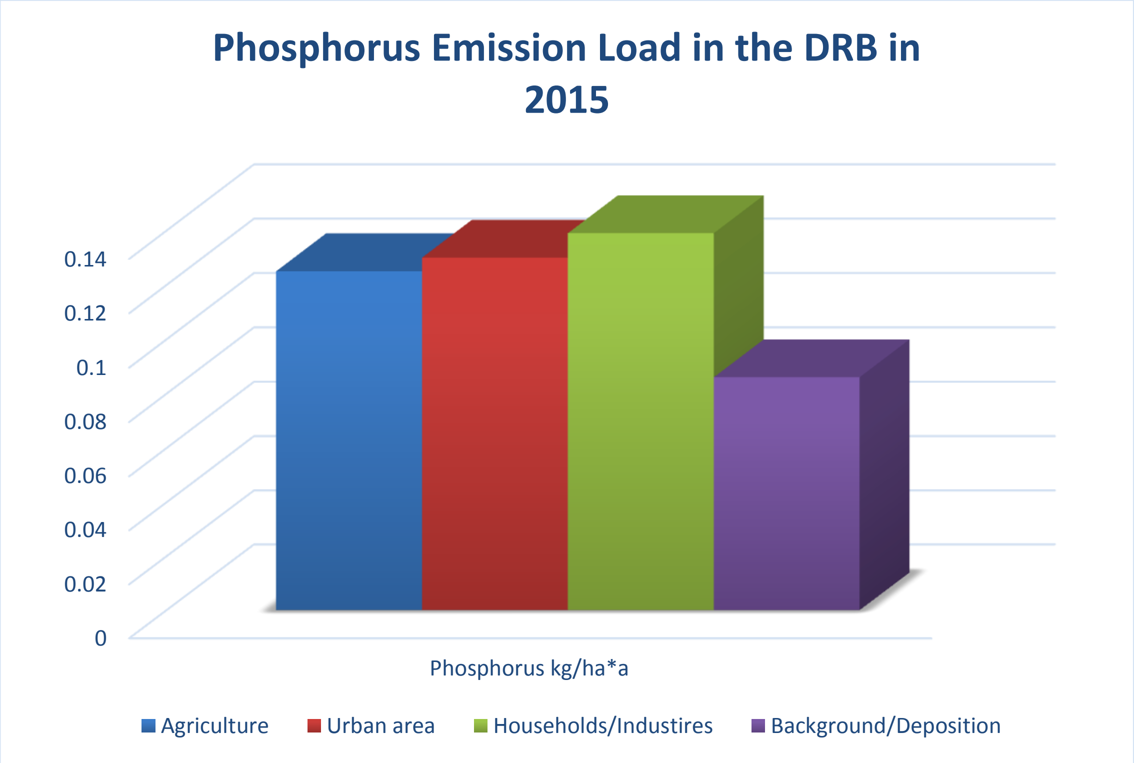

Figure 3-4. Sources and pathways of phosphorus load in the Danube River Basin in 2015.[14]

[13] ICPDR and IKSD, "The Danube River Basin District Management Plan."
[14] Popovici, "Nutrient Management in the Danube River Basin," 37.

Nitrogen and phosphorus have a strong influence on the health of a water body and as illustrated above the emissions of these nutrients are still very high. When addressing nutrient pollution, it is necessary to point out which is the source. Specifically, the large difference between diffuse and point source pollution entails the need always refer to the nature of the pollution input. Non-point sources constitute the major contributors of water pollution this adds an increased complexity in the establishment of a water pollution control because of the source and the timing are hard to predict.[15]

1.3. Pollution Pathways

Having analysed the sources of pollution, the pathways, or routes and means by which substances are released in the aquatic environment, have to be tackled. Substances once released may be immediately emitted in the waterbody or they may pass or be stored in an environmental media, as soil and air. The latter, is a pathway because once pollutants are emitted in the air, though wet or dry deposition these can be deposited in waterbodies or in the soil.[16]

[15] Tietenberg and Lewis, *Environmental and Natural Resource Economics*.
[16] European Commission, "Guidance Document No. 28: Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances," 14.

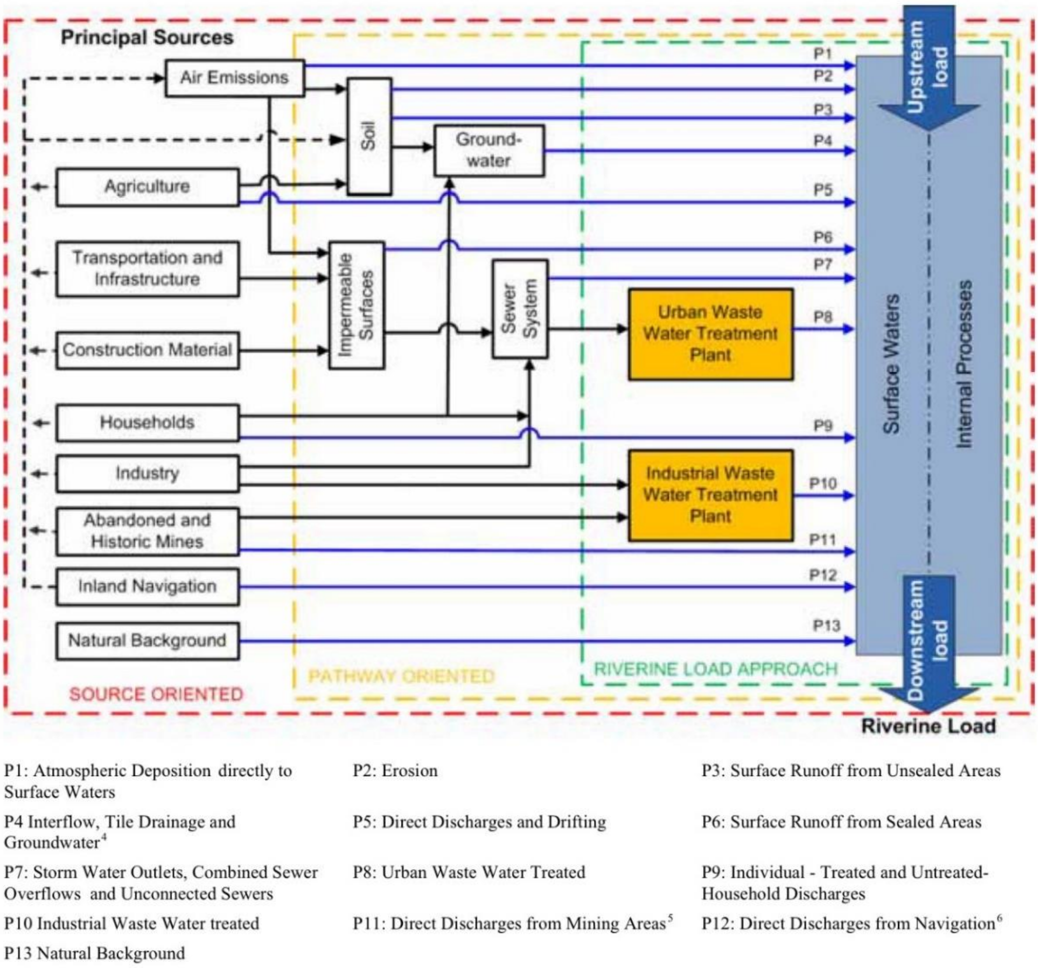

Figure 3-5. Material flow analysis of the sources and pathways of nutrients to surface waters.[17]

The main transport of pollutants to surface waters is accurately shown on the right in Figure 3.5. The scheme shows on the left the most important sources of pollutants, these can be directly introduced into the waterbodies (blue arrow) or pass through a media (black arrow). Nutrients originating in agricultural areas can be directly discharged into surface waters (P4) by surface runoffs they can pass through the soil and reach the surface waters via groundwater (P5). Waste waters from households can either be discharged directly into the waterbodies but usually they reach the water bodies once they passed though sewer systems and water treatment plants (P8 and P9). The material flow analysis also highlights which are the pathways of pollutants: such as soil, groundwater, impermeable surfaces, sewer systems and air. The nutrients transported by these pathways may take a very long time to reach the surface waters. Some examples of emission pathways to groundwater are: leaching from agricultural areas and from landfills and accidents. Emission pathways to surface water include the

[17] Ibid., 16.

diluted transport of surface runoffs, particulate transport of erodes surfaces, and drainage form agricultural areas.

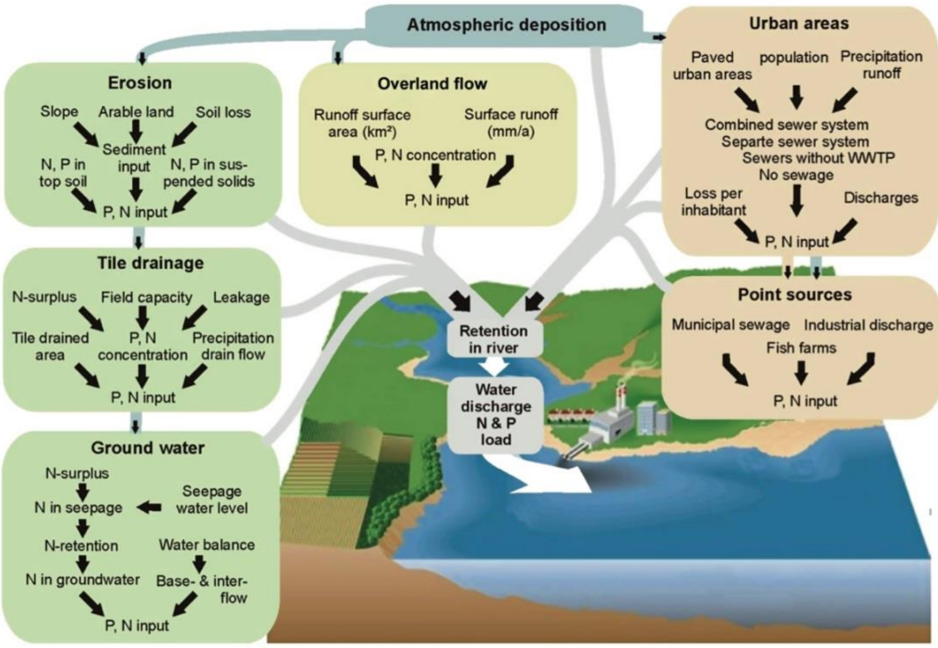

Figure 3-6. MONERIS, model for nutrient inputs in a river system.[18]

A model developed in Europe for the estimation of nutrient pollution deriving from different pathways is MONERIS (MOdeling Nutrient Emissions in River Systems). The data utilized by this model is based on water quality, river flow and geographical information system (GIS). It allows regional quantification of nutrient discharge via both point source and non-point source.

1.4. Nutrients as Waterbody Pollutants

Water pollution varies among different water bodies. The differences are due to various factors such as the local: industrial and agriculture production processes, consumption of products, chemical composition and properties of the substances, infrastructure for waste water management and the hydrological characteristics. The major classes of pollutants that can harm water ways include: toxic chemicals; pathogens and waterborne diseases; nutrients; biodegradable wastes; thermal pollution; and sediments. For the purpose of this dissertation the following part focuses nutrient pollutants: where they originate and which are the consequences of excess of nutrients.

[18] Popovici, “Nutrient Management in the Danube River Basin,” 30.

Nutrient pollution is the presence of high levels of nitrogen and phosphorous from agriculture fertilizers, animal manure, storm water runoff, garbage dumps, effluents of sewer systems, and effluents from WWTP depending on the level of treatment (primary, secondary, tertiary). Nitrogen is one of the major constituents of the atmosphere and it plays a leading role in the production of animal and plant tissue. Animals and plants use it to synthesise protein. The presence of phosphorus in waterbodies, on the other hand, does not derive from atmospheric deposition. This element is of vital importance for plants because it allows the conversion of sunlight into usable energy, and it is also essential for the growth and reproduction of cells.[19] The effects of phosphorus and nitrogen pollution are both direct and indirect. These effects on the ecosystem include eutrophication; improved primary productivity; reduced water clarity; increased phytoplankton biomass; loss of fishery resources; changes in ecological structure; decrease in oxygen levels (hypoxia and anoxia); and alteration in the trophic: structure, interactions, and trophodynamics of phytoplankton, zooplankton, and benthic communities.[20] Moreover, nutrients are the limiting factor for aquatic vegetation, hence when they are present in large quantities they fosters excessive growth of algal blooms.

Eutrophication is the term used to refer to waters that are rich with nutrients that alter the system. In other words, nutrient over-enrichment is the cause of eutrophication (which is the effect). This phenomenon can be beneficial because it can increase the primary productivity and lead to an increase in fishery, nonetheless, in most of the cases the presence of high nutrient levels has negative impacts on the waterbody. The large presence of nutrients supports the plant and animal presence in the waterbody. Consequently, due to the increased respiration, eutrophication is accompanied by a reduction in the oxygen levels. Nutrients are the limiting factor for aquatic plants, therefore by augmenting the amount of nitrogen and phosphorus aquatic plants proliferate. Consequently, the rate of death of plants also increases and with is the activity of bacteria that decompose the dead matter. Bacteria consume oxygen, and if the decrease of oxygen is not supported by the introduction of additional oxygen through photosynthesis or mixing processes then hypoxia or anoxia follows. Hypoxia is the situation in which the level of oxygen is less or equal to 2.0 milligrams per litre

[19] Minnesota Pollution Control Agency, “Nutrients: Phosphorus, Nitrogen, Sources, Impact on Water Quality: A General Overview.”
[20] National Research Council and Committee on the Causes and Management of Coastal Eutrophication, “What Are the Effects If Nutrient Over-Enrichment?”

(below this value there is evidence in the decline of species diversity in the system), while anoxia indicates the absolute lack of oxygen.[21] The development of hypoxia and anoxia depends also on the temperatures. These phenomena are more likely to occur in summer due to the warming of the water column, which leads to stratification. A barrier can form, that stops the introduction and mixing of oxygen from surface waters. Moreover, oxygen demand increases and the solubility of oxygen decreases as temperature increases.[22]

As mentioned, one of the effects of eutrophication is the increase in algal bloom. The *Cyanophyta* and green algae spread and form a thick layer of "green scum" on water surface. The "blooms" of the toxic algae are called HABs, and are characterized by the multiplying and occasional dominance of species of harmful or toxic algae. HABs cause harm because of the release toxins leading the organic matters in water to be decomposed into harmful gases that can poison the fish and seashells.

1.5. Nutrient Dynamics in Waterbodies

Tietenberg suggests a distinction between absorptive and accumulative pollutants. Absorptive pollutants can be up taken by the nature so no harm is done to the environment. The emissions can pose a damage to the environment if they exceed the absorptive capacity of the of the environment. Meaning that when the emission load exceeds the assimilative capacity of rivers, then the pollutants accumulate in the environment.[23] Heavy metals are an example of accumulative pollutants that have decreasing depositions along the rivers. Nitrogen and phosphorous can be assimilated by the environment but if they exceed the threshold then they have harmful effect. These types of pollutants are called fund pollutants.

In watersheds the vegetation, geology, and physiology influence the chemical reactions, the transport of the nutrients and the resilience time. The varying characteristics of the riparian zones have a strong influence on these factors. Riparian areas are located between the water and the terrestrial system, and here nutrients are retained, transformed and removed by the system.[24] For example, phosphorus is retained by riparian forests because transported by erosion. Forests have historically

[21] Ibid.
[22] Ibid.
[23] Tietenberg and Lewis, *Environmental and Natural Resource Economics*, 334.
[24] Topa, Gheorghe, and Vadineau, "Nutrient Storage in Riparian Vegetation in the Lower Danube Floodplain."

acted as nitrogen sinks, and the retention capacity depends on the age and on the degree of anthropogenic intervention. In the Chesapeake Bay's western shore and in the Danube crossing the Black Forest in Germany and the Carpathian forest nutrients are partially retained by the forests. Nonetheless, the assimilative capacity has reduced over time do to the increase of acid rain, thus of nitrogen deposition. Phosphorus and nitrogen behave in different ways within the watershed. Phosphorus's transport depends on the soil type, rainfall patters and on the slope, because it tends to be particle bound.[25] It also depends on the particle retention capacities of the riparian zones, reservoirs and wetlands and on the runoff. Nitrogen is widely used in fertilizers, the main compounds used are nitrate, ammonia, ammonium and urea. The crops uptake a certain amount of nitrogen and the rest of the nitrogen, given the high solubility in water, ends up in the groundwater and surface water. Nitrogen is also subject to losses due to the denitrification processes.[26]

The behaviour of nutrients in a waterbody is very important in the application of water quality trading. Since phosphorus and nitrogen can be absorbed by the environment not beyond certain amounts the objective of policy makers is to reduce the amount of nutrients within the assimilative capacities of the waterbody. But the water management also must consider the geographical location of the sources. When sources take part in the nutrient trade these must be quite close to each other in order to achieve local results.

[25] Boesch, Brinsfield, and Magnien, "Chesapeake Bay Eutrophication: Scientific Understanding, Ecosystem Restoration, and Challenges for Agriculture," 308.
[26] Ibid.

4. Water Quality Trading

4.1. What is Water Quality Trading?

4.1.1. Introduction

Water Quality Trading (WQT), or nutrient trading, is the term, which is used to refer to nutrient trading in waterbodies. John Dales in the late 1960's was the first one to propose the application of markets to improve water quality. This triggered the first experiments in water quality trading in the United States in 1980. Since then WQT has been developed and applied in various ways in different countries (Australia, Canada, New Zealand and on the Baltic Sea).[1] This concept derives from the success of emission trading in air pollutants, which was first introduced in 1975 in the United States and is now used worldwide as an effective measure to reduce pollution in the air.[2] Also, other environmental issues used trading programs, like wetland mitigation, steam bank restauration and endangered species habitat loss.[3] The accomplishments of these programs lead to a strong influence on the expectations of what markets can achieve in other fields. Truly, the application of market efficiencies for the achievement of environmental goals has been one of the major innovations for environmental policies. The advocates of market mechanism have increased outside the sphere of economics due to the many benefits that this approach has evidenced. Among the various benefits, which constitute the basic pillars of economics, are the reach of efficient gains and the stimulation of innovation. Most importantly when market approaches have been applied as means to reach environmental goals improvements were delivered faster and at a lower cost.[4]

4.1.2. Is WQT a valid cost-effective solution to reach quality goals?

Knowledge to date is limited, but it seems that trading may be part of the answer attain better water quality. To reach water quality targets the authorities set a binding watershed goal, which is defined as the cap. The setting of the emissions cap for the watershed, is based on the analysis of the maximum amount of pollutants that a

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[1] The Hunter River Salinity Trading Scheme in Australia, the South Nation Phosphorus Trading Program in Canada and the Lake Taupo Nitrogen Trading Program in New Zealand. Greenhalgh and Selman, "Comparing Water Quality Trading Programs: What Lessons Are There to Learn?"

[2] Ibid.

[3] Shabman, Stephenson, and Scodari, "Wetland Credit Sales as a Strategy for Achieving No-Net-Loss: The Limitations of Regulatory Conditions"; Boyd et al., "Trading Cases: Is Trading Credits in Created Markets a Better Way to Reduce Pollution and Protect Natural Resources?"

[4] Shortle, "Economics and Environmental Markets: Lessons Form Water-Quality Trading."

watershed can absorb while at the same time meeting the environmental quality goals. Therefore, the cap has to be partitioned between the various pollution sources.[5]

The authorities establish discharge allowance, or credit, equal to the emissions cap, which is a permission to discharge a defined amount of nutrients in waterbodies in a limited period of time. The difference between credits and allowances is that the former refers to a flow, expressed in ton/year, while the allowances, which are the most used nowadays refer to the entitlement to emit one ton at the time.[6] Once the authorized ton has been emitted, to continue discharging pollutants, the source has to request a new allowance. Discharge allowances are necessary to make water quality, which is a public good, acquire characteristics of a private good (rival and exclusive). Hence, the regulatory agency managing the program has property rights that it can enforce. Any discharger must hold an allowance to legally introduce pollutants into surface waters.

To comply with the regulatory obligations, point sources that are emitting too many nutrients, must install filter technology or modify the production processes to limit the amount of nutrient discharged. The costs for reducing emissions depend on the size, location, management practices, and overall efficiency of an individual source. Installing new emission control technology can be costly and can damage some businesses. So, nutrient trading is a valid alternative method for complying with the regulatory obligations. The market is created by trading allowances and the regulatory agency creates demand by limiting the quantity of allowances on the market. If a firm discharges more pollutants into the environment, than the amount it is authorized to, it is subject to a fine. So, profiting from the market, sources that pollute a lot or that face high pollution control costs can purchase equivalent pollution reductions from other sources at a lower cost, and meet their allowances. If a firm pollutes less than the discharge allowance it can profit by selling the excess pollution reduction. Non-point sources, can reduce their pollution discharge by applying efficient best management practices (BMPs), which must be assessed and accepted by the regulatory authorities, and can profit by selling emission reductions to point sources.[7]

An example can illustrate how WQT lowers the costs of reducing pollution. In a hypothetical scenario, there are two sources, A and B, source A should reduce its nutrient emissions by an additional 5 tons/a to reach the water quality goal. The cost for

[5] How the emission cap is calculated in the USA is analysed in section 4.2.2.
[6] Tietenberg, “Tradable Permit Approaches to Pollution Control: Faustian Bargain or Paradise Regained?”
[7] Ribaudo and Gottlieb, “Point-Nonpoint Trading- Can It Work?”

source A to reduce its emissions is 200.000 $/a, because it should install new technology. Source B does not have to reduce its emissions, it is already in compliance but it can reduce its emissions by 5 tons/a for 120.000$ $/a. If the two sources decide to trade the emissions, source A can by the emission reductions by source B and the total costs savings, or gains from the trade, amount to 80.000 $/a.[8] The cost saving is significant and the way that the benefits are shared between the sources is correlated to the price of the credits. If the price of a credit is 28.000 $/ton that source A would have to pay 140.000$ instead of 200.000$, saving 60.000$, while, source B would earn 20.000$ (140.000-120.000$).

The U.S. Environmental Protection Agency, in the Notice published in 2003, estimated the potential cost-savings of WQT compared to command and control approach. [9] In the reference year, 1997, the costs of private point sources for complying with the regulations were of around $14 billion and for the public point sources the costs were of around $34 billion. With the introduction of nutrient trading, the EPA estimated that at a national level the costs of complying with the Total Maximum Daily Load (TMDL) would be reduced by $900 million annually.[10]

Hereafter, theoretically through trading water quality targets can be met at a lower cost. Thus, the introduction of emission trading could be valuable alternative to reach water quality goals, in that it is cost-effective and it gives more flexibility to the sources on how emission limits shall be met.

[8] Van Houtven et al., “Nutrient Credit Trading for the Chesapeake Bay: An Economic Study.”
[9] Environmental Protection Agency, “Water Quality Trading Policy: Issuance of Final Policy.”
[10] Ibid.

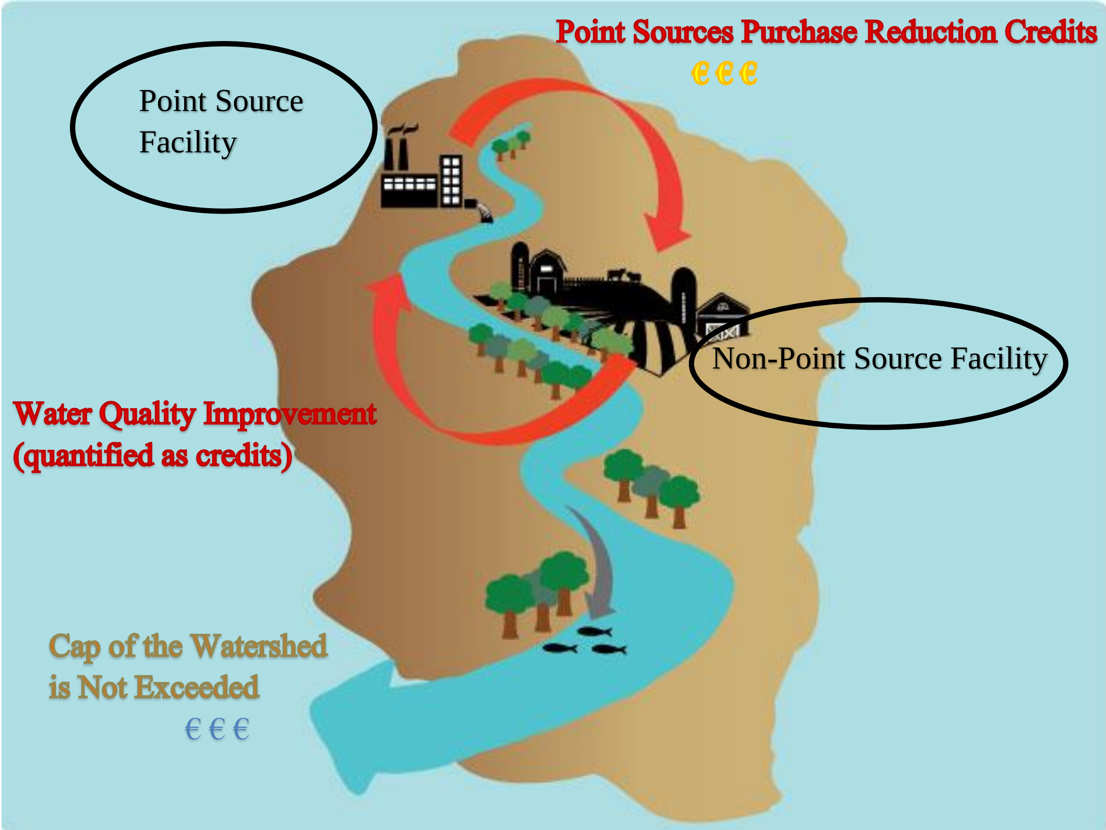

Figure 4-1. Illustration of how water quality trading works in a watershed.

4.2. Rules for proper functioning of the market

The proper functioning of the WQT market is insured by the compliance with some simple rules. The first rule, refers to the units of trade that must be clearly defined and must have an ecological and economical validity. This allows the regulatory agency to be able to enforce them. Additionally, the units of trade should be periodically measured. Also, a necessary rule to be followed, to ensure that expected water quality gains are achieved, is that buyers and sellers must act in the same time frame and there must be an equivalence between the discharge of the sold and purchased point.[11] Finally, the main rule that applies to all markets is that there must be a balance between demand and supply, in this case there must be alignment amongst the supply of non-point credits and the demand from point credits. These basic requirements are now analysed in more detail in two phases. In the first place the legal aspects of the market are defined. Secondly, the most relevant design features of the market are highlighted

[11] "Purchased reductions in discharge must be produced during the same time period that a buyer is required to produce them." Ribaudo and Gottlieb, "Point-Nonpoint Trading- Can It Work?", 7.

with an emphasis on what a regulative authority must consider when developing a WQT program.[12]

4.2.1. Legal aspects of the market

Any kind of market is legitimized by law. The establishment of a market necessitates legal authorization; an administrative system; defined permit entitlements; enforcement of trade agreements; and continuous monitoring and reporting to certify observance to the agreements.[13]

The market structures for WQT must not conflict with the national, international, regional or federal legislation and mandates. In the United States the Clean Water Act (CWA) does not explicitly authorize WQT but this can be inferred by many sections of the same.[14] As for Europe, as is described in Chapter 6, the Danube River Protection Convention and the Helsinki Convention neither promote or prohibit trading for water pollutants. Hence, even if there is not any explicit authorization for trading in the legislation, there are no barriers to WQT programs.

Once the WQT program is established there must be an administrative authority that inspects the monitoring and reporting of reductions and it must have enforcement capacities. The administrative entity has a pivotal role in the implementation and management of the program. In fact, it can assist the trading partners throughout the negotiations and can provide them with technical, economic and regulative assistance. In Corrales et al. [2013] we can find that the administrative authority facilitates trade by identifying the potential buyers and sellers, it helps the sources understand the trading policy, it controls the credits, and informs the parties about updates on regulation on prices and on sources demanding for credits.[15]

The premise of WQT is that the discharges are defined as legal entitlements, meaning the legal authorizations to discharge up to a certain limit. These entitlements in order to work in a market have the characteristics, according to the economic theory, of being: defined, privatized, enforceable and transferrable. Transferability is the right to pass the entitlement to others, and enforceability is the possibility to protect the entitlement and to ensure compliance with the transfer rules.

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[12] Ibid.
[13] Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."
[14] 33 U.S. Code §1312, 1313 and the U.S. EPA "Draft Framework for Watershed-Based Trading", 1996.
[15] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."

Enforcement is particularly crucial because it ensures responsibility and liability in trading programs. In case a trading fails the programs should clearly define who is accountable for remediation and who is liable. The transaction costs highly depend on the enforcement structures, that are established by the regulatory authority. In case of non-compliance the liability regime depends either on permit (issued by the national regulation) or contract (based on bilateral or multilateral negotiations) settings. In case of a permit the enforcement flows form the authority to the permittee, instead in the contract the enforcement flows amongst the parties. The party responsible for the failure of the trade, being the seller or the buyer, is liable and faces a penalty. Penalties for non-compliance, insure a well-functioning program and are an incentive for compliance.

Strongly connected to enforcement are the monitoring and reporting. These two are the most important steps that have to be considered when analysing a market structure because they have a large influence on the transaction costs. If the transaction costs are high, then they might constitute a barrier to trading. Periodic assessment of environmental conditions and of the monitoring compliance are needed to determine the effectiveness of a program. Point sources have monitoring and reporting requirements, like the taking of samples for water quality, maintaining the monitoring equipment, keeping records and, reporting.[16] Whereas, non-point sources do not have monitoring systems of the direct discharge, they can calculate the pollution discharges using models.[17] In general, credits are assigned to non-point sources based on the BMP. The nutrient reductions of these practices can be estimated. Thus, to mitigate uncertainty a trading ratio can be applied. To whom the responsibility of monitoring and reporting goes and who bares the costs must be specified in the market structure. The collected data should be inserted into a centralized database accessible to every party to facilitate the trade.[18]

4.2.2. Design features of the market

Once the legal requirements have been fulfilled the regulative authority must consider the specific design features of the water quality market. Unfortunately, worldwide there are not many active trading programs that can provide examples of design features that make a program effective. The design features depend on the watershed quality goals and on the specific characteristics of each watershed. Firstly,

[16] Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."
[17] Paccagnan, "I Permessi di Inquinamento Negoziabili per le Risorse Idriche: Applicabilitá all'Italia."
[18] Pharino, *Sustainable Water Quality Management Policy. The Role of Trading: The U.S. Experience*.

the quality goals must be established, stimulating the demand for nutrient credits. Then the commodity traded should be clearly defined, in order to then proceed with the selection of the type of trading and the identification of the sources that take part in the water quality market. Providing definitions of terms and standards, commonly understood, is especially important for the implementation of WQT in the DRB, due to the participation of many countries with different languages. If non-point sources take part in the WQT programs the formulation of trading ratios foster an equivalence between the credits sold and bought. To implement a successful program, it is also advised to communicate and involve stakeholders to increase the legitimacy and improve the effectiveness of the program.

The source of demand for nutrient credits by a point source is generated by the establishment of a cap on discharges that is inferior to the current one. The cap must be binding otherwise the regulated sources do not have incentives to demand credits in the market. [19] The demand depends on the cost-difference between further implementing technology to reduce emissions and the cost of buying non-point source reduction credits to compensate the emissions. In the American water quality regulations, the Clean Water Act provides a mechanism, the TMDL, which establishes a cap on the pollution discharges in impaired water based on Water Quality Standard. The goal of establishing a TMDL is to determine "the loading capacity" of a watershed, to be able to distribute the load among the pollutant sources guaranteeing that the water quality standards are achieved. All the contributing sources of the pollutants are contemplated. The TMDL was defined by the EPA as the "pollutant loading for a segment of water that results in an ambient concentration equal to the numerical concentration limit required for that pollutant by the numerical narrative criteria in the water quality standards".[20] Namely, the value of the TMDL depends on the assimilative capacities of the stream segment: its flow, the quality standards applied, the in-stream pollutant reactions the determine the mass of the pollutant in the water flow.[21] Depending on the waterbody, the process may be based on hectares, population, flow (e.g. WWTP flow). It is calculated through the following formula:

$$TMDL= \sum WLA + \sum LA + MOS$$

[19] Ribaudo and Gottlieb, "Point-Nonpoint Trading- Can It Work?"
[20] Environmental Protection Agency, "Water Quality Trading Policy: Issuance of Final Policy."
[21] Ibid.

The formula explains how the total maximum load is calculated by adding the sum of waste loads allocations of point sources (WLA) with the sum of the load allocations of non-point sources and background (LA), and finally with the margin of safety (MOS). The latter fills the gap in case of lack of knowledge regarding the relationship between WLAs LAs and water quality. For nitrogen and phosphorus, the MOS is implicitly incorporated through conservative model assumptions to determine the allocations. The TMDL are developed using different techniques including simple calculations of the mass balance to more difficult water quality models.[22] In the Chesapeake Bay Program, the WLA is calculated as the load that reaches a stream segment in a specific point of the stream's watershed.[23] The TMDL is then sub-allocated to the states that then allocates different shares to the sources.

In contrast, in Europe the quality standard is fixed as "good status" for waterbodies, there is no quantitative cap established for the amount of nutrients that can be discharged into a waterbody. A solution for Europe can be the establishment of a standard related to the current status and the credits are therefore assigned to the sources that reduce of a certain amount the current levels of impairment. This solution is what is applied nowadays in the US for non-point sources.[24]

The definition of a common unit for the commodity traded excludes the possibility of misunderstandings. The units that are usually adopted are expressed in kilograms per year. Additionally, the specifics of the pollutant traded must be analysed. Different pollutants interact in different ways with the water body because of their distinct chemical composition. This thesis focuses on the trade in nutrients, phosphorus and nitrogen, but some water quality trading programs in the United States have also applied the trade for salinity and for sediments.[25]

Having identified the pollutant and the goal for the watershed, the types of trading have to be addressed as well. The initial water quality trading programs applied in the United States envisaged trading between point sources, but due to the abundance of pollution that derives from agricultural areas the exclusion of non-point sources would be counter-effective. To start defining the sources that may take part in the market all the potential sources of the watershed must be assessed. The assessment

[22] U.S. Environmental Protection Agency, "Program Overview: Total Maximum Daily Loads (TMDL)."
[23] Ibid.
[24] Ibid.
[25] In the Hunter River Trading in Australia salinity credits were exchanged in order to maintain a certain salinity level in the watershed. The Pennsylvania's Chesapeake Bay Water Quality trading has addressed not only the trade in phosphorus and nitrogen but also the trade in sediments.

includes the analysis of the proximity of the source to the water body, its amount of emissions, the limitations on emissions that a source might already have and the costs for pollution reduction, and finally the willingness of the sources to take part in the WQT program. Once the type of trade has been identified, the regulators must decide on the allocation strategy. Permits can be allocated once at the beginning of the program or periodically. The periodic distribution allows to reduce pollution at a faster pace because it incentives polluters to obtain more allowances.[26] Permits are usually distributed through auction or grandfathering. Following the auction approach, the source buys the permit from the responsible governmental agency at the market price. The grandfathering method, is the most common method in the U.S. Regulators distribute allocations based on the emission history of the sources. It is widely spread because it is easier for regulators to implement it even if it creates some complications for the introduction of new sources.[27]

The regulative authority established the baseline participation requirement. The baseline is necessary for a source to generate credits from additional pollution reduction.[28] In practice this means that a source should reduce its emissions below its baseline if it wants to sell the credits. The identification of a baseline has important implications on the cost of the credits for non-point sources and consequently it influences the amount of money that flows to the non-point sources for the pollution reduction. Diverse trading programs have determined the baselines in distinct ways, two major approaches have been adopted. The first is the simplest, it is found on the agricultural control practices that were performed at a specific time. Hence, if the management practices are changed after the date these generate credits. The second, results in load reductions though a TMDL. The non-point sources cannot gain credits unless they meet the baseline requirements. The establishment of a baseline requirement, thus, indirectly obliges farmers to adopt very a stringent set of practices to reduce their emissions otherwise they cannot generate credits. All the least costly reductions are not worth it. A result is that the entry costs might be very high for the farmers.

[26] Pharino, *Sustainable Water Quality Management Policy. The Role of Trading: The U.S. Experience*.
[27] Ibid.
[28] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems"; Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."

Water quality equivalence can be achieved by introducing trading ratios. Trading ratios are used in many programs.[29] Given the past experiences in WQT five different ratios can be identified: the delivery, the uncertainty, the water quality, the retirement and the reserve ratio.[30]

The delivery ratio, or also known as the location ratio, reflects the pathway of a pollutant. It applies discount factors to compensate the pollutants path to arrive at the surface waters.[31] Thus, it considers the attenuation, meaning the rate of reduction of the nutrients from the environment's natural processes, like biodegradation. This ratio depends on the distance of the location to the impaired waterbody. Consequently, the greater the distance of a source to the impaired waters the grater the attenuation factor will be. This ratio allows to have an equivalence between the various sources of a waterbody.

The uncertainty connected to the non-point source discharge have led to the establishment of an uncertainty ratio. The uncertainty connected to nutrient discharge of non-point sources derives from the seasonal variability, the rain patterns, and the location's specific chemical and physical characteristics. Uncertainty derives also from the difficulty of measuring the results of the implementation of the BMP, which are usually estimated. The uncertainty ratio compensates the lack of certainty by applying a higher ratio, usually a 2:1 ratio is applied.

Water quality trading ratio, as the name indicates, measures the effect a source has on water quality or it may be used to monitor the effect of a pollutant in a specific area. Therefore, it might be used to require additional reductions to ameliorate the health of the water body. This ratio considers situations that require water quality considerations, like wetlands or wildlife reserves. The increase of pollution in these sensitive areas may have a greater impact, thus sources can have their reductions discounted. This ratio is like the location ratio because it also takes into account the particular position of a source, only that the location ratio looks at the distance of source form the impaired waters and applies attenuation factors, whereas, the water quality

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[29] The Long Island Sound, the South Nation River and the Pennsylvania Water Quality Trading Program (that applies three different types of ratio: delivery, reserve and edge-of-segment.

[30] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems"; The Chesapeake Bay Program Nutrient Trading Negotiation Team, "Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines."

[31] The Chesapeake Bay Program Nutrient Trading Negotiation Team, "Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines."

ratio addresses the location to address the specific conditions of the receiving waterbody. At times the water quality ratio and the location ratio can be used together.

If a part of the credits is excluded before the trade negotiations take place, then we talk about retirement ratio. A source purchases credits for a larger part of pollution than they intend to offset, then part of the credit is retired to increase the benefits for the waterbodies and to reduce uncertainty.

To mitigate the possibility of failed pollution reduction, a portion of the total credits can be "reserved", this is in fact called the reserve ratio. The reserved credits are placed in a fund and are used in case of default of purchased credits. This ratio is used to assure protection but does not account for the uncertainty of non-point source reduction efficiency.

The trading conditions and the guidelines of a trading program are determined by the market structure. The literature on the environmental market structures for water quality is very confused some refer to offset trading, credit trading, allowance trading and emission trading. Here I present the taxonomy that was presented in a paper by Woodward and Kaiser.[32] They distinguish four types of market structures: exchanges, bilateral negotiations, clearinghouses and sole-source offset.

In the exchange market, potential buyers and sellers meet in a public forum where they exchange a uniform good at a given price. The main requirement is the uniformity of the good exchanged and this poses some issues concerning water quality trading because the sources of pollutants and the actual pollutants are not uniform by nature. This is because the sources of nutrient pollution can be both non-point sources or point sources, and the amount of pollution deriving from non-point sources is always a slightly uncertain. Also, the impacts of the different sources vary, according to the distance from the receiving water body and other physical conditions. This results in a difficulty to compensate the increased pollution from one source with the reduction from another. Therefore, trading ratios are put in place. An additional complication that is associated with the exchange market is the fact that the abatement costs are not given but are determined by the location of the source. If the pollution increases upstream then the abatement costs downstream will increase. Hence, the use of exchange markets does not seem suitable for nutrient trading.[33]

[32] Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."
[33] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."

One of the most used market structures for nutrient exchange are bilateral negotiations. These in fact, are ideal if there is a diversity if the sellers and the traded good is variable. The adversity of negotiations is that the transaction costs might be very elevated due to the necessary controls on the respect of the limitations on point sources. Nonetheless, there are clear advantages compared to the exchange market, the structure allows for a case to case valuation to secure that the environmental standards are met. Besides, the parties can decide to provide incentives for the monitoring challenges associated with the non-point sources. These advantages coupled with the low initial costs to establish the market, confer an appeal to this market structure.

When a third party is involved as a link between the buyer and the seller we talk about water quality clearinghouses. The third party can be the state who facilitates the transaction between the buyer and the seller. The third party plays a central role in proving the participants with full information. The role of the intermediary is like that of the broker in the exchange market, with the difference that in the clearinghouses there is no contract between the buyers and the sellers, the interaction between the parties always passes through the intermediary. WQ clearinghouse are efficient if the parties in the trade are not numerous and they face similar abatement costs.

The last market structure, is the less used and it does not even a market structure because it does not require trading, it is a "compensation" between the different sources.[34] Sources that pollute more and exceed their limits can reduce their emissions offsite, instead of reducing emissions onsite. This structure can be used in case the others are inapplicable, it can still reduce the overall costs of achieving water quality.

The four market structures outlined above provide a helpful ground to analyse the various water quality trading programs. The policy makers can use these structures to decide the most cost-efficient solution for them. Moreover, it must be noted that the above-listed market structures are not rigid, they can function also side by side.[35]

The success of a program is highly dependent on the level of engagement of the stakeholders; interested citizens, universities, local businesses, local agencies, and public authorities should be involved throughout the development of the project and they should participate in order to implement an effective WQT program. The advantage of involving stakeholders is also to provide an increased legitimacy of the

[34] Paccagnan, "I Permessi di Inquinamento Negoziabili per le Risorse Idriche: Applicabilitá all'Italia."
[35] Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."

program and to allow the development of a quality trading program that satisfies the needs of the involved parties.

I provided an insight of the various elements that must be mentioned for development of a WQT program. If all the legal aspects and the specific market features needed for a specific watershed are taken into account the market should establish an effective water quality trading market.

4.3. Benefits and Challenges of WQT Compared to the Traditional Command-and-Control Approach

The traditional command-and-control regulation set limits to the emissions or to the mandates of specific pollution control technologies and they differ from WQT programs in that trading is not foreseen. The limitations of the command and control approach are that the polluters have less flexibility concerning the modalities to reach the water quality goals, also they do not establish a system of incentives to reduce pollution below the set goals. Also, WQT programs face many challenges but they also have advantages. Hereafter, I provide an outline of the advantages and the disadvantages of WQT programs.

4.3.1. Benefits of WQT Programs

The potential advantages of WQT programs, compared to the command and control programs, cover a wide range of aspects from environmental to economic and also social aspects.[36]

The first to benefit from the application of WQT programs is the environment according to Corrales et al. (2013). Environmental benefits are a consequence of the introduction of the water quality market that gives the possibility to the sources to reach their emission limits in a cost-efficient way. It has also been noted, since the market based approach gives more flexibility to the sources on how to comply with the regulations, these programs improve the compliance levels and prevent further pollution.[37] As described before, in a market-based nutrient trading program: sources that face high pollution control costs may meet their allowances by buying nutrient reductions from other sources at a lower cost. A source with low abatement costs may

[36] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."

[37] Shabman and Stephenson, "Achieving Nutrient Water Quality Goals: Bringing Market-Like Principles to Water Quality Management."

be incentivised to reduce its emissions below the requirements to gain profit. Having an economic incentive to participate in the trade can increase the willingness of polluter to reduce their emissions. Hence, trading may accomplish the same or better results for the quality of the waterbody and reduces the overall costs of compliance. The indirect benefits on the environment, that derive from the improved health of a watershed, are the enhanced wildlife habitat, with the potential protection for endangered species and the decrease of hypoxic areas.

Theoretically, water quality trade in theory allows to achieve water quality standards in a more equitable, efficient and cost-effective manner. According to the studies of the U.S. EPA, the expenses for the individual sources is lower because they can reduce their abatement costs and they can profit from the economies of scale. This leads to increasing compliance levels: the polluter is given more alternatives on the measures it can take to reduce nutrient pollution. As pointed out by Corrales et al., "the opportunity to trade allowances and adopt the best pollution control technology based on specific conditions, are the means of creating financial incentives for the pollution prevention program".[38] These incentives apply both to the sellers of credits and to the buyers: the sellers that have low abatement costs and can easily achieve their goals, benefit from the revenues from selling the credits; whereas the buyers of the credits benefit from the savings of implementing a low-cost alternative. In this way innovation is fostered and it can potentially lead to an increase in the demand for new emission control technologies.

WQT programs also include social benefits that were less relevant in the traditional programs. Communication between the non-point sources and the point sources is fostered, together with an increase in contact with the regulatory authorities and the various stakeholders that take part in developing a joint solution to ameliorate the state of a watershed. The interaction between the trading partners is nourished by the willingness to achieve common goals with economic mechanisms.

Table 4-1. Benefits of water quality trading programs.[39]

Environmental Benefits	• Achieve equal or greater reduction of nutrient pollution at an equal or reduced cost

[38] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."
[39] Ribaudo and Gottlieb, "Point-Nonpoint Trading- Can It Work?"

	• Enhanced compliance levels • Fosters a market demand for new emission reduction technologies • Creates an economic incentive to reduce emissions below the requirements • Indirect environmental benefits, improve nutrient pollution loading, ameliorate water quality, sustainable growth, improved wildlife habitat and protect endangered species • Encourages pollution reduction to occur in a shorter time
Economic Benefits	• Reduction of the abatement costs for the individual sources • The overall costs of reducing pollution in a watershed are lower • Dischargers profit from the economies of scale • Enhanced market demand for new technologies • Funding of new techniques to reduce and control emissions
Social Benefits	• Fosters communication with the stakeholders • Encourages the adoption of shared solutions within a watershed that has multiple pollution sources

4.3.2. Challenges of WQT Programs

If water quality trading has many advantages compared to a command and control approach, it also presents some challenges that can hamper the success of the program. The challenges, summarized in Table 4.2., are based on the experience gained from the programs implemented in the United States, so they also include some limits deriving from national and state legislation. The challenges that emerge can pose a risk to the fulfilment of the watershed quality goals and they can disincentive other states to adopt WQT as method to reduce water pollution. The main obstacles can be grouped in four categories of challenges: regulatory, uncertainty, economic and program design.

The regulatory framework in the United States has loopholes that can limit the flexibility in the market of credit exchange. CWA confers a legal permission to point sources to discharge pollutant into a river body but it does not give the same right to sources of diffuse pollution. If non-point sources do not take part in the credit exchange the WQT program would not be efficient because these sources are the major pollutants and because the credit exchange flexibility would be compromised. Some programs, like the Neuse River program, found a way to merge the existing regulatory structure with an emission trading market: performing trading under a group compliance permit. Whereby, a group of sources of pollution can decide to implement their own program to control emissions through which they would then have more credit exchange flexibility. The role of the regulatory agencies would not be to require technologies to reduce discharges but would be to assess monitoring and require measurements on the pollutant discharge. The program developed in the Neuse river established a cap for the watershed and distributed the allowances to the members, and the non-point sources took part as well. The liability was not on the individual sources but on the compliance of the whole group.[40] This is an example of how other ways can be found to comply with the regulations and at the same time include sources of diffuse pollution. In the case of Europe this limitation would not occur because according to the Directive 200/60/EC each Member State has to establish a program of measures for their river basin district and each of these programs shall include “basic measures” and the non-point sources are held liable for their pollution.[41]

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[40] Corrales et al., “Water Quality Trading Programs Towards Solving Environmental Pollution Problems.”

[41] European Council and European Parliament, Directive Establishing a Framework for Community Action in the Field of Water Policy.

The lack of a solid support from the environmental agencies to water quality trading programs is an obstacle to the development of these. In the United States, it emerged that at a national level there was a strong backing for the application of WQT programs but then at a local level there was more scepticism about the introduction of new approaches. The use of trading programs was taken into consideration only once the traditional approach was not effective. In Europe WQT has been rarely taken into consideration and has never been applied. The lack of support can mine the development of trading programs, but it can be overcome if the national and local authorities spend more energies in highlighting the long-term benefits of the application of trading programs to the pollutant dischargers.[42]

In addition to regulatory limits, also the uncertainty connected to the presence of non-point sources in the market and the fear of the formation of hotspots can challenge the introduction of WQT programs. Non-point sources must take part in the trade if water quality goals want to be met. However, the presence of non-point sources increases uncertainty. The uncertainty is connected to the problems with providing an exact measurement of the pollution discharge. This depends on factors that are uncertain and unpredictable, like weather patterns. The uncertainty can be overcome, using direct or indirect measurement tools. The former, includes the quantification flow and pollutant concentration. The latter, uses simulation models to control the effectiveness of the pollution reduction measures. In the Chesapeake Bay program scientists analysed the results of the BMP adjusted to incorporate uncertainties of the non-point sources. Then, they incorporated the outcomes as long-term averages in the bay water shed model. Hence, the program eliminated the need of uncertainty ratios when dealing with non-point sources.

The World Resources Institute, together with environmental agencies, has developed an online tool for the Chesapeake Bay to estimate the amount of credits generated by the pollution reduction measures. The online trading network is called NutrientNet, it estimates, given a certain mitigation practice, the nutrient reductions achieved, but also sources can insert credit offers and it serves as a communication platform for the sellers and buyers.[43] Another tool that has been used in some programs is the Nitrogen Tracking Tool (NTT) developed by the U.S. Department of Agriculture

[42] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."
[43] Nguyen and Woodward, "NutrientNet: An Internet-Based Approach to Teaching Market-Based Policy for Environmental Management."

(USDA) and the Natural Resource and Conservation Society (NRCS). It allows sources to calculate the amount of nitrogen and phosphorus credits generated and that can be then sold on the market, from a specific pollution reduction practice implemented.[44]The use of these tools combined with increased scientific research and the application of BMP by diffuse sources can reduce uncertainty.

Additional challenge posed by the presence of non-point sources in the market is the concern of hot spots. Hot spots are areas of the watershed where there is a high concentration of pollution. They form as a result of a weak equivalency between the credits exchanged. As revealed in the paragraph 4.2.2., the equivalency can be ensured by using trading ratios. Scientific analysis of the geographic and hydrologic properties of the watershed, and the characteristics of the pollutants, are necessary for the development of trading ratios. The ratios are used to account for pollution assimilation in the watershed (delivery ratio); to account of the impact of pollution in a sensitive area (water quality ratio) to minimize uncertainty (uncertainty ratio) and to insure a margin of safety for the program (retirement ratio). The use of these ratios is highly recommended but it must be considered that with high ratio the non-point sources have less incentives to participate in the trade.

The economic barriers to WQT include the costs for measuring and monitoring emission reductions and the transaction costs.[45] These costs can reduce the cost savings of the implementation of WQT.[46] The direct measurement of non-point source discharge is very expensive and it can hinder the cost-effectiveness of non-point source participation. Nonetheless, improvements in technology have provided new techniques for the calculation of effluent load reduction. These new models analyse the discharges based on the knowledge of the site-specific effluent loads, the land use, the type of soil, and the climate and weather conditions. Some examples of these computer models are: the Watershed Assessment Model (WAM); the Agricultural Policy/Environmental Extender model (APEX); and the Soil and Water Assessment Tool (SWAT). These are computer tools that are simple to operate and offer reliable scenarios that can be

[44] Saleh et al., "Nutrient Tracking Tool - a User-Friendly Tool for Calculating Nutrient Reductions for Water Quality Trading."
[45] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study"; Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems"; Woodward and Kaiser, "Market Structures for U.S. Water Quality Trading."
[46] Breetz et al., "Water Quality Trading an Offset Initiatives in the U.S.A Comprehensive Survey."

evaluated before any reduction measure is implemented.[47] However, it must be borne in mind that these are assumptions and thus have a degree of uncertainty, so they must be coupled with periodic monitoring to validate the results.

The largest barrier to WQT are the transaction costs that derive from monitoring, negotiations, research and enforcement. High transaction can decrease the volume of credits exchanged because they make it expensive to produce and exchange credits.[48] The search for trading partners can also increase the transaction costs so the involvement of a third-party (like in clearing houses and third-party aggregator) can reduce these costs. One of the roles of the regulative authority is to find a way to reduce these costs to make the market operate more effectively.

If WQT programs have many advantages they also have many challenges they must address. Even so, the examples above demonstrate how for every challenge there can be a solution that is most appropriate for a certain situation and are illustrated in Table 4.3.

Table 4-2. Challenges of water quality trading programs.[49]

Regulatory	• Deficiency of regulatory liabilities for nonpoint sources • Weak information on the long-term benefits of trading programs • Limited support form national and local authorities to the use of WQT programs • Scepticism of the local authorities to adopt new solutions to address water quality

[47] Corrales et al., "Water Quality Trading Programs Towards Solving Environmental Pollution Problems."
[48] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."
[49] Ribaudo and Gottlieb, "Point-Nonpoint Trading- Can It Work?"

Uncertainty	• No clear qualification of the non-point source effluent reduction • Formation of hot spots • Required additional scientific proof to evaluate trading ratios • Weak trust among the trading partners and with the regulative authorities • Participants may not have all information on the mechanisms of the market
Economic	• Costs of monitoring and quantifying non-point source discharges • Transaction costs
Program Design	• Sufficient demand and supply

Table 4-3. Overview of benefits and challenges of WQT and their possible solutions.[50]

Benefits	Challenges	Solutions
Attainment of water quality targets	creation of hotspots and uncertainty	use of trading ratios and improve models for quantification
Ecological Benefits	Scepticism on use of environmental trading	increase communication and education on the long term benefits
reduced costs and potential economic profits	high monitoring and transaction costs	online transactions and models
increased communications among nonpoint and point sources	individual perception of risks and equality	efficient communication mechanisms
New technologies for pollution reduction	no flexibility in innovative technologies	substitute monitoring with adoption of new technologies

[50] Ibid.

5. The Chesapeake Bay

The eutrophication of the Chesapeake Bay has been extensively studied due to the importance of the watershed in the United States and due to its negative impacts on the environment. The Chesapeake Bay is the largest estuary in the Unite d States, it has a strong economic, social and environmental importance for the nation, also due to its proximity to the nation's capital. The excess nutrient discharges in the Bay have impaired the waters and led to an increase in eutrophication. The low concentration of oxygen in the waters has created a decreased the population and productivity of benthic animals and has also affected the deep-water habitats.[1] The Chesapeake Bay, actually, is an important breeding ground for certain species, like the striped bass, that are very sensitive to low levels of oxygen and alterations of the food chain. Thus, the issues concerning the Chesapeake Bay have raised special attention amongst scientists and policy makers.

Up to the 20th century public concern and research focused more on localized problems of Bay, such as toxic waste, industrial and municipal discharges, toxic pesticides and effects of power plants and broader issues like over harvesting of fish. Towards the end of the century, it came to be clear that eutrophication had harmed the quality of the Bay and that it had severe consequences for the Bay's resources. Thereafter, nutrient pollution reduction became the top priority of policy making and water management in the Chesapeake Bay.[2]

In 1983, the Chesapeake Bay Agreement was signed by the main government entities of the Chesapeake Bay region: Maryland, Pennsylvania, Virginia, the District of Columbia, the U.S. Environmental Protection Agency (EPA), and the Chesapeake Bay Commission. The agreement, initiated the voluntary collaboration between the scientific community, the local governments and the civil society, with the goal of restoring a healthy Bay. The poor water quality of the Chesapeake Bay, lead to the insertion of this in the list of impaired waters. Thus, Total Maximum Daily Loads was established for the Chesapeake Bay, pursuant the requirements of the Clean Water Act (CWA). As a cost-efficient way to keep emissions below the maximum levels, the riparian states of

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[1] Boesch, Brinsfield, and Magnien, "Chesapeake Bay Eutrophication: Scientific Understanding, Ecosystem Restoration, and Challenges for Agriculture."

[2] Ibid.

the Bay (Maryland, Pennsylvania, Virginia and West Virginia) established a water quality trading program: the Chesapeake Bay Nutrient Trading Program.

In this chapter I present an overview of the evolution of the public policy up to the establishment of the CBNTP. Moreover, I explain the functioning of the WQT program in the Bay.

5.1. The Chesapeake Bay and its Eutrophication Issues

5.1.1. The Chesapeake Bay Context

The abundance of nutrient discharges and runoffs from point-sources and non-point sources have caused large algal blooms, which led to the formation of "dead zones". Due to the status of the watershed the Environmental Protection Agency (EPA) has placed the Bay in the list of impaired waters. According to a study conducted by the EPA, in a year with average rainfall, the water of the Bay that comes from sources, other that the Ocean, carries 110 thousand tons of nitrogen and around 10 thousand tons of phosphorus.[3] The pressure on the Bay increased over time with steady decrease of the riparian forested area, which was a sink for nutrients, and with the growth of the population. From the 1600's the riparian forests decreased by 60% and these have been converted into agricultural and urban lands.[4] The Chesapeake Bay Program, decided to plant 1.5km of forest buffers per year to prevent pollution from entering the water and to stabilize the steam banks. Nonetheless, the Program has not been able to reach this goal yet, for example in 2014-2015 only 7% of the goal was reached.[5] Additionally, the growth of the population in the area lead to additional stress on the waterbody. Indeed, experts predict that the population of the Bay will increase to over 20 million in around 13 years' time.

5.1.2. Sources of Nutrient Pollution in the Chesapeake Bay

In general, there are hundreds of tons of nitrogen and phosphorus that flow into the watershed each year originating from a large variety of sources throughout the Bay. Despite the wide use of technologies and practices to limit pollution discharges all of these sources emit loads of nutrients into the Bay. Figure 5.2. shows, the which are the

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[3] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."
[4] Chesapeake Bay Program, "Bay Barometer: A Health and Restauration Assessment of the Chesapeake Bay and Watershed in 2008."
[5] Chesapeake Bay Program, "Bay Barometer: Health and Restauration in the Chesapeake Bay Watershed 2015-2016."

major source and pathways that contribute to nutrient pollution. In fact, according to recent data, gathered through the Chesapeake Bay's Watershed Model, most of the nitrogen emissions are due to runoffs from agricultural areas, followed by waste water discharges from industrial facilities and waste water treatment facilities, which contribute almost 20% to the total nitrogen emissions, and runoffs from agricultural areas that are slightly less influential than the latter (16%). The trend of the origins of phosphorus emissions are similar to the ones of nitrogen. 54% of the phosphorus load originates from agricultural areas from animal manure and chemical fertilizers. Additionally, roughly, 19% of the phosphorus emissions are WWT facilities and industrial facility's discharge and the rest from urban runoffs. Of the runoffs from urban areas almost 52% of nitrogen and 39% of phosphorus come from areas that are regulated by municipal separate storm systems.

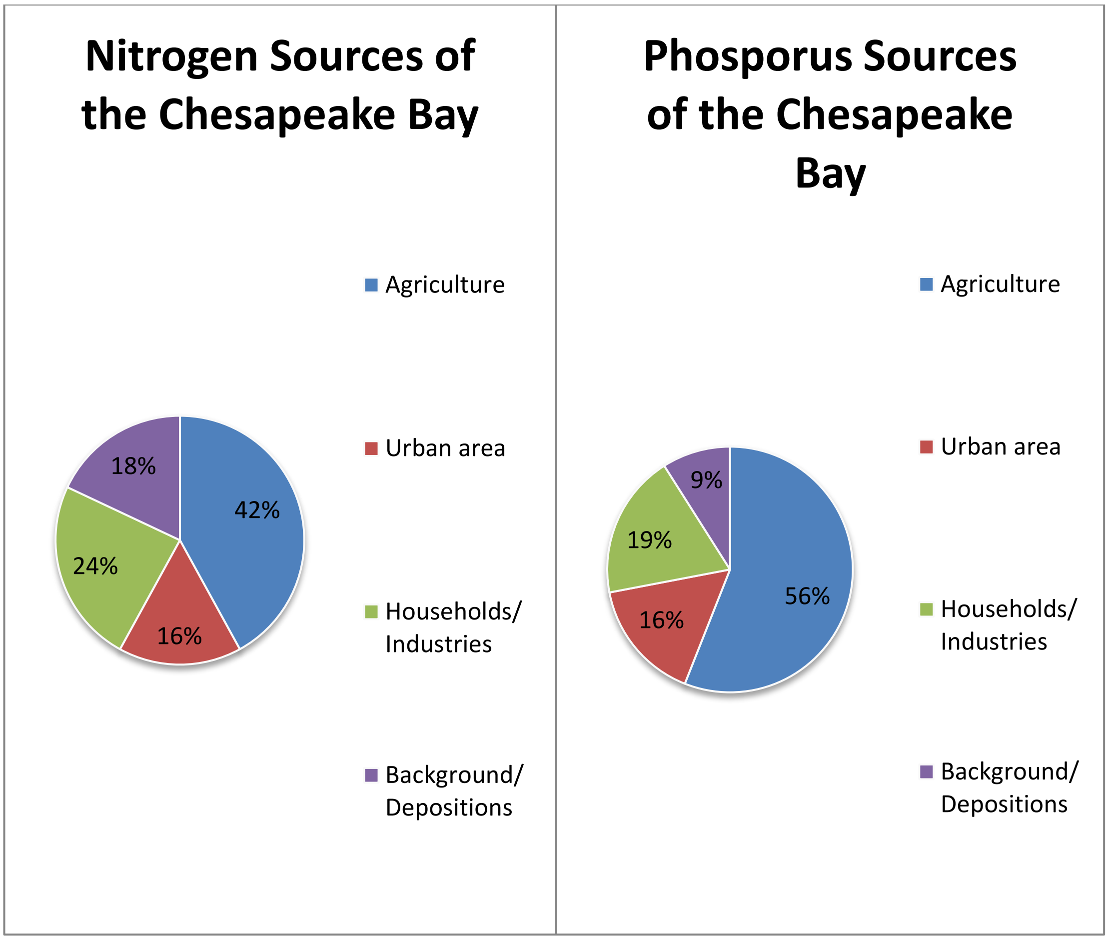

Figure 5-1. Shares of sources and pathways of nitrogen and phosphorus in the Chesapeake Bay.[6]

[6] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."

5.2. Regulatory Framework

5.2.1. Clean Water Act

The establishment of a WQT in the Chesapeake Bay was done within framework of national legislation and federal and state statutes. The Clean Water Act is the principal national law governing water pollution. Its objective is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters".[7] Under the Act, point sources can discharge pollutants within the limits of a permit that is issued by the EPA or by a state through the National Pollutant Discharge Elimination System program (NPDES).[8] The NPDES is meant to control the emissions form point-sources. The CWA, requires states to establish water quality standards for their water bodies. These should have as main principle that the introduction of pollution in the waterbody is allowed up to the point where it harms the environment. When a waterbody does not meet the quality standards, then the state should report it to the EPA, which decides if to add it on the list of impaired waters.[9] For the water bodies, like the Chesapeake Bay, that do not fulfil the quality standards or are expected to not reach the standards in the future, a state must create a Total Maximum Daily Load (TMDL) of pollutants, to bring the water body in compliance with the standards.[10]

The establishment of the TMDL is a complex process that starts with the analysis of the amount of pollution that a waterbody can take without deviating from the quality standards. The amount of pollution, or the load, is then divided and distributed to all the sources that are responsible for the release of pollutants; including point sources, non-point sources and natural back ground. The regulators provide nutrient requirements to non-point sources (load allocations) and to point sources (waste-load allocations). The TMDL has to be approved by the EPA and the monitoring of the water quality has also to be reported to the EPA.

In section 309, to address pollution runoffs from land surfaces, the CWA defines non-point source control programs. The control programs, are management programs developed by the USEPA that are implemented by the states. The latter, can chose the management programs that they prefer among those proposed by the EPA. In many

[7] Federal Water Pollution Control Act, sec. 101.
[8] Ibid., sec. 402.
[9] Showalter and Spingener, "Pennsylvania's Nutrient Trading Program: Legal Issues and Challenges."
[10] Federal Water Pollution Control Act, sec. 303 (d).

other parts of the EPA, non-point sources are directly addressed because it is fundamental that these are regulated to ensure water quality.

5.2.2. Regulations Adopted for the Chesapeake Bay

The realization that the issues connected to the water quality of the Chesapeake Bay are related to the land use and to direct discharges into the Bay, happened in the beginning of the 1970's. In 1972, the Tropical Storm Agnes provoked floods in the Chesapeake Bay, and raised the awareness of the strong influence of point sources and non-point sources for the quality of the water body. Thereafter, the water management efforts were directed to find ways to alleviate the amount of pollution entering the waterbody.

In 1983, after a five-years study, Maryland, Virginia, Pennsylvania, the District of Columbia, and the EPA developed the first Chesapeake Bay Agreement. The Agreement, established the monitoring of nitrogen and phosphorus discharges, and identified the cost-effective measures to be adopted to reduce nutrient pollution. The Second Chesapeake Bay Agreement, in 1987, established a basin-wide strategy, which required signatory states to reduce their nitrogen and phosphorus discharges by 40% by 2000. The strategy was based on the nutrient reductions from controllable sources. The Third Chesapeake Bay Agreement in the year 2000, promoted the cooperation of the states to achieve "a clean Chesapeake Bay by 2010".[11] The Chesapeake 2000, was far more comprehensive and far-reaching compared to the previous agreements. It reaffirmed the commitment of reducing nutrients in the Bay by 40%, and added the objective of removing the Chesapeake Bay from the list of impaired waters by 2010. To reach this goal it promoted innovative measures, such as nutrient trading. The latter, was taken into consideration because, even if the Chesapeake Bay has an improved water quality, the current reduction techniques did not help to achieve the 40% nutrient reduction goal.

For decades, the regulatory authorities have tried to restore the Bay but the progress has been very slow and the Bay remains highly polluted. The Executive Order issued by President Obama in 2009 boosted the efforts to ameliorate the water quality status. In the Chesapeake Bay Protection and Restauration Executive Order, the Bay was recognized as being a national treasure. Thus, the increased efforts resulted in action plans, recommendations for improvement, progress reports and in 2010 the

[11] Showalter and Spingener, "Pennsylvania's Nutrient Trading Program: Legal Issues and Challenges."

release of the EPS's final TMDL. To keep track of the amelioration of the water quality in the Bay the Federal Leadership Committee for the Chesapeake Bay (FLC) receives and assesses the annual progress reports. The FLC is formed by the representatives of each federal agency engaged in the program, includes representatives of the Departments of Agriculture, Interior, Defence, Homeland Security, Commerce, and Transportation.[12]

5.3. Chesapeake Bay's Water Quality Trading Program

5.3.1. Initiation of the Program

The U.S. EPA studied for many years trading programs as cost-effective solution for reaching water quality and these studies and interest in the topic increased when President Clinton openly endorsed market based approaches as environmental management tools.[13] Indeed, a Trading and Offsets Workgroup along with the Bay's stakeholders convened to study nutrient trading.[14] Uniting various stakeholders meant to have representatives of the interested states negotiate together a set of guidelines for the implementation of a trading program. The guidelines, would in fact take into consideration the features of each state: social, economic and geographic. Each state has its own jurisdiction but it is necessary to establish consistency and compatibility among them to ensure the fulfilment of the goals and adopt common definitions. The negotiating team had to also, delimit the geographic area in which the trading would take place. This is a key consideration, because if the areas are too small then there might not be enough sources that can take part in the trading, or the distance between the sources can obstacle the correct functioning of the program.[15] Finally, in 2001, a set of guidelines and principles of nutrient trading were agreed upon by the Chesapeake Bay partners. The main key principles agreed include that nutrient trading would not contribute to the impairment of waters or have any adverse effect on the water body; the trading program is restricted to only the sources that were on the major tributaries of the Bay; and the program and the activities of the traders would have to be consistent with,

[12] Federal Leadership Committee for the Chesapeake Bay, "Strategy for Protecting and Restoring the Chesapeake Bay Watershed: 2014-15 Milestones Progress Report."
[13] President Bill Clinton and Vice President Al Gore, "Reinventing Environmental Regulation."
[14] The stakeholders involved represented the interests of: the states of Virginia, Maryland, Pennsylvania and the District of Columbia; the interests of the regional environment, of local watersheds, of local governments, of the public and municipalities; as well as the US EPA, and the Chesapeake Bay Program.
[15] The Chesapeake Bay Program Nutrient Trading Negotiation Team, "Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines."

federal, state or local laws.[16] The guidelines are voluntary, so each state is responsible for creating its individual trading policy, creating a system for certifying credits, and developing a mechanism for monitoring and evaluating the results. As a result, a few years later in 2005, the states of Virginia and Pennsylvania were the first stated to develop nutrient trading programs to meet nutrient loads allocations. Virginia's program is based on legislation, while Pennsylvania proposed policies and guidelines. Both the programs are restricted to the trade among sources of the major waterways, nonetheless, since each state oversees developing its own trading program, the programs are very different from one another.

6.3.2. Functioning of Nutrient Trading Program in the Chesapeake Bay

The starting point of a water quality trading program is the establishment of a cap for the entire watershed. As I mentioned, the cap for the Chesapeake Bay was determined by the TMDL. Determining a cap, is necessary to ensure that the water quality goals are followed. Moreover, the establishment of the maximum amount of pollution discharged allowed, fosters the issuance of allowances and credits, that are fundamental to make the trading start because they trigger demand and supply. The water quality goal for the Bay, was set up, in accordance to the 1987 Chesapeake Bay Agreement, to a reduction of pollution by 40% from 1985 levels. Hence, 1985 marked the baseline for the determination of the nutrient reduction objective.[17] The determination of the cap and the baseline, allow then to specify the nutrient emission caps for each of the ten tributary basins in the Bay.[18] The EPA divided the Chesapeake Bay into basins and then further subdivided them according to state boundaries and then allocated the total load among these twenty districts.

The TMDL elaborated in 2010, designed to ensure that in 2025 the Bays waters are restored, the TMDL of nitrogen and phosphorus for each basin is reported in Table 5.3. The table elucidates how the total cap is distributed to the various tributaries and then divided among the states. The states are responsible for developing a tributary strategy to achieve the nutrient reduction goals. The agricultural reductions elaborated

[16] Chesapeake Bay Foundation, "Nutrient Trading."
[17] The Chesapeake Bay Program Nutrient Trading Negotiation Team, "Chesapeake Bay Program Nutrient Trading Fundamental Principles and Guidelines," 11.
[18] These are expressed in the Tributary Strategies.

by the states, with the cooperation of the EPA, are the Watershed Implementation Plans (WIP).[19]

Table 5-1. Allowed Nitrogen and Phosphorus Loads for each state, and relative river, in the Chesapeake Bay.[20]

Chesapeake Bay TMDL watershed final allocation of nitrogen and phosphorus by jurisdiction and by major river basin.			
State	Basin	Nitrogen Load tons/year	Phosphorus Load tons/year
Pennsylvania	Susquehanna	31253	1315
	Potomac	2141	191
	Eastern Shore	127	4.5
	Western Shore	9	0
	Total	33530	1510.5
Maryland	Susquehanna	492	22
	Potomac	7429	408
	Eastern Shore	4404	462
	Western Shore	4100	231
	Patuxent	1297	108
	Total	17722	1231
Virginia	Eastern Shore	594	63
	Potomac	8060	639
	Rappahannock	2648	408
	York	2453	244
	James	10473	1075
	Total	24228	2429
District of Columbia	Potomac	1052	54
	Total	1052	54
New York	Susquehanna	3978	258
	Total	4385	285
Delaware	Eastern Shore	1338	117
	Total	1475	130
West Virginia	Potomac	2463	263
	James	9	4
	Total	2472	267
Total Basin Allocation		84864	5906.5
Total Nutrient Input Allowed in the Chesapeake Bay		around 91 000 tons per year	

[19] Shortle et al., "Building Capacity to Analyse the Economic Impacts of Nutrient Trading and Other Policy Approaches for Reducing Agriculture's Nutrient Discharge into the Chesapeake Bay Watershed."
[20] Environmental Protection Agency, "Chesapeake Bay TMDL Executive Summary."

Under the umbrella of the Chesapeake Bay trading program each state developed its own trading system through different mechanisms, these can be briefly described hereafter. The guidelines of the Pennsylvania trading program are provided by the Final Trading of Nutrient and Sediment Reduction Credits-Policy and Guidelines, issued by the Pennsylvania Department of Environmental Protection.[21] The program allows trading between point sources and between non-point sources and point sources, to reach the nutrient limit load. The generation of the credits by non-point sources depends on the baseline, which comprises the compliance with one of the following laws: regulation of nutrient management, agricultural erosion or soil control. The baseline is achieved by introducing best management practices (BMP), such as grassed waterways, covering the crops, installation of manure storage facilities, and terraces and partitioning of the land or simply reaching the threshold requirements.[22] The Programs uses the WRI NutrientNet as platform for calculating non-point source credits. Furthermore, the Pennsylvania nutrient Trading Program, allows different types of interactions between the participants of the trading program. These market structures are exchange market, bilateral negotiations and clearinghouses. In these market structures, a trading ratio of 1:1 is applied, but to protect from uncertainty of non-point sources a 10% reserve ratio, a delivery ratio and an edge of segment ratio are used. The edge of segment ratio, has only been applied in the Pennsylvania nutrient trading program, it finds the amount of a pollutant expected to reach surface waters "at the boundary of a Chesapeake Bay Watershed Model segment through surface runoff and groundwater flows form a pollutant source within a watershed segment".[23]

The Maryland Nutrient Trading Program is governed by the Maryland Departments of Agriculture and Environment. These establish the policies and administer the trading program. The trade is allowed among point sources and point sources and non-point sources. The baseline used must be the most stringent among the TMDL of the watershed segment and the local TMDL. Agricultural areas may use BMP to generates credits with the condition that the BMP funded by federal or state programs are excluded. Maryland has its own nutrient trading tool that merges the NutrientNet

[21] Final Trading of Nutrient and Sediment Reduction Credits-Policy and Guidelines.
[22] Pennsylvania Association of Conservation Districts, Inc., "Pennsylvania's Nutrient Trading Program: Opportunities for Farmers to Gain Revenue While Improving Water Quality."
[23] Virginia Department of Environmental Quality, "Background Information: Prepared for Trading Ratio Study October 2012."

and the USDA-NRCS Nutrient Tracking Tool. When the trade involves nonpoint credits then a 10% retirement ratio is applied. The two market structures allowed in this program are the exchange market and the bilateral negotiations.

The water quality trading program in Virginia is governed by a state statute and a set of regulations. The most peculiar feature of the State's program is the Nutrient Credit Exchange Association (VNCEA), which is a private association that has the purpose of facilitating and coordinating trade among the various sources. When credits are exchanged through the VNCEA, then, the market structure used are clearing houses. Instead, when credits are exchanged with non-point sources, bilateral negotiations are used.[24] Like the program developed by Maryland, also in Virginia state cost-shared BMP are excluded from the trade. When non-point sources are parties to the trade a 2:1 trading ratio is applied, but no ratio is applied with storm water trade and in the trade among point sources. This program had an initial slow growth because of the lack of demand for demand for credits. The situation improved as soon as the transportation sector realized the gains that can be achieved when entering the water quality trading market. As a result, in 2015, Virginia experienced an unprecedented situation, the demand for P credits exceeded the supply of the Potomac River Basin. The features of the programs applied in the Chesapeake Bay are very different form one another because the policy makers developed programs that match the needs and the characteristics of the sources of their state. A common feature, is that all the programs measure success through water quality monitoring.[25]

The trading programs in Pennsylvania, Maryland and Virginia occur within specific trading areas. Figure 5.2 shows the major tributaries of the Chesapeake Bay, thus can provide a visual aid to understanding the paths of the rivers and which state they cross. The Susquehanna River Basin and the Potomac River Basin are the two largest basins. The Susquehanna crosses Pennsylvania, New York and Maryland, while the Potomac passes through Maryland West Virginia and Virginia. The Rappahannock and the York are located within Virginia and the Patuxent River Basin entirely belongs to Maryland.

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[24] World Resources Institute and USDA Office of Environmental Markets, "Comparison and Effectiveness of Chesapeake Bay Nutrient Trading Program Policies."

[25] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."

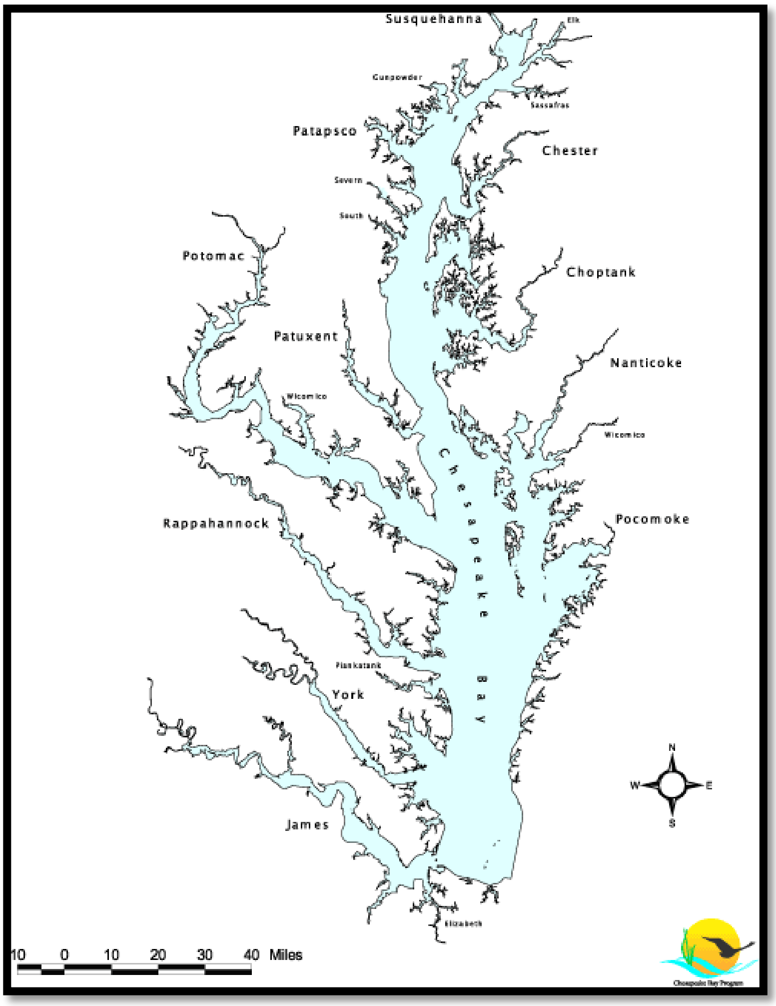

Figure 5-2. The tributaries of the Chesapeake Bay.[26]

Pennsylvania allows trading between the two basins within the state portions. Nutrients can be traded within and between the two basins involved, the Potomac and the Susquehanna basins. Much broader is the trading area for Maryland, that comprises in-state trading amongst the Patuxent, Potomac, and "Everywhere Else", which is a combination of three smaller basins: Eastern shore, Western Shore and the Susquehanna.[27] Maryland's' trading program allows trading between the major basins inside the state but not with the section Everywhere Else. Trading in these two states can occur with the condition that if a credit buyer is in an area that has a local TMDL, it will have to purchase credits within that local TMDL. The trading program in Virginia, allows trading within the following river basins: Eastern Shore, James, Rappahannock, Potomac-Shenandoah and York River. There is a trading restriction for the upper estuary of the James Basin because of issues concerning hot spots.

[26] http://www.cbf.org/about-the-bay/maps/major-tributaries-of-the-chesapeake-bay

[27] World Resources Institute and USDA Office of Environmental Markets, "Comparison and Effectiveness of Chesapeake Bay Nutrient Trading Program Policies."

5.4. Final remarks

Currently, the trading program in the Chesapeake Bay occurs within the states and within the major basins of those states. Trade within states is more manageable due to state regulations. However, the first programs were established 12 years ago so now these should be more functional and understood by the various sources. Hence, it would be advisable that these programs extend to allow trade on a watershed-wide basis. This would allow greater flexibility of the programs, due to the increased number of participants and number of low cost credits with consequential greater economic benefits. On the other hand, some experts underline how trading programs are already very complicated and enlarging them would result in many complications, as for example create disadvantages for the downstream states.[28]

Since the introduction of the TMDL in the Chesapeake Bay there has been a low decrease in nutrient loads in the Bay. These trends evidence that there has been a slight decrease in nutrient entering the Bay, that might be caused by the introduction of nutrient trading combined with more efficient technologies for pollution control. Nonetheless, there is no evidence of the correlation between the decrease of nutrients and the impact of water trading programs. The Chesapeake Bay program is still at its beginning and there is not sufficient data to assess the success of the trading programs in the region. The information available only concerns how the programs are structured, namely, the market structure adopted and the state sections in which the trading is allowed.

[28] Ibid.

6. The Danube River Basin

Eutrophication has raised concern in the Danube River Basin (DRB), especially in the receiving Black Sea. Recent studies have classified about 65% of the Danube River length as being at risk because of nutrient pollution.[1] Moreover, the Black Sea's ecological situation has ameliorated in the last decade, with a reduction of eutrophication, the disappearance of anoxic areas and the regrowth of phytoplankton and zoo-benthos.[2] Yet, there is still a need to improve the situation. The nutrient pollution levels are still above the 1960 levels and the decrease has not been sustainable. The non-sustainability of the decrease in nutrient levels derives from the consideration that if on the one hand nutrient decreased due to the ban on detergents containing phosphorus and the improved nutrient removal from the waste water treatment plants, on the other hand the reduction was also due to the economic crisis that affected the countries of the Danube region. It entails that an economic growth in the region would result in increasing nutrient pollution. Hence a sustainable solution for the reduction of nutrient pollution in DRB must be found.

Many regulatory regimes have been implemented in the DRB in the last ten years to fulfil water quality goals established for the DRB and for the Black Sea. The implementation of a nutrient trading system combined with an integrated water management system, promoted in the EU's WFD, could be a possible solution for the eutrophication problems in the Black Sea.[3] According to the literature, implementation of WQT in the Region would not only result in an enhanced effectiveness in reaching the desired results, but also in an enhanced efficiency due to the cost reductions that the program would entail.[4]

In this chapter I initially provide some information on the Danube River Basin's need of an effective nutrient pollution system. Then, I focus the analysis on how a WQT could fit into or complement the current regulatory systems for water quality management.

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[1] Popovici, "Nutrient Management in the Danube River Basin."
[2] Ibid.
[3] "integrated water management system in the DRB is based on the use of a wide range of instruments or means of regulation as e.g. water quality standards, emission norms, monitoring and technical norms, designation of protected areas, and exchange of information and cooperation" United Nations Office of Project Services, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction," 7.
[4] Ibid.

6.1. Danube River Basin and the Eutrophication Issues

6.1.1. The Danube River Basin Context

The DRB bordering 19 countries has an immense environmental, historical, economic and social value. These values have to be protected from the increasing pressure of the large population and of the serious pollution issues.[5] The waters are used for various reasons: navigation, tourism, supply of water to industries and agriculture, drinking water, power generation, recreational purposes and for fisheries. These uses add to the pressure on water quality and quantity.[6]

6.1.2. Nutrient pollution in the Danube River Basin

The Danube surface waters have experienced a growth in nutrient pollution. From around 1958 to the end of the 1980's the inorganic nitrogen and phosphorus content has increased 4-6 times and the organic nitrogen and phosphorus has increased 2-3 times. These pollutants are carried by the river and 80% of the N load and 75% of the P load, are then discharged into the North-western part of the Black Sea.[7] The increase of nutrients is due to the agricultural runoffs, to the insufficient treatment in the sewer systems and in some cases to the direct discharge of manure and industrial discharges into the water.

During this period, all the countries along the Danube made extensive use of fertilizers in agriculture. In fact, data demonstrates that the sale of fertilizers doubled during this time.[8] This trend deviated with the breakdown of the Soviet Union in 1989. The use of fertilizers in the Eastern European countries dropped because agriculture passed to a small-scale system just for food supply to the regional population. Since other countries bordering the Danube, like Germany and Austria, did not augment their consumption of fertilizers, the nutrient pollution concentration steadily decreased in the DRB and therefore in the Black Sea. Now, the current levels of nutrient pollution in the Black Sea are acceptable but still higher that the 1960 levels. The North-western Black

[5] 83 million people. Malagó et al., "Modelling Nutrient Pollution in the Danube River Basin: A Comparative Study of SWAT, MONERIS and GREEN Models."
[6] Popovici, "Nutrient Management in the Danube River Basin."
[7] United Nations Office of Project Services, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction."
[8] Ibid.

Sea (NWBS) has been assessed as having a “good ecological status”.[9] There are still some problems but there are related to fisheries and not to nutrient pollution. In a business are usual scenario the nutrient pollution would increase, hence, the present nutrient load must be “frozen”.[10] If the current level is established as the reference level, then the water quality management strategies should aim at mitigating and counter-acting any possible increment of nutrient pollution.

The major source of nitrogen pollution in the Danube Basin is agriculture due to the application of fertilizers, even if it must me noted that he situation is different for each riparian country. If agriculture is the main source of nitrogen with a share of 51%, atmospheric deposition follows with a share of 26%. This pathway is very significant because nitrogen is one of the most important components of the atmosphere and contains the nitrogen oxides that form in combustion processes. Atmospheric deposition also influences the number of urban runoffs and runoffs from natural lands. These areas also provide a significant amount of nitrogen, that cannot be easily controlled. In regard to phosphorus, the share between the various sources and pathways is almost equal. The amount of phosphorus that originates in from households and industries is slightly more than the other sources but has improved compared to the past. In 2012, the EU promoted the elimination of phosphorus from laundry detergents lead to a significant decrease of P from households, compared to the 1960’s.[11]

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[9] United Nations Office of Project Services, Global Environmental Facility, “Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading.”
[10] Ibid.
[11] Barcelo and Kostianoy, “The Danube River Basin.”

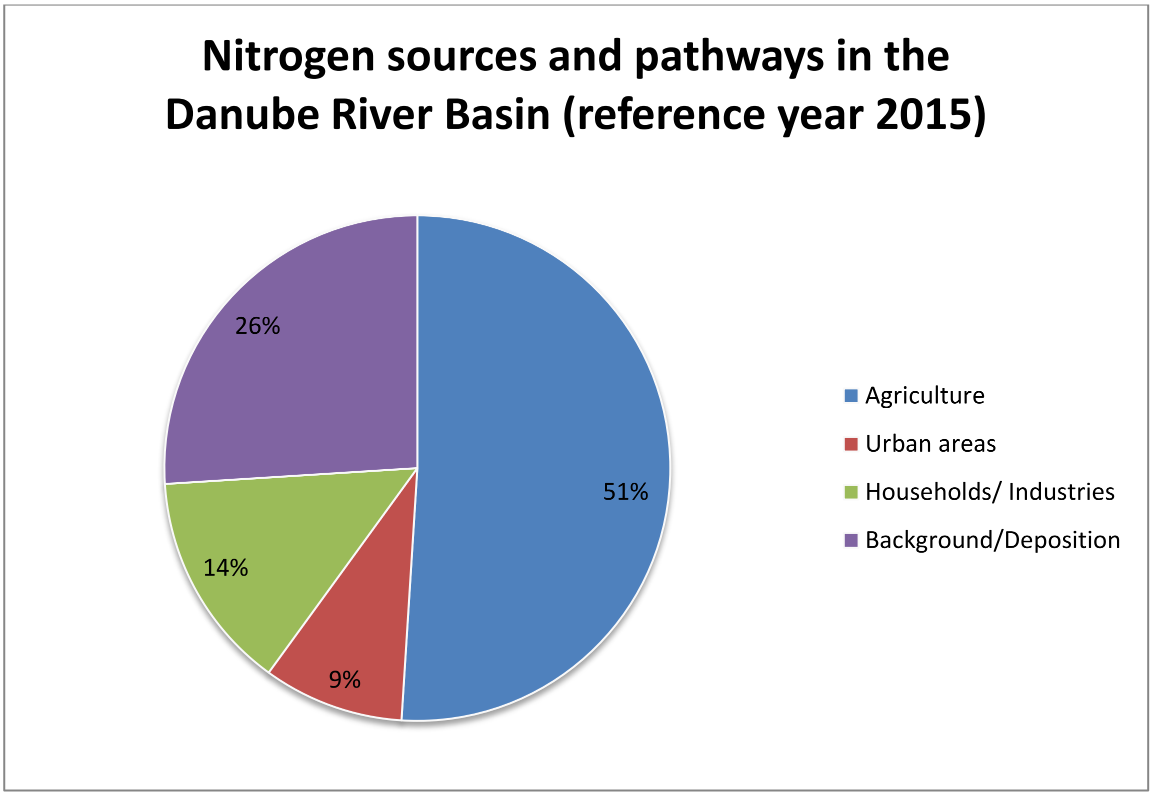

Figure 6-1. Shares of nitrogen loads in the DRB in 2015.[12]

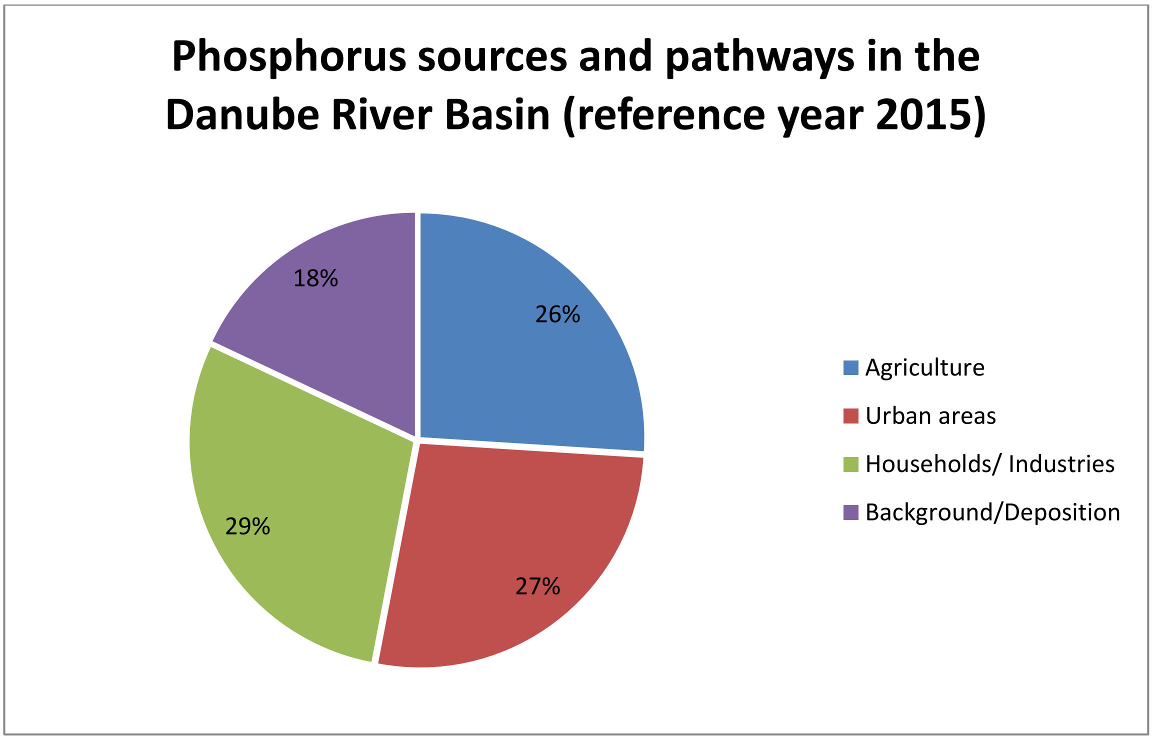

Figure 6-2. Shares of phosphorus loads in the DRB in 2015.[13]

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[12] Ibid.
[13] ICPDR, "The 2013 Update of the Danube Basin Analysis Report."

The total phosphorus load highly depends on diffuse source emissions. These contribute 78% of the total emission compared to point sources that only contribute 22% as illustrated in Figure 6.5. Compared to the nitrogen emissions the phosphorus emission from non-point sources mainly originate in urban areas that produce 60% of the total emission. The agricultural areas contribute only 30% to the total emissions.[14] This entails that measures can be adopted in the urban water management system can decrease the P pollution.

In 2015 data revealed that the total nitrogen load was 602.000 t/a (7.5 [kg/ha*a]) upstream and during the same time frame downstream measurements indicated that the downstream (river mouth station Reni) nitrogen loads were 510.000 t/a (6.3 [kg/ha*a]).[15] Similarly, the upstream phosphorus load was 46.000 t/a (0.61 [kg/ha*a]) 25.000 t/y (0.31 [kg/ha*a]) of phosphorus. [16] These values taken at the river station Reni are considerably lower than the values measured at the source. Therefore, the Danube retains much of the nutrients. 15.3% of the TN is retained by the river and undergoes a process of denitrification. Also, sedimentation and the uptake from aquatic plants is the cause of the loss of 45% of the TP.[17]

The Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction reports that the limiting factor in the NWBS is phosphorus, while in the central part of the Black Sea, nitrogen is the limiting factor. For this reason, tacking only phosphorus would not be efficient. The counter acting strategies in the Danube System should target both nitrogen and phosphorus, this is called the "two-pronged strategy".[18] The two-pronged strategy consists of targeting phosphorus emissions and simultaneously monitor the ratio of P and N in the NWBS. If the ratio changes, then the reduction measures have to be applied also to nitrogen.

To sum up, the Danube has a large influence on the water quality in the NWBS: 80% of N and 75% of P loads in the NWBS originate from the Danube. With the fall of the Soviet Union and communism, the load of nitrogen and phosphorus emitted in the Danube has decreased. This lead to current levels of nutrient pollution that are

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[14] Ibid.
[15] Upstream data: Popovici, "Nutrient Management in the Danube River Basin"; ICPDR, "The 2013 Update of the Danube Basin Analysis Report."
[16] Ibid.
[17] ICPDR, "The 2013 Update of the Danube Basin Analysis Report."
[18] United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."

environmentally acceptable but there has to be a sustainable management of the emissions to make sure that these levels do not increase. Moreover, the Danube is phosphorus constrained rather than nitrogen constrained, thus the former is subject to more attention. Knowing which are the sources of nutrient emissions and improving the monitoring system are necessary for the implementation of a trading system.

6.2. Regulatory Framework

The water quality management of Danube River Basin has been regulated, throughout the years by many international policies and regulations, that also fostered cooperation between the riparian states. The control of the Danube pollution has been subject of attention from the European Union. The River Basin is not only the second largest in Europe, but it also borders many countries that are members of the EU. Hence, many directives and regulations have been adopted throughout the years to insure water quality in the DRB. These European regulations are then translated into national regulations and policies by the riparian states for the protection of the waterbody. Therefore, the current framework for the protection of the Danube is formed by international and European water legislation, multilateral agreement between counties and national laws of the Danube countries.

6.2.1. The Water Convention

At the international level the Convention on the Protection and Use of Transboundary Water Courses and International Lakes and the subsequent Danube River Protection Convention (Water Convention) have been implemented for the protection of the Danube. The Water Convention, establishes that the contracting states may set national or joint emission limits and both point sources and non-point sources should prevent, control and reduce water pollution that can cause transboundary effects.[19] When taking the appropriate measures just mentioned, the parties must follow the precautionary principle, the polluter-pays principle and the sustainability principle.[20] The latter means, that the use of water has to be sustainably managed so that the needs of the present to not compromise the needs of the future generations. Moreover, the Convention lays out that all the parties must, adopt, develop and implement compatible appropriate, administrative, economic, financial and technical measures to ensure

[19]Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Art.1.
[20] Ibid. Art. 2 (5a,b,c)

relevant measures are applied at the national level.[21] These instruments and measures include the introduction of permits for the point source discharge. Additionally, both point sources and non-point sources must use best available technology and best environmental practices. Furthermore, the members have to exchange information and cooperate to implement harmonized policies. Finally, another relevant provision of the Water Convention sets out that the adopted agreements should foster the development of a joint body.[22] The role of the joint body/ies is to ensure cooperation between the conventions and to perform many tasks. These tasks include gathering and evaluating data from sources, elaborating joint monitoring programs and water quality criteria, and develop water pollution reduction action programs.

6.2.2. The Danube River Protection Convention and the ICPDR

The Water Convention established the legal basis for the adoption of the Danube River Protection Convention (DRPC). The Danube River Protection Convention sets the structure for cooperation between the riparian states for the protection and sustainable use of the DRB. To facilitate the implementation of transboundary water management the DRPC established a transnational body, the International Commission for the Protection of the Danube River (ICPDR). The ICPDR is comprised of the parties to the DRPC but is also open to other organizations.[23] The Commission addressed recommendations and proposals to the contracting parties. The parties to the Convention cooperate through joint activities, consultations and exchange of information. Since 2000, the ICPDR has become the platform for implementation of the EU Water Framework Directive. Alongside these tasks, some of the main aims of the Commission are to safeguard the Danube's water resources for the future generations; prevent eutrophication of waters; promote healthy and sustainable river systems.[24] In fact, the ICPDR was the initiator of the study on nutrient pollution trading in the DRB.[25]

The multilateral agreements also play an important role in the protection of the DRB. Measures adopted in these agreements such as the establishment of monitoring

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[21] Ibid. Art. 3

[22] Ibid. Art. 9

[23] The parties of the Convention are: Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Moldova, Rumania, Slovak Republic, Slovenia and the EC. Ukraine has signed the Convention but has not ratified it and Bosnia/Herzegovina and Serbia, Montenegro are observer states. United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."

[24] ICPDR, "About Us."

[25] United Nations Office of Project Services, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction."

programs and control measures for point sources and non-point sources, are important to highlight when analysis the possibility of implementing WQT programs in the DRB.

6.2.3. The EU Water Framework Directive and Related Directives

At the European Union level the Water Framework Directive (WFD) was established with the aim of uniting all requirements for fresh water management into one single comprehensive directive. It constitutes an important instrument for water quality because all the Danube countries are either EU Member states or they are accession members, like Bulgaria and Romania. The other counties of the DRB that are not EU member states still are expected to follow the EU regulations on water quality.[26] Hence, the Directive must be studied to understand the mechanisms that can facilitate nutrient trading.

The WFD promotes an integrated water system management for the achievement of a "good status" for the European waters within 15 years.[27] The good status for waters is defined in art.2 of the WFD; this establishes that waters are in good status if they meet the requirements of the existing water protection Directives or if they meet new ecological quality standards. The WFD also refers to a good "ecological status" and good "chemical status" of surface waters. The ecological status depends on the biological community of the waters that must be like what they would be with minimum anthropogenic intervention. The good chemical status relates to the standards of chemical composition of the waters established at the national and European level.

The integrated strategy for the resolution of water quality issues also implicates that the water quality standards that are set must be reached by regulations and control of emissions and use of land. The European Community Members and the members of the DRPC have agreed that the EU WFD should be the primary regulative framework to protect the Danube and the Black Sea. Consequently, it is necessary to point out which other directives that depend on the WFD are relevant for nutrient trading.

[26] United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."
[27] European Council and European Parliament, Directive Establishing a Framework for Community Action in the Field of Water Policy, pt. Art. 1.

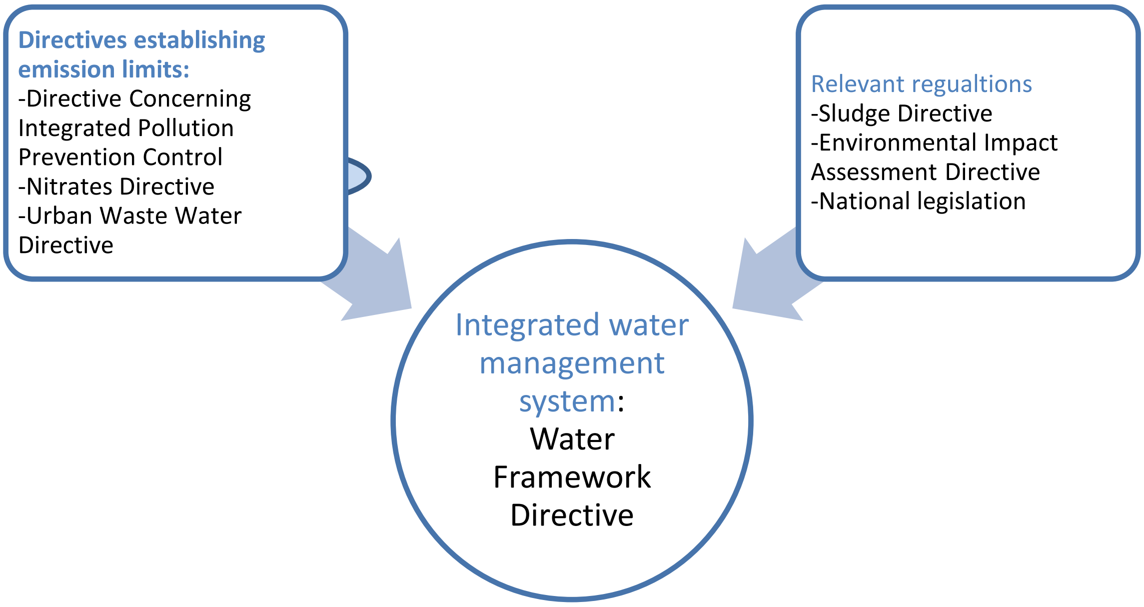

Figure 6-3. The integrated water quality management system of the EU WFD.[28]

The Integrated Pollution Prevention and Control Directive (hereinafter IPPC Directive), establishes permits on the emission limit values that non-point sources and point sources must comply with. To comply with the emission limits, non-point sources should base their compliance measures on the best available technology.[29] Since, continuous monitoring is required entities must carry out self-monitoring, as defined in the permit, and must report to the pertinent authority. This allows the authority to take necessary measures in case it discovers that an entity is not complying with the emission limits.

The objective of the Urban Water Waste Directive is to safeguard the environment from negative effects of urban waste water, such as eutrophication. The Directive sets water quality standards for the concentration of nitrogen, fertilizer plans, conditions for the development of national action plans, requirements for manure storage, preventive measures, and others. All these requirements and standards are meant to regulate the emissions from non-point sources. The Waste Water Directive and the Nitrates Directive prescribe the maximum daily average for the concentration of total nitrogen.[30] They also identify the criteria for the appointment of Nitrates

[28] United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."
[29] Directive Concerning Integrated Pollution Prevention and Control, pt. Art. 10 (2).
[30] European Council, Directive Concerning Urban Waste-Water Treatment.

Vulnerable Zones and nitrogen sensitive areas. In these areas, more advanced treatments must be taken.

The European Directives mentioned apply only to the EU member states, nonetheless, Balkan countries together with Moldova and Ukraine are in the process of aligning their national legislation with the EU regulations. Moreover, other international agreements are important in the consideration of the water quality for the DRB. The 1992 Helsinki Convention on the Protection and Use of Transboundary Water Courses and International Lakes, for example triggered the adoption of the DRPC and many bilateral agreements among the riparian countries of the DRB.

The Directives above mentioned, have already resulted in improved water quality marked by a reduction of both nitrogen and phosphorus loads in the Basin. According to the calculation of scenarios, conducted through MONERIS, allow to compare the nutrient loads in 2006 and in 2015. In 2006, the N emissions to surface waters were 686 kt/a, whereas the calculated values of 2015 are 605 kt/a, which is a reduction of 12% (81 kt/a). For phosphorus, P emissions to surface waters were in 2006 of 58 kt/a, whereas the calculated values of 2015 were 35 kt/a, which is a reduction of 65.7% (23 kt/a).[31] These measurements highlight a significant decrease of nitrogen loads and a drastic decrease in the phosphorus loads. This nutrient load reduction is a demonstration that the implementation of the WFD is successful and also the 2012 ban on P containing laundry detergents.

The regulatory framework concerning water quality in the DRB, is important to understand to analyse the feasibility of the introduction of WQT as additional instrument to prevent the eutrophication of the water body and of the NWBS. The Conventions and Directives that have been mentioned above do not prohibit nor promote the use of trading in water nutrients or pollutants in general. However, this legislative framework contains various measures and obligations that are relevant for the introduction of WQT. These elements include, among others, the regulation of: inventories, monitoring obligations, reporting, establishment of maximum nutrient concentration limits.

[31] Popovici, “Nutrient Management in the Danube River Basin”; ibid., vii.

6.3. Water Quality Trading in the Danube River Basin

Water quality trading was never introduced into the Danube River Basin as additional tool to reduce nutrient pollution. Nonetheless, the Danube Regional Project in collaboration with NIRAS, a Danish engineering and consulting group, commissioned a study to assess the feasibility of nutrient trading in the Basin. The study, entitled, Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Reduction, was initiated in December 2003 and was concluded in February 2005.

In order to determine whether nutrient trading is a valid instrument for nutrient reduction in the Basin, the study was structured in three main parts. Initially, the status of nitrogen and phosphorus loads and their relative sources was determined. Consequently, the legal and regulatory framework of the EU and of the Danube riparian states was analysed to assess their compatibility with the introduction of market instruments. Finally, the economic instruments for nutrient reduction were evaluated and the systems used in other countries were investigated. The study concluded that given the current regulatory and legal framework, the introduction of nutrient trading would be feasible.[32] The only requirement would be for all the riparian states that are not EU members (Bosnia and Herzegovina, Serbia and Montenegro, Moldova and Ukraine) to be aligned with the EU's Water Framework Directive. Moreover, concerning the economic instruments, the study analysed the water quality trading programs in other countries, highlighting the pros and cons. It concluded that the introduction of a nutrient trading program in the DRB would not be easy due to the complex nature of the Danube region. Furthermore, it was underlined that additional investigations and feasibility assessments should be conducted.

The conclusion of the study and of the related workshop, is that the Danube River Basin is not ready for introducing water quality trading. The motivation that was given in the study is that new EU member countries and acceding countries, are already consuming most of their energies in the pursuit of fulfilling the requirements of the EU WFD, thus do not have the adequate means to tackle the implementation of a trading program.

[32] United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."

7. Comparative Analysis of the Case Studies

The Chesapeake Bay and the North-western Black Sea have had long term eutrophication issues. Both waterbodies receive waters from a wide-spread river system, which crosses diverse jurisdictions. Therefore, not only one regulation applies to the entire river system but many different regulations which have to be harmonized in order to achieve an overall goal for the waterbody. For these reasons, the Chesapeake Bay and the Danube River Basin (DRB) can be compared. In this chapter I will assess the differences of the two watersheds.

Table 7-1. Comparison of the Chesapeake Bay and the Danube Basin.

Comparison Table Between the Chesapeake Bay and the Danube Basin		
	Chesapeake[1]	Danube[2]
Area [km^2]	165.759	801.463
Length [km]	843	2.857
Population	18.000.000	80.000.000
Catchment regions	6 states	19 countries
Mean streamflow entering the Bays [m^3/s]	2.302	6.550[3]
Total Nitrogen Load [t/a]	98.429	605.000
Total Phosphorus Load [t/a]	4.445	38.500

The United States' largest estuary is the Chesapeake Bay, which is also the third largest in the world. It has a length of over 800 km and covers a total area of 165.759 km^2.[4] Half of the water comes from the Atlantic Ocean and the remaining comes from

[1] Moyer, Blomquist, and U.S. Geological Survey, "Summary of Nitrogen, Phosphorus, and Suspended-Sediment Loads and Trends Measured at the Chesapeake Bay Nontidal Network Stations: Water Year 2014 Update."

[2] International Water Assessment Center, "Danube: General Description"; Chesapeake Bay Program, "Chesapeake Bay 101: Facts and Figures."

[3] The peaks of the stream low entering the delta are: min. 1.612 m^3/s and max. 15.540 m^3/s.

[4] Boesch, Brinsfield, and Magnien, "Chesapeake Bay Eutrophication: Scientific Understanding, Ecosystem Restoration, and Challenges for Agriculture."

the river, streams and drainage systems.[5] As shown in Figure 7.1. the watershed stretches from Maryland to Virginia and it comprises water coming from the rivers of six states: Delaware (in orange), Maryland (yellow), New York (pink), Pennsylvania (purple), Virginia (peach), and West Virginia (green), and encompasses the whole District of Columbia. The Bay has three diverse geologic regions: the Atlantic coastal plain, the Piedmont plateau and the Appalachian province.

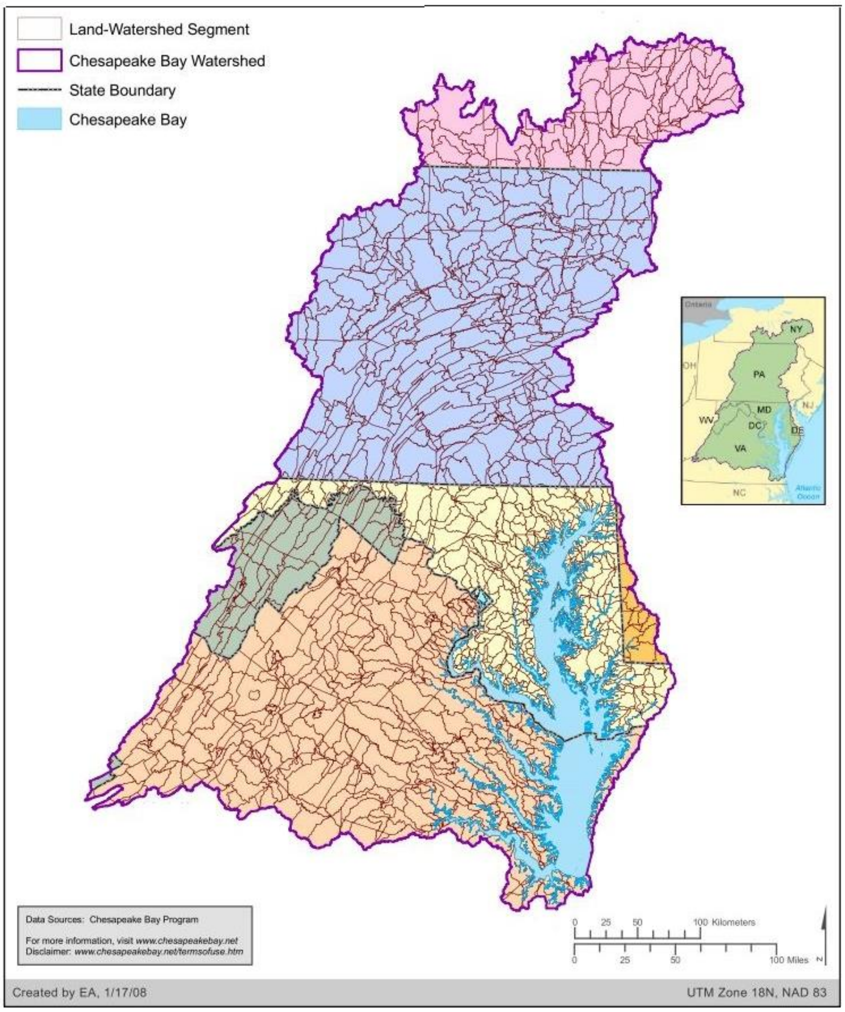

Figure 7-1. The Chesapeake Bay watershed and the riparian countries.[6]

With a total area of 801,463 km^2, the Danube River Basin is the second largest river Basin in Europe. It originates in Germany's Black forest and it empties in the Black Sea, comprising 27 major and 300 minor tributaries.[7] The Danube's drainage basin is the world's most international river basin as 19 countries share the catchment.[8]

[5] Van Houtven et al., "Nutrient Credit Trading for the Chesapeake Bay: An Economic Study."
[6] Chesapeake Bay Program, "Chesapeake Bay Watershed Model."
[7] ICPDR and IKSD, "Facts and Figures Brochure," 10.
[8] Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Montenegro, Poland, Romania, Serbia, Slovak Republic, Slovenia, Switzerland, Ukraine. Danube Pollution,

14 of these countries are referred to as “Danube Countries” they cover a total of about 2000km^2 and a schematic illustration of these is shown in Figure 7.2.[9]

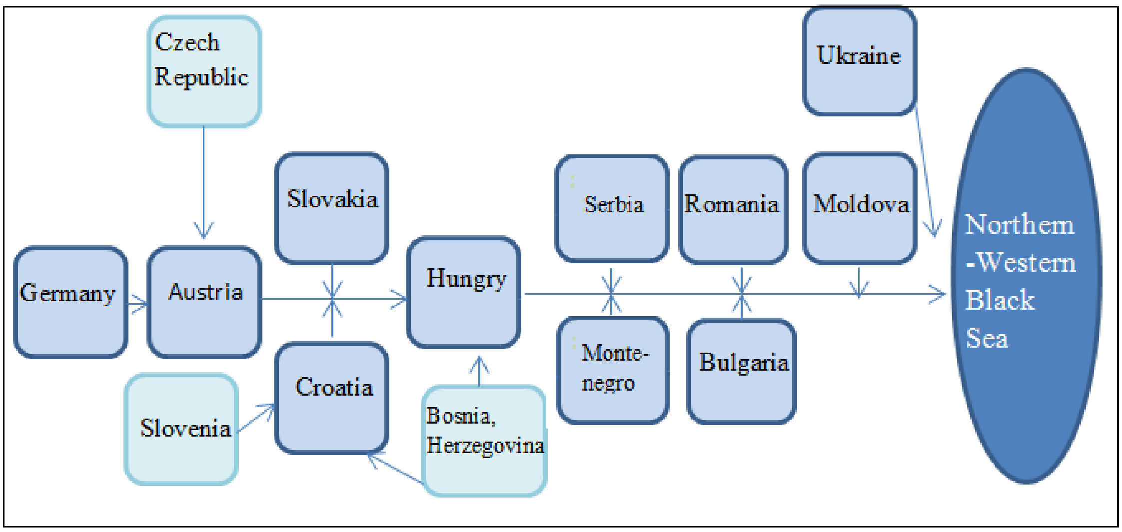

Figure 7-2. Schematic representation of the Danube riparian counties.

The Danube Basin has a variable climate due to the extensive area it covers and to the its topography. The climate on the DRB is: continental on the central and eastern regions, Atlantic in the western area, and Mediterranean on the south-western part of the basin. This region mainly consists of forests (35%), cultivable land (34%) and grasslands (17%).

The two basins, as explained, are vast and pass through regions with different legislations. Nonetheless, the distinguishing factor is that while the Chesapeake Bay passes through 6 states the Danube passes through 13 countries. The various riparian states of the Bay may have different legislations but they are all part of the United States of America. Consequently, the divergences between the regions are minor in terms of economic development, history, environmental regulations and population. The Danube region instead is characterised by a multitude of countries that present extremely different characteristics. A first dissimilarity among the Danube riparian countries that is worth noticing is the language. This poses complications in terms of providing definitions that are commonly understood and agreed on. Then the historic development of the states is heterogeneous. While the countries that are more upstream have experienced an early economic development the countries downstream are still in the process of developing. Moreover, these counties have different political systems and approaches, which complicate the application of a uniform policy for the Basin. Hence,

[9] Malagó et al., “Modelling Nutrient Pollution in the Danube River Basin: A Comparative Study of SWAT, MONERIS and GREEN Models.”

if the states of the Chesapeake Bay present some dissimilarities they eventually all rely on a common national policy and legislation. In contrast, the countries of the DRB not only have different legislations but also, they are not all in the European Union so they don't have a unique political direction.

The activities of the 18 million people that populate the Chesapeake region have overwhelmed the watershed and have led to an increased eutrophication.[10] The poor water quality has ruined the habitat of many animals and plants. In fact, it is the habitat of 3.600 species of fish, other animals and plants. The population of the DRB is much higher, almost 5-fold the population of the Chesapeake Bay with 80 million inhabitants. The DRB is also characterise by a rich biodiversity, counting 100 species of fish from almost 230 found in Europe.

Differences in the water quality legislation also make the European situation be very distinct from the American one. The EU Water Framework Directive comprises the Urban Waste Water Directive, which imposes stringent limitations on nitrogen and phosphorus discharges of WWTP. The standards are set depending on the size of the waste water discharge and the qualities of the affected waters. For discharges into 'sensitive areas', which are subject to eutrophication, the values for the percentage of reductions apply as following:

Table 7-2. Requirement for discharges from urban waste water treatment plants into sensitive areas.[11]

Parameters	Concentrations	Min. percentage of reduction
Total Phosphorus	2 mg/l (10.000-100.000 p.e. 1 mg/l (more than 100.000 p.e.)	80
Total Nitrogen	15 mg/l (10.000-100.000 p.e.) 10 mg/l (more than 100.000 p.e.)	70-80

[10] Chesapeake Bay Program, "Bay Barometer: A Health and Restauration Assessment of the Chesapeake Bay and Watershed in 2008."
[11] European Council, Directive Concerning Urban Waste-Water Treatment, sec. I.

The Water Framework Directive applies to the EU member states, but also other riparian countries are currently in the process of aligning their legislation to the EU standards. These standards are very rigorous and require a lot of effort from the states to attain their goals. Hence, this leaves little space for the introduction of water quality trading. In the United States, in contrast, there are no minimum requirements for nitrogen and phosphorus for WWTP. The national standards are technology based and do not cover nutrients. Nutrient limits in the United States, therefore, are not based on a national technology standard but on local water quality standards, established in most cases by the states. Hence, water quality trading has emerged in the United States as a valid way to regulate WWTP, because allowing trade to occur helped the WWTP to be more accepting of the fact that they are regulated and other sectors are not.

So, in the U.S. trading programs are an interesting alternative to reduce nutrient emissions when a water body is impaired. In fact, once a waterbody is declared impaired by the U.S. EPA, the latter then determine a TMDL, which is a product of an extremely long process that takes many years to put in place. The TMDL then becomes the cap of the waterbody which is then quite easily sub allocated to the sources. The cap is enforceable so its introduction leads to an amelioration of the waterbody. Theoretically, trading allows to reduce the costs for the sources of complying with the water quality goals and is assumed to increase the likelihood that the regulated entities will agree to the cap. In contrast, introducing nutrient trading in the Danube River Basin does not seem to be a cost-efficient solution. The legislation in place in the region already imposes stringent limitations on the nutrient emissions from WWTP but also from diffuse sources (Nitrate Directive). Therefore, the introduction of a trading program would require additional investments and establishment on new institutions to regulate the trade, which make its introduction not cost efficient in the short term. Also, there is evidence that the mechanisms in place in the DRB are already resulting in nutrient reductions along the Basin with a reduction of 12% of the nitrogen load since 2006, and an outstanding reduction of 65% of phosphorus loads.

8. Conclusion

After the success of the Emission Trading System in Europe and the Acid Rain Program in the United States, the interest of policy makers has turned towards market based approaches as means to solve environmental issues. According to the environmental economic theory, the introduction of trading systems for environmental "goods" entails multiple benefits for both the trading partners and for the environment itself and is more cost-effective than command and control policies. The net reduction of GHG, was a clear demonstration that these theories can be accurate. However, concerning water quality there is insufficient data to prove that WQT is a cost-effective solution compared to command and control systems.

I believe that WQT has been introduced in America and not yet in Europe because the former, historically, has demonstrated to rely more on market-based approaches compared to Europe. Command and control systems have always been more accepted from a political perspective because they are an efficient instrument to prove that action is being taken to tackle a serious issue as improving water quality. These methods deliver quantitative standards of goals to be attained in a geographical area, whereas markets leave a lot of freedom to the participants and the outcome cannot be fully predictable. The numerous economic benefits promoted by the theorists of WQT has lead the U.S. Environmental Protection Agency, to be drawn to this new approach. Moreover, market-based approaches are more accepted amongst polluters since the possibility of retrieving credits for free is more appealing than being directly charged on emissions. However, it must be underlined that as yet there is no solid empirical proof that market based tools are more cost-efficient than command and control policies. All the literature applied in this dissertation provides hypothetical cases that validating the effectiveness of theses economic instruments but none prove the empirical efficiency of the same. Additionally, no data has been provided up to today that can be used to compare the outcomes achieved through command and control systems and trading systems. As stated in the Danube Study on Pollution Trading and Corresponding Economic Instruments from Nutrient Reduction, "the efficiency of the market based instruments is still a theoretical construction".[1]

[1] United Nations Office of Project Services, Global Environmental Facility, "Danube Study on Pollution Trading and Corresponding Economic Instruments for Nutrient Trading."

To conclude, it is impossible to assert that water quality trading is a cost-effective solution for the eutrophication of waterbodies. Nonetheless, theory has provided indications that it can provide many economic benefits for the participants. Hence, with time when more data will be available on the effects on the waterbodies and on the gains of the sources of pollution of the introduction of trading programs, a more concrete comparison between WQT and command and control can be made. Only then, Europe can take into consideration introducing such measures to tackle water quality issues. The US introduced the programs based on the possible economic gains but for Europe the introduction of innovative solutions for water quality management have also to be politically accepted.

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