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International Boundaries on Unstable Ground

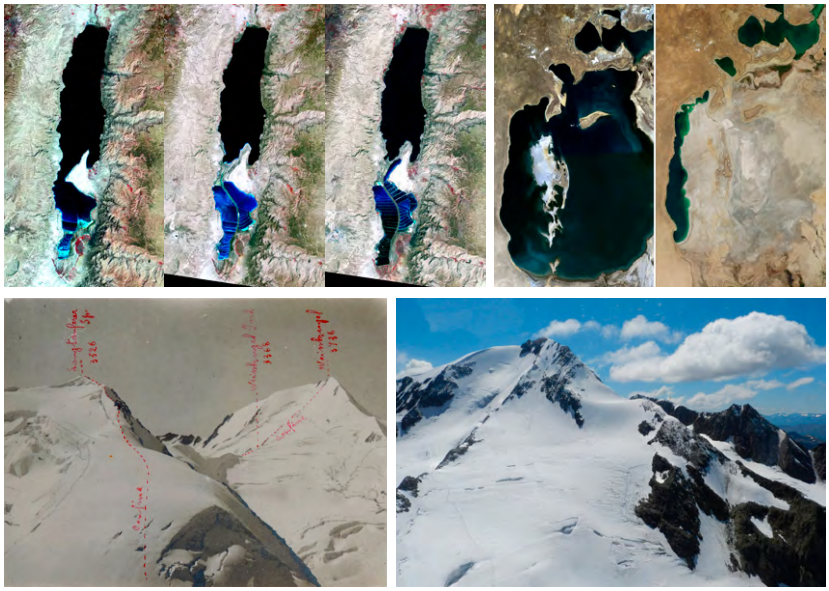

FIG COMMISSION 1

Professional Standards and Practice

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Haim Srebro

INTERNATIONAL FEDERATION
OF SURVEYORS (FIG)

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PREFACE

"Borders", "demarcation lines" or "frontiers" are on one hand evoking negative associations like separation and segregation. But on the other hand they also serve for good being often the basement of a peaceful and life together with our neighbours. In the latter sense each borderline is also an important element of a prosperous coexistence. The legal act of establishment and recognition of borders between private properties is normally regulated in the national law based on a common understanding and on one constitution.

Defining, establishing and maintaining international boundaries is a very demanding task. The underlying legal framework is more complex. Several states with different constitutions and varying legal opinions are involved. International agreements are the base for the recognition of a border between two or more states.

This FIG Publication on International Boundaries on Unstable Ground is a supplement and extension to FIG Publication 59 on International Boundary Making, published in 2013. Both publications are edited by Haim Srebro. The authors Vincent Belgrave, Andrea Cantile, Donald Grant, William A. Robertson and Haim Srebro are all highly qualified experts and practitioners in "boundary making". In this issue they focused on the boundaries in rivers and lakes and on the boundaries on unstable ground especially on glaciers and in conjunction with tectonic plate movements.

This publication is a fine and profound supplement to publication 59. It also covers the new challenge of precise GNSS-measurements in conjunction with international borders.

FIG thanks the authors for their valuable contribution as international experts of boundary-makers. We hope that this publication will be an informative guide for the definition of future international borders.

Rudolf Staiger
FIG President 2019–2022

My sincere thanks to Dr. Haim Srebro, Chair of Working Group 1.3 International Boundary Settlement and Demarcation for writing the International Boundaries on Unstable Ground as a supplement to the International Boundary Making to promote just, peace and inclusive societies throughout the world and achieve the United Nations Sustainable Development Goal No. 16 on Peace, Justice and Strong Institutions.

Winnie Shiu
Chair Commission 1 (2019–2022)

INTRODUCTION

This FIG Publication on International Boundaries on Unstable Ground is a supplement and extension to FIG Publication 59 on International Boundary Making (https://www.fig.net/resources/publications/figpub/pub59/figpub59.asp). Publication no. 59 mainly elaborated on the process of international boundary making, including allocation, delimitation in an agreement, demarcation, survey and documentation, and boundary maintenance. In addition, the publication elaborated on the joint professional support of the boundary making process. The practical parts mainly referred to land boundaries. The specified goal of the process being to achieve a long lasting stable agreed boundary line.

The main implementations of territorial boundary delimitation are demarcation of international boundaries and demarcation of internal boundaries in states, including administrative boundaries and boundaries delimiting land properties and rights of use. The cadastral boundaries are important for ensuring stable legal territorial matters. In order to fulfil the specific requirements of boundary making in these cases, the law requires fixed unequivocal and unambiguous defining of the boundary lines.

The goal of stability of an international boundary is very important. It is the leading essence of the boundary line in order to enable peaceful and productive environment, including safe legal order and arrangements on both sides of the boundary. The goal of stability of international boundaries has been defined by the International Court of Justice[1]. The ICJ has confirmed principles of stability of boundaries. Yet, the main practical principles regarding this issue refer to stability of land boundaries, including respecting of boundary markers as such by the states concerned.

Part of the problems of boundary delimitations resulted from selection of insufficient or unstable features, either artificial man-made changing features like roads, or common natural geographic features that have been chosen for delimitation of boundary lines. Such are boundaries along mountain crests and water sheds, as well as on dynamic earth's physiographic features, such as rivers, glaciers, lakes, marshes, shorelines, edges of deserts, and even boundaries on dynamic land moving due to tectonic activities.

While demarcation problems along mountain crests are usually a result of vague delimitation that faces the detailed character of the real world, such as cases where a boundary line along mountain crests crosses valleys between mountains, or in cases where the high crests do not coincide with the general watershed line. Other demarcation problems depend on the dynamic character of chosen natural geographic features. Such are rivers and shorelines that change every second and along the year. The origin of many natural geographic feature based problems is an outcome of climate changes and global warming. Many others are a result of man-made activities.

The main problems due to global warming refer to boundary lines delimited with reference to water bodies: river boundaries, boundaries in lakes and marshes, boundaries along shorelines, and boundaries on glaciers. Rivers, lakes and marshes lose water and dry. Global warming causes lakes and marshes to shrink and in some cases to disappear. It causes glaciers to melt so that the under glacier base ground is exposed gradually. Since the boundary line on glaciers used to be delimited along the crests of the glaciers, the result of the melting process of the icy natural crests is that the newly ex-

1 Case concerning The Temple of Prea Vihear [Merits], 1962 ICJ Reports 6.

posed bare rocky mountain crests are located in different locations than the icy crests. Since the boundary line used to be delimited along the icy crests the neighboring parties have to define where should be located the new boundary.

The cases of river boundaries are much more diverse and much more widespread. More than one third of the international boundaries throughout the world are river boundaries. The impact of the drying process of rivers due to global warming is combined with the influence of the population growth all over the world and with artificial man-made works along rivers. Water supply is the most essential natural resource required for human living and therefore a large part of the global population lives along rivers. The need for water leads to development of large artificial water projects on rivers, sometimes building big dams and reservoirs, changing dramatically the natural water flow of the river downstream, and changing its natural balance and behavior. The water flow of a river may also be used for the production of energy, building hydroelectric power stations, with dams, reservoirs and other works and installations that change the natural behavior of rivers. These phenomena complicates the maintenance of boundaries in rivers, especially due to the trend used in many boundary agreements that the boundary follows continuous gradual natural changes in the river (accretion) and does not follow artificial changes in the river. The extent of man-made influence on the river flow all over the world leads to severe problems regarding boundaries in rivers everywhere. This reflects severe disadvantages of choosing natural geographic features for international boundary delimitations in the past, and especially for the common trend of using rivers as international boundaries. Jones, in his remarkable hand book on boundary-making already recommended in 1945 (Jones, 1945) to avoid the use of natural geographic features, and especially rivers for boundary delimitation.

Unfortunately, natural geographic features, and especially rivers, were widely used by the colonial powers for boundary delimitations during the second half of the 19th century and the first half of the 20th century. Holdich, who participated in implementing this approach of the British Administration explained the advantages of this approach (Holdich, 2016), and while not ignoring disadvantages in certain cases, praised the use of rivers for delimitation in many cases by the words: "It is a God-sent feature for boundary-making". He explained the advantages of natural boundaries over artificial boundaries a century ago: "They are readily delimitated and demarcated; they are inexpensive and immovable; they last well under conditions of climate, and they are, as a rule, plain and unmistakable." Unfortunately, the numerous cases of disputes regarding past delimitation of natural boundaries, and especially river boundaries, show big disadvantages of natural boundaries. Part of it is a result of global warming and global population growth. Fortunately, since the situation a century ago, the development of improved mapping infrastructure all over the world, and the development of high quality mapping technology and systems, including the use of satellites for real time accurate global positioning all over the world, supplies much better tools for precise boundary delimitation and demarcation.

Since FIG is a global NGO organization that integrates various kinds of professions regarding surveying, geodesy and additional close professional fields, including many practitioners from the member organizations, many people from the academic world, and people from affiliate national organizations, we have chosen in FIG Publication no. 59 an approach that combines theoretical and methodological parts and practical cases over the world. The practical cases in publication 59 referred to boundaries in the Middle East, with the outstanding Israel-Jordan boundary that fully implemented the

methodological model; the Iraq-Kuwait boundary that was demarcated by the UN itself; cases in Africa, including the Ethiopia-Eritrea, Cameroon-Nigeria and Sudan-South Sudan Abyei boundaries, all of which were relatively new delimited boundaries. In addition, it included old delimited boundaries between Nepal and India and China. Thus, it included both the international boundary in the lowest place on Earth (The Dead Sea) and the highest place on Earth (Mount Everest). We continue with the same approach in the current publication which is a supplement to Publication No. 59. Regarding river boundaries we bring the practical case of the Jordan River, the lowest river on Earth in its southern section, south of the Sea of Galilee, flowing to the Dead Sea from about -220m to -430m (below sea level). The Jordan River flows along the Dead Sea Rift along the tectonic border between the African Plate on the west side and the Arab Plate on the east side until it flows into the Dead Sea. The practical cases of boundaries on glaciers were chosen along the Italian-Swiss and the Italian-Austrian boundaries on the Alps in Europe. The reason for that was the special approach of the moving border that has been adopted in these cases. An example of the influence of tectonic plate movement on the demarcation of an international boundary is shown in a review of the Iraq-Kuwait boundary demarcation after 20 years.

It is worth mentioning that natural fenomena that influence the stability of international boundaries are sometimes interrelated. Movement of tectonic plates along the course of a river may directly influence its course, or indirectly because of collapses of its walls that block its flow, enforcing it to find or create a bypass. Such is the case of the Jordan River. The melting of glaciers, that influences the boundary line along crests, may also have an influence on the boundary line in a lake in the case that there is a boundary line in the lake, by causing a rise of the water level and horizontal changes in the coastlines of the lake. In the case of a river and a lake that both serve for boundary delimitation, if the lake partially dries, the river has to find or create a new channel through the dried area in order to get to the lake. This new channel is usually not identical with the old boundary line in the drying lake. Such is the situation between the Jordan River and the Dead Sea.

Part 1, Chapters 1, 2 and 3, deals with boundaries in rivers and lakes. Chapters 1 and 2 deal with river boundaries. Chapter 1 elaborates on methodological aspects regarding river boundaries. Chapter 2 elaborates on the practical case of the international boundary between Israel and Jordan, in its river section that follows the Jordan and Yarmuk Rivers. The article describes changes in the two rivers during the last century, as a result of natural and artificial changes and analyzes the influence of these changes on the international and cadastral boundaries. Chapter 3 deals with boundaries in lakes, showing examples of the shrinking of the Aral Sea and Lake Chad, and elaborating on the example of the changes in the Dead Sea level and shores due to global warming and man-made influence.

Chapter 4 deals with the international boundaries of Italy, describing the boundaries between Italy and Switzerland and Austria on the glaciers of the Alps. It describes and analyzes the continuous gradual process of melting of the ice over the last century as a result of global warming. The original agreed delimitation of the international boundaries between the relevant states was along the crests of the mountains that used to be icy crests. The melting of the ice exposed the rocky crests that used to be beneath the ice. Since the exposed rocky crests follow different locations than the original delimitation and demarcation on the crests of the glaciers, the neighboring states face a problem: Should the boundary follow the old historic delimitation of the boundary or

should it move to the newly exposed crest of the mountain. The article analyzes the process of negotiations between the concerning parties and introduces the chosen solution called the moving border.

Chapters 5 and 6 deal with the uncertainty of delimitation and demarcation of international boundaries on the long run, including land boundaries all over the world, due to dynamic plate movement. Chapter 5 looks at the geodetic and geophysical issues that earth dynamics may impose on the reliable enduring definition of international boundaries, being aware that no place on the surface of the Earth can be truly considered to be fixed in place due to pervasive tectonic motion. The practical case of the Iraq-Kuwait Boundary shows that despite an initial coordinate accuracy of 2 cm, the global positional accuracy has been degraded to meters during only 20 years. Chapter 6 reviews surveying standards and datums used to support international boundary positioning and documentation. Poor boundary delimitations, including poor maps, may contribute in the future to instability of the boundary and to boundary conflicts. The article elaborates on the pervasive use of satellite positioning during the last decades for international boundary delimitations. It refers to the problem to maintain on the long run permanent stability of international boundary monuments and coordinates, arguing that local reference systems may not be adequate for maintaining the stability of international boundaries. The author suggests that the delimitation, demarcation and maintenance of international boundaries would be future proofed by being connected to a regional densification of ITRF. In addition, for future consistency, the ellipsoid for calculations, the datum and the coordinates for calculations, as well as the long term adjustment to the ITRF could be a standard requirement in the technical specifications of all international boundary agreements.

The publication has been prepared by senior practical professionals, with expertise in boundary delimitation, demarcation and documentation. Three of them served as Director Generals of national surveying and mapping organizations (Dr. Haim Srebro in Israel and Dr. William Robertson and Prof. Donald Grant in New Zealand), one served as a chief geographer in a national organization (Prof. Andrea Cantile in Italy), and one (Vincent Belgrave) was a chief surveyor in a few UN missions regarding boundary settlement. All of the authors have long practice in international boundary settlement and demarcation.

This FIG Publication has been prepared under the framework of the FIG Commission 1: Professional Standards and Practice work plan for 2018–2022 (Commission Chair: Winnie Shiou. Chair of WG 1.3 on International Boundary Settlement and Demarcation: Dr. Haim Srebro). Special thanks to the honorable **Prof. Moshe Brawer** for peer reviewing the entire publication and adding useful remarks. The publication is intended to promote the sharing of methodological knowledge and experience regarding delimitation of international boundaries and to promote Peace throughout the world.

Haim Srebro, Editor
Chair, FIG Commission 1 Working Group on International Boundary Settlement and Demarcation
September 2020

PART I
BOUNDARIES IN RIVERS AND LAKES

FOREWORD

In the face of global phenomena during the last century, the most prominent of which are the rapid population growth and the fast depletion of the available fresh water due to global warming and over-exploitation of fresh water, as well as water pollution, a shortage of fresh water for large populations has developed and has caused a serious shortage of food and drinking water.

These shortage conditions contribute to massive population migrations, create tension between states, as well as increase the potential for international disputes and possibly wars. This situation strengthens the importance of consensual regulations regarding the rights of using water sources at regional and international levels. Well-defined and fixed international boundaries are an important component of such regulations, as a condition for maintaining stability; however, they are insufficient because the colonial powers failed to support stable territories and boundaries by choosing unstable natural features like rivers and lakes for defining the international boundaries. Many independent states have inherited such colonial boundaries according to the *uti possidetis* principle.

The global population has increased about five times since the end of the 19th century; global warming increased later, particularly in recent decades. The result of both processes is that agreements regarding the regulation of water use and its exploitation are required in addition to a precise definition of agreed international boundaries. These processes are especially relevant where the boundaries follow or cross water bodies such as rivers and lakes. The use of water upstream influences the potential use of water downstream, both with regard to the volume of water and its quality.

The importance of water regulation at the regional level is especially relevant within the drainage basin of an international boundary river. Delimitation of international boundaries has to take this into consideration.

The time delimitation of international boundaries, based on natural features, especially rivers, has been found to be problematic, leading to numerous boundary disputes and territorial claims. In 1945, in his handbook on boundary making, Stephen Jones recommended to avoid using rivers for delimitation of boundaries. Unfortunately, the use of rivers and lakes for boundary delimitation was used frequently by the colonial powers, in order to reduce expenses and save time, as stated by Holdich: "…it is a GOD-sent feature for boundary-making, and requires no assistance from man" (Holdich, 1916, p.156). Accumulating evidence has shown that rivers and lakes are unstable and change continuously due to changes in the water level and to many natural events and man-made activities.

Chapter 1 deals with the methodology of river boundaries. Chapter 2 deals how changes in the Jordan and Yarmuk Rivers influence the boundaries. Chapter 3 deals with boundaries in lakes and the case of the Dead Sea.

Note: The views expressed in these articles are the author's and do not necessarily reflect the views of the Government of Israel including the Survey of Israel, or the view of the Israel-Jordan Joint Boundary Commission.

Haim Srebro

CHAPTER 1:
BOUNDARIES IN RIVERS

Haim Srebro, Israel

Key words: International boundaries, river boundaries, Israel-Jordan boundary

Abstract

International and cadastral boundaries are important for ensuring stable legal territorial matters. As such, they should be accurately defined. In certain cases, boundaries are defined on the dynamic earth's physiographic features, such as rivers, glaciers, lakes, and on dynamic land, moving due to tectonic activities.

This article deals with the long-term location and management of boundaries in rivers. A few countries have agreed that the boundary will not follow changes in the river (like in the Mongolia-China Border Treaty), whereas most agree that the boundary will follow slow, natural and gradual changes in the river (like is stated in the Israel-Jordan Peace Treaty).

The international boundary under the British Mandate between Palestine and Trans-Jordan in the Jordan and Yarmuk rivers was defined in 1922. The cadastral boundaries were defined in these rivers in the 1930s along the international boundary.

For more than 70 years, until the Israel-Jordan 1994 Peace Treaty, the rivers have changed their channels east and westward to distances up to hundreds of meters. During that period the mandatory boundaries in these rivers changed their political status to the armistice lines, the cease-fire lines, and to international boundaries between sovereign states.

These lines were usually delineated on topographic maps in the rivers, drawn by cartographers following contemporary map revision. During that entire period the cadastral boundaries were not changed in order to adapt them to the actual position of the rivers and to the delineated international boundaries.

Owing to large water works on both rivers, including the construction of dams and diversion channels in order to meet the increasing needs of the population on both sides, the water flow of the rivers decreased dramatically to less than one tenth of the original natural flow. The Israeli population today is more than ten times bigger than it used to be in Palestine a century ago (1920). The changes in the water channels during the last 26 years since the 1994 peace treaty are in the magnitude of 10–20 meters versus hundreds of meters in the past. In addition, intensive land cultivation adjacent to the river banks has stabilized them.

In 2000, due to the construction of a dam on the Yarmuk River, both sides jointly fixed coordinates of the relevant boundary line in the river according to the boundary delineation in the peace treaty.

The author thinks that the accumulated artificial changes along both rivers have cancelled their natural behavior and have influenced the changes in the river channels. Therefore, both sides should consider the option that the boundary lines in both rivers

should be fixed by coordinates according to the peace treaty delimitation, and enabling the cadastral boundaries to be fixed according to the fixed international boundary line.

This article analyzes the theory and practice of boundary line management in light of changes in rivers from the time of the Romans until today. Chapter 2 analyzes the special case of the boundary line in the Jordan and Yarmuk rivers, and introduces a proposal for stabilizing this boundary line.

1 INTRODUCTION

The purpose of boundary demarcation is to increase certainty regarding delimitation of rights on both sides of a demarcated boundary. The absence of a clear boundary line contributes to ongoing friction between those who consider themselves as the rightful owners or those who claim rights in cases of insufficient clarity. Such friction may lead to disputes, confrontation and even violence. The territorial arena, where delimitation of ownership of the rights of use is required is an important example.

The main implementations of territorial boundary delimitations are as follows: demarcation of international boundaries and demarcation of internal boundaries in a state, including administrative boundaries of government ministries and agencies, boundaries between local government entities, boundaries defining land properties and rights of use.

In order to fulfill the specific requirements of boundary making in both cases, the law requires unequivocal, fixed, and unambiguous defining of the boundary lines. In order to preserve the stability of the boundary lines, they should be precisely documented in a way that enables their maintenance and restoration (Srebro, 2014).

In the past, the tendency was to define boundaries by verbal descriptions referring to prominent landscape features, especially natural impassable barriers that are seen from far away. Such boundaries, which are regarded as natural boundaries, were based on features such as mountain ridges, rivers, shorelines, valleys, swamps, and edges of deserts. The colonial powers were inclined to delimit natural boundaries. The British Empire adopted natural boundaries during the 19th and the beginning of the 20th centuries, when dividing the British Empire into protectorates. It was easy to implement such a division, saving a lot of field work. In the course of time, the system of defining natural boundaries, by utilizing descriptions of prominent landscape features, proved to be unsuccessful in the long run, creating international disputes as a result of unclear boundary lines (Srebro, 2005). Boundary delimitations, based on river boundaries, presented other difficulties, in addition to the basic disadvantages of using natural boundaries, since a river is not a steady natural feature, it continually changes with time. A chain of mountains or a valley usually lacks a precise geographic definition that is required for boundary demarcation; however, after the two sides overcome their disputes, they agree on a consensual line and define it by coordinates or demarcate it by physical markers. A river is not a consistent geographic entity, because it depends on water sources that often change. The water volume of its flow changes, and consequently, the water's intensity and the speed of the flow also change. The water level may increase or decrease. The river may erode its banks, may deposit sediments along the stream, and may change its course. Since the river changes and is unable to preserve its course, it is impossible to establish a fixed boundary line that passes through the flowing river.

This makes river boundaries leading members in the family of long-term unstable boundaries. This family also includes boundaries in changing lakes, boundaries over melting glaciers, and boundaries on unstable lands due to significant tectonic movements. Cases of unstable boundary rivers are much more frequent than the other cases of unstable natural boundaries. More than one third of the international boundaries throughout the world are river boundaries, the total length of which is about 77,000 km (Donaldson, 2011; IRBD, 2008). The longest of them passes along more than 2,000 km alongside the Rio Grande between Mexico and the U.S. A.

The main problems arise in cases where the boundary line has to be changed owing to a change in a course of a river. In the case of international boundaries, this often initiates disputes between states, causing national discontent in the state that loses lands to another state. In land property cases it harms land property owners who lose property, sometimes cultivated lands, and registered land rights. Other problems in land boundaries arise when the river's course changes and the boundary line does not change accordingly. This causes problems in preserving the stability of the boundary line and its precise definition. In spite of arguments regarding the boundary line, other kinds of disputes may also raise. The severest one refers to the problem in which one of the sides loses accessibility to the river in the area of change. This may be reflected in losing rights of using the river's water and may be more severe in navigable rivers. Between states, such a case could result in confrontation. This was one of the reasons for the confrontation between Iraq and Iran regarding the boundary in the Shat-Al-Arab River.

States may overcome such problems by signing supplementary agreements, to ensure their rights to use the river waters in such cases. States may take drastic measures, such as forcing the stream into a steady water course such as a concrete canal. This has been implemented along part of the Rio Grande between Mexico and the U.S.A. In addition to its high cost, especially in the case of wide rivers, this solution has caused ecologic problems down-stream.

Rivers around the world are diverse regarding their size, their flow, their behavior during various seasons, the use of their water and additional parameters. The basic distinction regarding this subject refers to whether the rivers are navigable or non-navigable. Legal principles regarding land boundaries in rivers in cases of changes in the water course have been established and implemented since the time of the Romans. During the Middle Ages and later on, the Roman principles regarding this issue were adopted. In the 18th century, the scholar Grotius expanded these principles, and applied them to land property boundaries between individuals and to boundaries between states.

These principles distinguish between two types of changes in the water course of a river: one is a natural, slow and gradual change during the accretion/alluvion process. It cannot be perceived when it occurs, when the water of a river carries away soil from one bank of the river to its other side (usually under different ownership). In the case of an international river boundary, the river often carries away soil, transferring a piece of land from one state to another. According to the accretion principle, in such cases the boundary line follows the changes in the course of the river, and the course of the boundary line is consequently changed to the new location of the river course.

The other case refers to a sudden and steady change in the water's course of a river (avulsion), which can be perceived when it occurs, either as a result of natural reasons or as a result of man-made activities. According to the principle of avulsion, such a

change does not justify a change in the boundary line. This case should be considered as if a new river has been formed elsewhere. The boundary line remains in the former abandoned water course even if it is dry. In this case there is a break off between the course of the river and the course of the boundary, and one of the states loses its access to the river at this location.

In order to avoid situations of unstable boundaries that are predicted to cause future disputes, some countries have tried to fix the river boundary between them, with reference to the position of the course of the river on a jointly agreed date. In order to overcome the dynamic nature of the river, they have tried to physically force the river's flow into a rigid concrete canal. Usually this did not solve the problem because new problems arose. In other cases, countries agreed to fix the boundary line in coordinates. This option is much easier to implement today than in the past, since the use of satellite surveying, like GPS, is much more common. Even the International Court of Justice has adopted this method in its decision concerning the dispute between Benin and Nijer regarding the boundary line in River Niger, defining the boundary line in a list of coordinates (ICJ, 2005). The Israel-Jordan Joint Team of Experts (JTE) similarly fixed the boundary line in the River Yarmuk, following the construction of a dam on the river (Srebro, 2012).

The absence of one comprehensive method that can prevent river boundary problems and disputes is why, in spite of the development of law regarding this subject, including common law, in spite of decisions in courts and arbitrations, and in spite of many bilateral agreements between states that could support customary law, an obligatory international convention regarding defining and maintaining river boundaries has not been developed. This is unlike the UN Convention on the Law of the Sea 1982 (UNCLOS).

This argument was even used by the British administration in Palestine and Trans-Jordan to justify their decision in 1927 regarding the boundary in the Jordan River, following a flood that altered the water course of the river, consequently transferring a strip of land from Palestine to Trans-Jordan (Toye, 1989 pp. 795–805).

Chapter 2 deals with the international boundary between Israel and Jordan in the Jordan and Yarmuk Rivers, and with the land settlement boundaries of Eretz Yisrael (Palestine) and of the State of Israel along these rivers – in light of legal principles, court decisions, agreements, and customs regarding delimitation of international river boundaries and regarding the attitude to the delimitation in cases of changes in the river's course. The water's courses of both rivers have changed since the original definition of the boundary between Palestine and Trans-Jordan under the British mandate in 1922, owing to natural and man-made changes. Part of these changes resulted in fixing the boundary line in coordinates.

2 BOUNDARY DELIMITATION IN RIVERS

Disputes over lands have been known since ancient times, as well as the requirement to settle land boundaries and manage and register land transactions, early before the development of international boundaries. Since an objective means of defining boundaries by coordinates did not exist in ancient times, boundaries used to be defined by describing them in reference to natural landscape features, augmenting the descriptions by using physical man-made markers. Because of their nature, artificial markers were known to disappear over time, especially if there were interested people nearby. Therefore, some cultures sanctified such boundary markers and even ordered punishment and divine curses for offenders who damaged them (Solel, 1991). The use of landscape features in boundary descriptions used to be the first choice. This included roads, trees, rivers, constructions, and stone fences. Rivers were easy to recognize in the field and were natural obstructions and barriers. They were used as borders at the local, tribal, administrative, and international levels.

At the local level, land was cultivated until the bank of the river. The edge of the cultivated land moved according to the high and low tides and according to the changes in the river's course. Village lands used to be limited by rivers, especially in cases of wide rivers, which were difficult to cross. At the tribal and national levels, the river was used as a defense line against aggressors, and therefore, it was used as a boundary. With the development of civilization and the construction of bridges over rivers in fertilized and populated valleys, rivers also acted as a bridge between populations living on both sides of the river. Owing to their easy visibility, being easily used as natural borders, rivers eliminated the need for field marking and surveying, and were still used for boundary delimitation in the 20th century.

In order to define a boundary in a river the two countries should make decisions regarding a few questions: Where should the boundary be delimited – in the river (in its center or elsewhere) or along its banks? How should the boundary maintenance be managed over time, considering that the river is a living dynamic entity that changes according to the flow of water from its sources? How should the rights of use be allocated and how should they be divided between the states on the two sides and along the river? The allocation of the rights to use the river's water is important because of the global developing water crisis as a result of the climate change and the warming of the Earth. This phenomenon dries water sources and significantly reduces the water volume and the flow of rivers. It is also important due to the rapid increase in the world's population and especially for populations living along rivers and using their water (Graiger and Conway, 2014). Exploitation of river waters influences boundaries in rivers, but this subject is not discussed here in depth.

Usually it is common that a boundary river between two countries is equally shared between them, and that the boundary is delimited in the center of the river. The case of the river boundaries between Germany and the Netherlands is an exception, however, because according to the agreement between the two countries, in cases where the international boundary between the countries follows a river, the closer bank belongs to the relevant country and the river is common to both countries. In certain cases in the past, where a strong power or a strong country ruled one of the banks of the river,

it was determined that the boundary line follows the bank of the weaker country and that the water is under the sovereignty of the stronger one.[2]

There are a few methods of delimiting a boundary line in the center of a river. The main distinction is between navigable and non-navigable rivers. In the case of non-navigable rivers it is common to delimit the boundary in the geographic center of the river[3]. This is valid in land settlement boundaries inside a country where land properties are located on the two sides of the river and the boundary passes in the center of the river. It is also valid in the case of a boundary line along the median line between two countries. There are a few methods of delimiting such a center line. One common method is the equidistance one, in which the center line is defined by connecting points along the center of the river, which are at the same distances from prominent points on the two sides (along the two banks) of the river (Boggs, 1940; Srebro, 2005). Where a river splits up into two water courses it is common to choose the main one (Boggs, 1940; Jones, 1945).

In navigable rivers, consideration is usually given to the access of each of the countries to the navigation course and preference is usually given to defining the boundary line along the main navigation course. The navigation course is usually defined along the course of deepest places (also called thalweg, though the meaning of the term is not unequivocal). The ICJ referred to this in the decision regarding the Botswana-Namibia dispute (ICJ, 1999), determining a leading rule, though not a decisive one, regarding the preference of the thalweg in navigable rivers. The ICJ repeated this in the decision regarding the Benin-Nijer dispute (ICJ, 2005)[4]. The Court adapted the boundary line to the existing islands along the river's water flow.

One of the factors that should be considered before deciding on an international boundary line in a river is the drainage basin. The involvement of a few states in delimiting an international boundary in a river, and its potential influence on additional states sharing a common drainage basin greatly complicate the situation and its resolution.

Every river, including a boundary river, depends on water supplied from various sources, including subsurface sources, within its drainage basin. Unilateral use of water from such sources and from river tributaries may significantly influence the water volume of a river, reducing it and lowering its water level. The vertical changes in the water level modify the horizontal location of the river banks, narrowing the river width; thus, they influence the boundary of the river between the respective states. Consequently, this may influence the sovereignty and the rights of use of the water, and it is considered as a unilateral influence on the multilateral rights. This situation may be worse in cases where international boundary lines cross rivers shared by a number of states downstream, like in the case of the Nile River or the Euphrates River. Any large water project including construction of dams, and diverting water into reservoirs upstream, has serious implications on the population of states downstream. In arid areas in particular, combined with the increasing phenomenon of global warming, this may be fatal to

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2 A similar approach was adopted along the eastern bank of the Rhine River between France and Germany following the results of WWI.

3 "Where properties are separated by a natural non-tidal river or a stream, the presumption is that the boundary follows the center line of the water (*ad medium filum aquae*) so that each owner has half of the bed." (UK Land Registry Guidance – Land Registry plans: boundaries (practice guide 40 supplement 3, updated 25 June 2015)).

4 "144. The Chamber would recall that, in the case concerning *Kasikili/Sedudu Island (Botswana/Namibia)*, the Court observed that: "Treaties or conventions which define boundaries in watercourses nowadays usually refer to the thalweg as the boundary when the watercourse is navigable and to the median line between the two banks when it is not, although it cannot be said that practice has been fully consistent."" (*I.C.J. Reports 1999 (II)*, p. 1062, para. 24).

the indigenous population. In addition to the basic problem of delimiting international boundaries in rivers, it emphasizes the importance of and the need for multinational coordination, as well as cooperation and regulation agreements between all states sharing common drainage basins along boundary-rivers and boundary-lakes.

Jones (Jones, 1945) suggested a few questions to be considered before delimiting a boundary line in a river: 1) Is the river adequate to serve as a separating line; 2) Is the river flowing through a steady channel with steady banks; 3) Does it have a clear main channel; 4) Are there islands in the river under clear sovereignty; 5) Which boundary lines fit various sections along the river; 6) Which water level should be considered and defined as a reference for the boundary delimitation; and 7) Will there be a need for a permanent boundary maintenance commission?

There is no single formula for boundary delimitation in rivers, not even for different sections of one river. Delimitation of boundaries in rivers requires detailed large-scale mapping, including detailed topographic mapping along the river banks, and additional data about the river flow and the river bed.

The main methods of delimiting boundary lines in rivers are as follows: 1) The median line, 2) the channel, 3) the thalweg, 4) a river bank, and 5) arbitrary straight lines between turning points. All lines except the arbitrary polygon depend on the water level. Therefore, the water level should be defined as part of an agreement of a boundary line in a river. Jones recommends that the delimitation should be defined by a demarcation commission that should consult a hydrologist who is an expert regarding the specific river.

The median line is the most common method for delimiting boundary lines in non-navigable rivers and in lakes, in order to achieve equitability, whereas the thalweg in the main channel is the most common method for delimiting boundary lines in navigable rivers.

The definition of a median line, as suggested by Boggs for boundary agreements is: "the median line being a line every point of which is equidistant from the nearest points on the shores of the two respective sovereignties; the shore line being the line of mean high water (or mean low water or other indicated stage of water) "(Boggs, 1940).

A suggested method of drawing a median line, as introduced by Boggs, is described later on in Chapter 3 of this publication. The exact median line has a shape of an irregular curve, since it depends on irregular shorelines. Therefore, it is recommended to simplify the curved line (especially in lakes and seas) by incorporating a series of straight line sections, and considering the compensation of the residuals on both sides of the simplified median line.

The main channel of the river, which is usually the widest, the deepest, and carries its main water volume, usually serves as the reference river channel.

The thalweg, which is usually represented by the line of the deepest points, is frequently used for delimiting boundary lines in navigable rivers, and serves as the leading option in these cases. However, since the term thalweg is ambiguous, it should be specifically defined when used. The location of the thalweg may change during floods, and may cross the median line in several locations. The demarcation commission should be given ample freedom and flexibility to simplify the thalweg line, as well as the median line, in order to define them by coordinates of turning points between straight line sections.

Delimitation of the boundary line along one of the banks of a river is rarely used. It is not recommended, since one of the parties loses direct accessibility to the river's water (unless agreed upon by the parties). In addition, it is technically complicated to define an exact line along a natural river bank, since the bank line is directly dependent on every change, due to the water level of the river and to the slope of the bank, as well as to continuous accretion and erosion of the river banks and due to sinking sediments. The bank line is especially sensitive to water changes regarding wide flat river banks.

When delimiting a boundary line in rivers, the parties should consider in advance measures to be taken in the future for boundary maintenance and future boundary restoration or reconstruction. However, this issue is less critical in cases where the river bed is narrow and the banks are steep. In such cases the river channel is relatively steady. It is most critical in flat and flooded areas, like river deltas, where there is no main river channel, there are large amounts of silt sink, and the river course changes frequently. Except for these extreme cases, most cases are more balanced: they involve a main channel that may change and meander, either slowly and gradually due to accretion or suddenly due to avulsion.

Such cases should be anticipated in the boundary agreement and rules for boundary line maintenance should be established in advance. A special boundary maintenance commission should handle such cases over time. The working tools of such a committee could include periodic mapping and monitoring of the changes, and even adjustment of the boundary line if required and agreed upon by the parties. Another option chosen by many states is to preserve the original boundary line as a fixed line along the original channel even if the river departs from the original channel (as agreed by Switzerland and Austria).

Islands in a river may also cause problems regarding the boundary delimitation. An island may join one of the banks or it may disappear and a new island may emerge. Sometimes the main channel or a thalweg moves from one side of an island to the other. Boggs recommended to draw a preliminary median line between the shorelines in order to define the original sovereignty of an island, and then respectively to delimit the thalweg.

It is recommended to use definite points for boundary delimitation, and to avoid the use of indefinite terms like a river source and geographic names that may change in the future. The confluence location of two rivers is not a well-defined point. Specific rules for delimiting the boundary line on bridges, dams, and other future installations should be pre-defined.

The many changes along rivers require a permanent or semi-permanent boundary maintenance committee for maintaining the boundary line itself, as well as for dealing with issues of water use, preservation issues, fishery, ownership and sovereignty, construction, as well as maintenance of bridges and dams, among others.

3 BOUNDARY MAINTENANCE IN RIVERS

Maintenance of boundaries in rivers is basically required because of the changing nature of river courses. This is one of the cases of changing boundaries caused by physical long-term changes in nature. Other cases are changes of boundaries due to changes in lakes, due to melting glaciers, or as a result of tectonic movement of the earth.

Rivers, by their nature, continually change with time. An increase in the water volume causes the tide to elevate and the extent of the river banks is governed by the side slopes of their banks. Sometimes the strong flow creates floods, sweeping the soil from the bed or the banks of the river. After heavy rains or melting snow, the flow of a river increases, and large amounts of eroded soils are carried away by the flow and sink as sediment along the stream. Sometimes the river overcomes obstacles in the course of the stream and cuts through a new water course, shortening the existing course, or meanders aside where the valley is wide, the slope is moderate, or the soil is soft. On the other hand, when the flow slows down and the weak stream does not have enough power to overcome the obstacles of silt that accumulate along the stream, and if the soil is soft and the land is flat, the river bypasses the obstacle. The width of the river and its water course changes if it passes through a wide flat valley and not through a narrow, deep rocky gorge.

The dilemma of maintaining a boundary line in a changing river concerns whether to keep the original boundary line in spite of the changes in the river or to move the boundary line to the new water course. In the past, the main legal and scholar discussions regarding this issue referred to river changes because of the transfer of soils from one bank of the river to the opposite one. In fact, often the river carries eroded soils from upstream out of the area of change, or from one of the banks, and the sediments sink downstream, sometimes on the bank of the same state from which the soil has been taken.

From the legal point of view, the distinction is between slow, gradual, and natural changes in the water course and between sudden sharp changes, whether natural or man-made. Such an example regarding land property law, reflecting common law, can be seen in the British Land Registration Law (LRA, 2002). According to this law, a boundary line that follows a river or a stream between two registered land parcels is located in the center of the water course and changes according to the change in the river, if the change is natural and gradual over time (UK Land Registry, 2015)[5]. Changes of that type – alluvion, accretion, diluvion or erosion – are recognized in land property law within the common law as changing borders of parcels, in spite of the fact that the boundaries are delimited in registered plans. The British Land Registry law even specifies that if the owners on both sides of the river want to deviate from this rule and agree on it, they must register that agreement in order to receive recognition by the Registry.

On the other hand, if the change in the water course is a result of man-made activity, the changes in the course are not recognized by common law as leading to a change in the boundary line. In the case of a sudden and steady change in the water course, whether natural or as a result of man-made activity, the boundary line remains in its

5 "The doctrine of accretion and diluvion recognises the fact that where land is bounded by water, the forces of nature are likely to cause changes in the boundary between the land and the water. We would expect these changes to be gradual and imperceptible. As the watercourse changes naturally and progressively with time, so the land boundary follows it. There may be some gain, there may be some loss. The law accepts this and considers it to be fair."

former place, before the change in the water course (UK Land Registry, 2015)[6]. In case of wide rivers that are subject to high and low tides, the land settlement boundary bordering the water is located at the front line of the mean high and low tides. It is common that the water space beyond that line belongs to the state.

The legal grounds of the accretion/alluvion doctrine evolved in the Roman laws, which had determined that a slow gradual change in the water course causes the boundary line to follow the river to its new course[7], but that a sudden and continuous change does not change the boundary line. In time, this legal custom took root and found expression in the theory of law and in the studies of law during the Middle-Ages and in modern times. In the 13th century the British jurist Bracton clarified that the legal principle of adding land as a result of river accretion is valid when the process is slow and unperceivable, but if the process of change is perceivable, then the land transfer is not legally valid (Bracton, 1883 according to Donaldson, 2011). Bractons attitude had a significant influence on the development of common law.

In the 18th century the Dutch scholar Grotius expanded the legal principle of changing the boundary line as a result of accretion, from the land property domestic law to international boundaries in rivers. In his work: *Of the Rights of Wars and Peace* he determined that rivers are natural boundaries that used to serve as natural barriers, defending from enemies, and they define legal limits between states. His view was that the Roman law regarding the boundaries of private property in the case of alluvion should also be valid in the case of boundaries between kingdoms. A river that defines a boundary defines it in a specific course, and if the course is changed slowly and gradually in a natural process, while transferring soil from one side of the river to the other side, it changes the boundary of the territory. However, if a river changes its course suddenly from one place to another, this is not considered any more as the old river in a new course, but as a new river, and it does not change the boundary of the territory (Grotius, 1715).

The views of Grotius were adopted and later on developed by Vattel (1787), who held the view that the alluvion principle that had been developed regarding private land property rights is also relevant for defining international boundaries in rivers. He expressed this view in 1758 in his publication: The Law of Nations (Droit de Gens).

There is analogy between the doctrine applied to land boundaries and the doctrine applied to international boundaries. The similarity is greater in cases of non-navigable rivers and streams. In these cases, delimitation of the boundary line in the center of the water course is considered most justified regarding the two states. Nevertheless, delimitation of international boundaries is more common in wide navigable rivers, flowing between countries, since such rivers had usually separated between tribes and peoples and had served as barriers, defending them from invasion.

The historic use of rivers for boundary delimitation has taken root and it left its mark on many river boundaries existing today. Some of them are domestic, separating districts, sometimes autonomic ones. Such examples are river boundaries between states

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6 "If a violent flood wrenches the watercourse suddenly but permanently into a different direction so that a substantial and recognisable change in the boundary has taken place, then the doctrine of accretion does not apply. Neither does it apply if the changes are man-made." And elsewhere: "Where there is a sudden, but permanent change in the course of the stream, whether or not it is due to natural causes, the boundary will remain along the center line of the former bed."

7 The Roman law says: "what the river adds to your field by alluvion, becomes yours by the law of nations" (Donaldson, 2011). The Justinian Institutes, that catalogued the Roman legal tenets remarked: "20. The law of all peoples makes yours any alluvial accretion which a river adds to your land. An alluvial accretion is one which grows on so gradually that you cannot tell at any one moment what is being added. 21. If the river's current rips away a piece of your land and carries it down to your neighbor, it clearly remains yours (Birks and McLeod, 1987 cited by Donaldson, 2011).

in the US, like the Missouri River between Nebraska and Iowa; along the Mississippi River between Missouri and Illinois, Kentucky and Tennessee (and between additional states along its course). Other examples are the boundaries along the Huang He River in China between Shaanxi province and the Henan and Shanxi provinces. Parts of these river boundaries follow rivers that pass between countries, like along the Rhine River between Germany, France, and Switzerland. Some examples are the boundaries along the Danuba (Also called: Donau, Donev, Donaria, Doni, Dona) between Bulgaria and Romania, and between other countries along its course, and for example, the boundaries along the rivers Argun and Amur/Heilong Jiang between Russia and China, and along the Shatt-al Arab between Iraq and Iran.

Wide international rivers are usually used for sailing. Therefore, navigation is an important parameter that is considered when choosing the center or the main course of navigation for delimiting the boundary line. There is no obligatory international convention regarding river boundaries, similar to the convention regarding delimitation of maritime boundaries (UNCLOS 1982). Therefore, one usually relies on the decisions of ICJ and of international arbitration tribunals, on customary practice in agreements between countries, and on the written opinions of scholars.

In the middle of the 19th century, the reference to the accretion/alluvion doctrine became standard in legal materials discussing river boundaries in international law (Donaldson, 2011). The decisions and customary practices regarding the issue in the 20th and the beginning of the 21st centuries reflect significant reliance on the decisions of the US Supreme Court from 1892 and later in disputes between states in the USA regarding river boundaries between them (in addition to previous cases in 1875 and 1890 that were not between states). The relevant decisions referred to the influence of natural and gradual or sudden changes in rivers on the boundary lines. In 1892 the US Supreme Court decided that the boundary between Nebraska and Iowa in the Missouri River would not follow a change in the course of the river, because it had been a sudden change (US Supreme Court, 1892, Iowa vs Nebraska). Similar decisions of this court regarding river boundaries in the US followed this decision.

The most famous arbitration decision regarding this subject, which is used even today as precedence for a decision of an international court or tribunal regarding the legal acceptance of the accretion and avulsion principles in international law, was given in 1911 regarding the US-Mexico dispute (the Chamizal Case). The arbitrators decided that the piece of land that had been transferred from the Mexican side to the American side, as a result of changes in Rio Grande water course, belongs to Mexico. The arbitrators accepted the Mexican argument regarding sudden changes in the water course and rejected the American claim that the changes were gradual. However, the US did not comply with the decision. In 1963 the disputed area was divided according to an agreement between the two countries. Following this arbitration decision, the principle of accretion/alluvion was established regarding accepting the principle that the boundary line follows changes in the water's course of a river, if these changes are slow and gradual, but when the change in the water's course is sudden, in an avulsion process, there is no change in the boundary line and it remains in its former course (Shaw, 2014). The arbitrators in this case determined, for the first time in an international decision, that the principles of accretion and avulsion are known principles in international law[8].

8 The arbitrators in the Chamizal case gave significant weight to relevant decisions of the US Supreme Court regarding accretion and avulsion. They also referred to the early comments in this regard of the US Secretary of the Interior in 1856 Cushing, who was considered an authority on international law, at the time of drafting the US-Mexico boundary treaty

The Shatt-al-Arab case between Iraq and Iran was another early known dispute. The 1937 agreement regarding the boundary line in the river determined that the boundary line will follow the deepest course of the river. Various methods regarding delimitation of the boundary line have been adopted in different sections along the river.

Many scholars have described methods to delineate a median line, every point of which is equi-distant from prominent points on the opposite banks (Boggs, 1940; Jones, 1945; Bouchez, 1963; Srebro, 2005). A 1934 decision by the US Supreme Court delimited a boundary line in the thalweg of a river. According to the Iran-Iraq agreement the deepest water course is decisive. Lauterpacht (1960) discussed the choice between the deepest course and the deepest navigation course. The definition of thalweg is more complicated when an island splits up the stream into a few channels. In such cases the main possibilities are: to choose the main water course or to draw a line through the island. The 1924 Norway-Finland agreement shows an early example of such a case. Bouchez (1963) and Biger (1988) emphasized that a navigation channel has width and it is not a line. However, agreements define boundary lines and the width is taken care of by supplementary agreements.

Unilateral artificial changes in a river are forbidden. In any case of a change in the course of a river as a result of man-made activity, the boundary line does not change. It will remain in its former course, even if the result of it is that the boundary will pass out of the river. In any case, two countries that come to an agreement regarding their boundary line in an international river (when no other country is involved) are sovereign to agree as they desire regarding its place, on the method of delimitation, and on the way of maintaining the boundary line in case of changes in the river. Examples of different approaches are reflected in the following: the 1963 China-Mongolia agreement (Department of Commerce, 1971) says that in case of a change in the river bed the boundary remains in its place unless otherwise agreed[9], whereas the 1994 Israel-Jordan peace treaty says that in case of natural changes in the course of the river (accretion or erosion) the boundary line will follow the changes unless otherwise agreed.

References are at the end of Part I, p. 55.

(Donaldson, 2011). The arbitrators quoted Cushing's comment: "If the river deserted its original bed and forced for itself a new channel in another direction, then the nation through whose territory the river thus broke its way did not lose the land so separated; the international boundary in that case remaining in the middle of the deserted river bed" (IBC, 1911).

9 "If, for natural reasons, the bed of the main course of the boundary river should change, the original boundary line shall be retained, unless the two parties decide otherwise."

CHAPTER 2:
PRACTICAL CASE – THE INFLUENCE OF CHANGES IN THE JORDAN AND YARMUK RIVERS ON THE INTERNATIONAL AND CADASTRAL BOUNDARIES

Haim Srebro, Israel

1 THE BOUNDARY LINE IN THE JORDAN AND YARMUK RIVERS

1.1 Geographical Background

The Jordan River is the longest river in Israel. It flows from north to south along the Jordan Valley, which is part of the Dead Sea Fault (the Syrian African fault), along 250 km, from its sources in the vicinity of Mt. Hermon until reaching its estuary, into the Dead Sea, the lowest place on earth. Its drainage area is about 18,300 square km. The Jordan River consists of two parts. The northern part – the upper Jordan (also called the mountainous Jordan) flows between the Golan Heights on the east and the Galilee Mountains on the west, in a fast stream along a steep slope into the Sea of Galilee. Its average annual water volume is about 500 MCM. The southern part – the Lower Jordan – exits the Sea of Galilee and flows southwards through the Jordan Valley until the Dead Sea. To the east of it are the Gilad and Moab mountains, the heights of which rise up to 1237 m. In the north-west it fringes the Lower Galilee and the Bet Shean Valley, which are relatively low. The Shomron and Judean mountains, which follow it on the west side, are lower than the mountains on the east side, though they rise up to 1000m

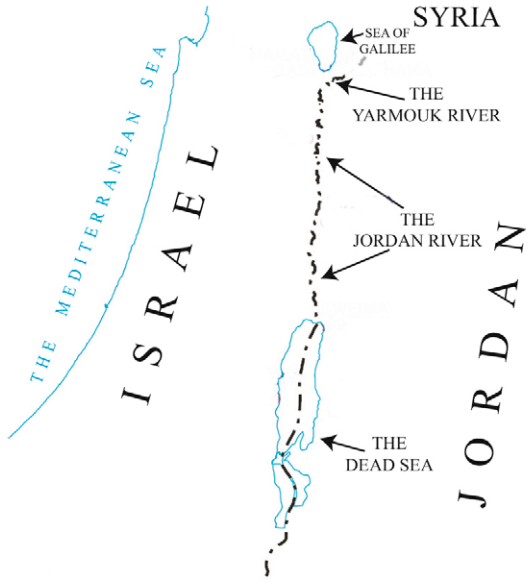

Figure 1: *The Israel-Jordan boundary in the Jordan and Yarmuk rivers.*

in the south. The Israel-Jordan international boundary runs through the Lower Jordan along 105 km of direct distance and about 200 km along the meanders of the water's course in a slope of 0.8%. The current ratio between the distances is about 1:1.86, more than the average of 1:1.5 of twisted rivers throughout the world. The common width of the river is 27–30 m and its depth is 1–3 m. In some areas it may be crossed by foot. The river bed passes through a flooding path along the lower level of the Jordan Valley, which is called Geon-Ha'Yarden (The Zor), 1200 m wide, but in few places only a few hundred meters wide. The river cuts its bed in soft alluvial soil that has accumulated on top of thin grain sediments of Lissan formation, composed of lime stone, gypsum and minerals that had sunk during the time of ancient Lissan Lake. The lowest level of the Jordan Valley, through which the river flows, is limited on both sides by slopes, 5–25 m high (up to 40 m in the south), above which on both sides exists the mid-level of the Jordan Valley called Kikar Ha'Yarden – the Ghor. The lands on this level are largely cultivated on the north-western Israeli side and all along the Jordanian east side (as a result of the Ghor Canal –the Abdulla Canal – and additional water projects). On both sides, above the mid-level of the valley, is located the upper level of the valley.

The Jordan Valley area, through which the Jordan River flows, is considered to be on the edge of a dry desert, located on the "shadow of rain". The climate is hot and dry. The average temperature is 24°C (30°C during summer and 15°C during winter). The precipitation is low (400mm north of the area, 250 mm near Tirat Tsvi. 150 mm in the area of Jericho). Being on the "shadow of rain" on the west side, the surface flow usually appears in short ranges of floods coming from the east as a result of rains in the mountains. The main wadis from the east are Wadi Zarqa and Wadi al-Yabis, in addition to the Yarmuk River, which used to be the main water source of the lower Jordan, until it ceased to supply water to the Jordan River due to the construction of dams on the river, to the Ghor diverting canal and to other water projects.

The natural annual water volume of the lower Jordan before the construction of the water projects used to be 1200–1500 MCM. According to Brawer (1968), the peak of the flow of the Jordan River into the Dead Sea was 1650 MCM, in the years 1942–3. Since the construction of the Deganya dam in 1932, there has been a significant decrease in the flow of the Jordan River. Most of this was due to a series of dams constructed on the Yarmuk River by Syria and Jordan in the 1960s, to the construction of the Ghor canal, which diverts the Yarmuk water to the Jordanian side of the Jordan Valley, to the construction of the Israeli National Water Carrier (the last two were launched in 1964), and due to the closing of the Deganya dam, preventing the water from exiting the Sea of Galilee to the lower Jordan River.

The main sources of the base flow of water to the lower Jordan today are the salt water carrier along the Sea of Galilee, the sewage water from the Israeli fish pools and cultivated lands, and the excess of irrigation water and sewage water from the Jordanian cultivated lands.

The base flow is about 20MCM a year (Holtzman, 2002), which is the only source during dry years, increasing up to 120–150MCM draining to the Dead Sea during rainy years, including the additional surface flow, added mainly by lateral wadis. This is about one tenth of the flow in the past. The weak water flow contributed to the development of the dense bank plantation that stabilizes the river banks, reducing the river meandering process. Farmers on both sides of the river cultivate the lands beyond the river banks along the Zor.

Being part of the Dead Sea Fault, the Jordan Valley is influenced by tectonic activities. High magnitude earthquakes occur as a mean, once every hundred years. Over 500 people died and 700 were wounded on both sides of the valley during the 1927 earthquake. The mean annual relative shift between the two sides is about 1 cm of the east side northward.

A few processes have influenced the course of the lower Jordan during the last decades. Before the construction of the water projects that dried the river, the channel of the river had been naturally pushed westward inside the Zor by alluvial sediments carried away by lateral seasonal floods of the wadis draining the rain waters and the surface flow from the high mountains on the east side. As a result, the river bed is closer to the western edge of the Zor. A research study shows that since 1945 the lower Jordan meanders have been shortened and the ratio between its straight length and its actual (twisting) length decreased from 1:2.4 to 1: 1.86. The reasons for that phenomenon are as follows: (a) A decrease in the water flow and the prevention of alluvial sediments that used to be carried away by the Yarmuk River, sinking along the course of the lower Jordan. In addition, the silt that used to be carried away by the wadis draining from the east was also blocked by local dams. The absence of silt has increased the velocity of the river's flow, increasing its erosion power. (b) Artificial stabilization of the river banks in order to prevent flooding of the cultivated lands, sweeping away cultivated soils and disturbing the natural trend of the river to meander. (c) The water level of the Dead Sea is decreasing rapidly due to reduced water sources and to rapid evaporation. This increases the slope of the lower Jordan, increasing its velocity and increasing its trend to shorten the river channel by shortening or deserting existing meanders.

The Yarmuk River is the main tributary of the Lower Jordan. It is a perennial stream, 17 km of its length follow the Israel-Jordan boundary, and an additional 17 km, which were not specified in the Israel-Jordan peace treaty, follow the boundary between the Golan Heights and Jordan. Its drainage area is 7250 square km (Kalvo and Ben Tsvi, 2005) in the Golan Mountains as well as in the Bashan and in the Gilad. The Yarmuk begins at the valley of Damascus and flows to the south of Syria, between the Horan and the Bashan in the north and the Gilad in the south, westwards until its confluence with the Jordan River in Naharayim, about 10 km south of the Kinneret (Sea of Galilee). The Jordan-Syria and Jordan-Israel boundaries follow the Yarmuk along its western lower part. The river bed along its lower part passes through a deep canyon with basalt walls until its exit from the mountainous area to the open area of the Jordan Valley near Naharayim. Its annual water volume flow is 460 MCM, flowing mainly during winter floods. It passes through soft lime stone and it used to carry large amounts of alluvial silt to the lower Jordan. This silt used to sink along the course of the river and its estuary to the Dead Sea.

During the years 1927–1932 the Naharayim Dam was constructed near its confluence with the lower Jordan as part of a hydro-electric power station, and a basin was dug for a reservoir as part of the project. Since the 1960s Syria and Jordan have constructed dams on the river for supplying drinking water and for irrigating agricultural lands in Jordan. In 2000 a dam was constructed jointly by Jordan and Israel on the river, near Adassiya-Ashdot Yaakov to support Jordanian water requirements, as part of the implementation of the 1994 peace treaty. The main water project on the Yarmuk is the Ghor canal (the Abdulla Canal), which has been built in stages since the 1960s. This canal diverts the Yarmuk waters southward along the mid-level of the Jordan Valley, east of the river, until reaching an area near the Dead Sea. The canal is the main water source

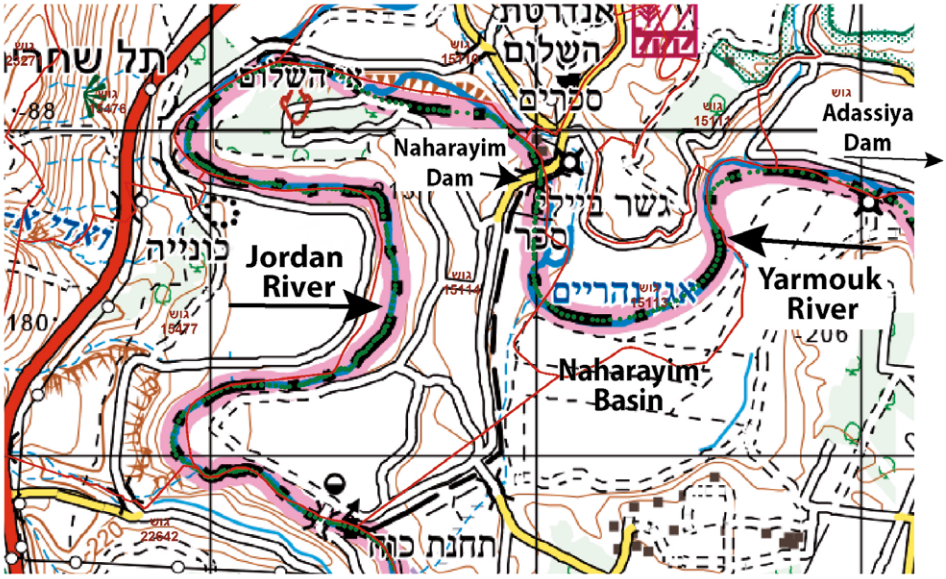

Figure 2: *The Jordan-Yarmuk intersection area today.*

of the Jordanian agriculture in the Jordan Valley. These water projects have dried up the main water source of the lower Jordan.

The Yarmuk Valley has been used by military forces throughout history as a pass from the East towards Palestine. A few famous battles took place in this area, such as the Yarmuk Battle between the Muslims and the Byzantines in 636 AD, and the journey of Sallah A-Din to Palestine. In 1905, the Ottoman authorities built a railway along the valley to connect the Hejaz railway to Haifa and Palestine.

Both rivers are narrow rivers of the type that is considered non-navigable.

1.2 Historical Background Regarding the Boundary Line

During the 1920 Paris conference Great Britain and France agreed that part of the boundary between the French Mandate over Syria (and Lebanon) and the British Mandate over Palestine (and Trans-Jordan) and Mesopotamia, would pass along the Yarmuk River.

The mandatory eastern boundary of Erets-Israel (Palestine) in the Jordan and the Yarmuk rivers was defined by the British High Commissioner and published on September 1, 1922 in an Order in Council (OIC) as part of the line separating Palestine and Trans-Jordan. The purpose of this definition was to include it in article 25 of the British Mandate over Palestine, in order to define a line to the east of which the special rights to build a homeland for Jews in Palestine will not be valid. The definition of this boundary line was approved by the League of Nations on September 23, 1922 as part of the documents of the Mandate. The description of the line in the Order was published in the Official Gazzete on September 1, 1922, and a similar definition was included in the agreement between the governments of Great Britain and Trans-Jordan in 1928. Since the beginning of the mandatory period until the independence of Jordan in May 1946

Great Britain governed both sides of the two rivers. Between May 1946 and May 1948 Great Britain governed only Palestine on the west side of both rivers. During both periods the separating line had the status of an international mandatory boundary.

On April 3, 1949, after the War of Independence, Israel and Jordan signed an Armistice Agreement, defining an Armistice Demarcation Line (ADL), which was valid until the Six Day War in June 1967. A cease-fire line between the two states existed along the rivers between 1967 and the October 26, 1994 peace treaty. The peace treaty defined an international boundary line between the states.

2 THE COURSE OF THE BOUNDARY LINE IN THE YARMUK AND JORDAN RIVERS

According to the 1922 OIC this line follows the center of the rivers:*"a line drawn… up the centre of … the River Jordan to the junction of the latter with the River Yarmuk, thence up the centre of the River Yarmuk …".* No maps were attached to the boundary definition.

The 1940s 1:20,000 British Mandatory maps showed the actual courses of the two rivers, and in many cases, mainly in the Jordan River, they also showed former abandoned courses of the river, usually showing the boundary line along the new course of the river.

The ADL had been originally delimited on a 1:250,000 map that was signed by both sides and attached to the General Armistice Agreement (GAA). However, a map of that scale is not adequate for delimiting a boundary line. In addition to the poor quality of the map, the width of the delimited line, which covers 400 meters, does not properly represent the course of rivers the actual width of which is tens of meters. Shortly after the GAA, the line was transferred to a mosaic of 1:100,000 maps. This was an improvement but these maps were also not suitable for the required purpose. In addition, the delimitation differences between the locations of the ADL on both maps exceeded one kilometer in certain locations. The ADL only partly followed the international mandatory boundary. The West Bank had been annexed to the Kingdom of Jordan. Along the section of the Jordan River, from its confluence with Khor Buleibil southwards until the Dead Sea, the Jordan River became a domestic Jordanian river. The ADL along the Jordan and Yarmuk rivers from Khor Buleibil northwards followed the verbal description of the international mandatory line except the section of the course in the Naharayim basin, where a straight diagonal armistice line replaced the course of the rivers.

In spite of the fact that the GAA did not specify any instructions regarding the adaptation of the ADL in the rivers to the changes in the course of the rivers, the line was changed in order to adapt it to the changes in the rivers, except for the Naharayim basin where the ADL did not fit the river course. The 1:20,000 Israeli maps of the 1960s showed the actual courses of the two rivers, discarding former courses of the Jordan River, showing the boundary line in the actual course of the river at the time of the mapping. This shows that the cartographers of the maps published during the mandatory and armistice periods adapted the presentation of the boundary line in the river to the changes in the course of the river. Early maps of the Survey of Israel show that the international mandatory boundary in the Yarmuk River was shown on these maps in its original location in the 1920s, before the Naharayim basin was excavated for the Hydro-Electric Power Station.

After June 1967, the southern section of the Jordan River returned to be the separating line between Jordan and Israel, changing the status to become a cease-fire line.

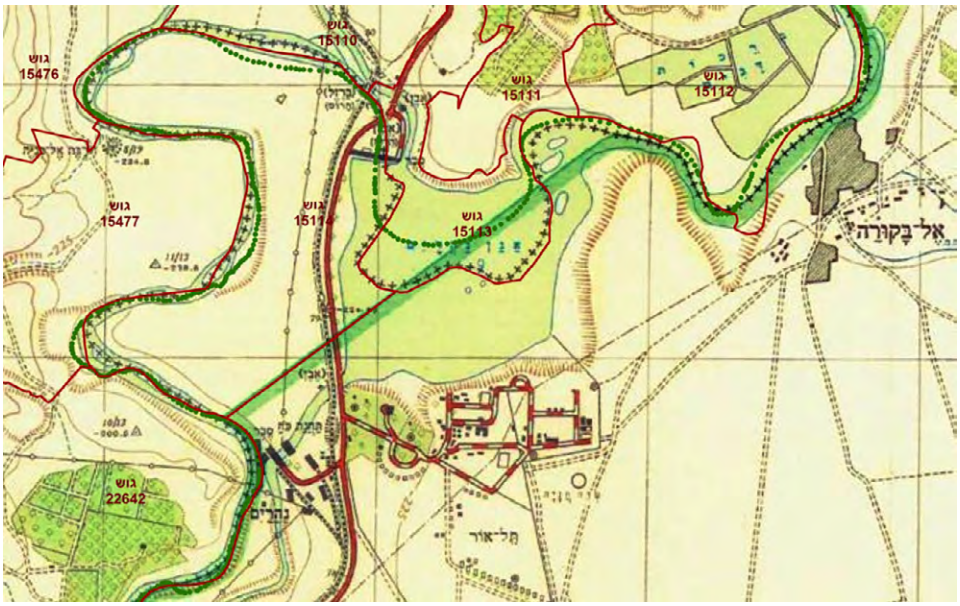

Figure 3: *The ADL in Naharayim shown on an Israeli 1953 map (the diagonal green line). Additional lines shown are: the international mandatory line (+++), the land settlement line showing the rivers in the 1930s (in red), and the 1994 international boundary line (in green dots).*

In addition to the section between the Dead Sea and Hamat-Gader (Al-Hama), a new section, a line of about 17 km long, had been added along the Yarmuk, separating the Golan Heights and Jordan. Until the 1994 Israel-Jordan Peace Treaty the cartographers continued the trend by adapting the cease-fire line to the actual course of the rivers.

The Israel-Jordan boundary was defined in the 1994 peace treaty as follows: *"**Article 3 – International Boundary**: 1. The international boundary between Israel and Jordan is delimited with reference to the boundary definition under the Mandate as is shown in Aneex I (a), on the mapping materials attached hereto and coordinates specified herein. … 5. It is agreed that where the boundary follows a river, in the event of natural changes in the flow of the course of the river as described in Annex I (a), the boundary shall follow the new course of the flow. In the event of any other changes the boundary will not be affected unless otherwise agreed."*

The boundary line in the Yarmuk and Jordan rivers had been delineated in Annex I (a) to the agreement in the center of the courses of the two rivers, as interpreted by the Joint Team of Experts (JTE) on 1:10,000 orthophoto sheets made from 1993 photographs. In order to decide about the delimitation of the boundary line in cases where small islands existed along the course of the river, the chairs of the JTE jointly decided during a helicopter flight whether the boundary line follows one of the channels chosen as the main channel or whether the line bisects the island.

The peace treaty says that as required or once every five years the boundary line will be adapted in the case of natural and gradual changes (accretion) in the course of the river. As presented here, since 1994 only slight changes in the course of the Jordan River have occurred, most of them less than 10 meters, in comparison with changes

Figure 4: *The international boundary in Naharayim on the orthophoto of the 1994 peace treaty.*

of hundreds of meters in the past. This is a result of the drastic reduction of the water flow in the rivers due to excessive use of the water resources of both rivers to support the growing requirements of the population on both sides. The population on both sides of the rivers has expanded more than ten times since the beginning of the British Mandate. The issue of maintaining the river boundary has been discussed by the JTE, by discussing ideas like preparing an orthophoto every five years for monitoring the river course lines, and other ideas.

In addition to geographic changes there were changes of the political status and the legal status over the years. We will describe the changes with reference to a sub-division of the river boundaries regarding three sections: the Yarmuk River from Hamat-Gader/Al-Hama to the confluence of the river with the Jordan River (in Naharayim); the Jordan River from Naharayim to Khor Buleibil (near Tirat Tsvi); and the Jordan River from Khor Buleibil to the Dead Sea. During the British period all three sections were considered part of the international boundary between Palestine and Trans-Jordan. Later on, in the Yarmuk section, the ADL followed the Yarmuk except for a sub-section in the Naharayim basin where the ADL followed a line east of the rivers. It is worth noting that during the years 1950–1967 the Syrian Army dominated the northern bank of the Yarmuk between Hamat-Gader/Al-Hama and Tel Dover, violating the GAA. During the years 1967–1994 the line in this section changed status, becoming a cease-fire line, but since the 1994 peace treaty, it has returned to be an international boundary. The line along the Jordan River, from its confluence with the Yarmuk at Naharayim down to Khor Bulei-

bil, was considered as an ADL in the years 1949–1967 and a cease-fire line in the years 1967–1994. Since 1994 it has been part of the Israel-Jordan international boundary. The line along the southern section of the Jordan River between Khor Buleibil and the Dead Sea was a domestic Jordanian administrative line during the years 1949–1967, a cease-fire line during the years 1967–1994, and since 1994, according to the Israel-Jordan Peace Treaty it defines a line between the Hashemite Kingdom of Jordan and an area that came under Israeli military control in 1967 (the West Bank). There is an additional 17 km line along the Yarmuk north-east of Hamat-Gader/Al-Hama between the Kingdom of Jordan and the Golan Heights, which has been under Israeli rule since 1967 and under Israeli law since December 1981. The boundary line in this sub-section had been considered a cease-fire line during the years 1967–1994, and since 1981 Israel has considered this line the boundary of the Golan Heights, whereas Jordan has considered it as part of the historic Jordan-Syria international boundary, which had been initially agreed at the 1920 Paris Convention, agreed in 1922, and finalized between Great Britain and France on October 31, 1931 (US, 1969).

3 LAND SETTLEMENT BOUNDARIES ALONG THE RIVERS

Most of the block plans along the lower Jordan and the Yarmuk Rivers, north of Khor Buleibil, have been land settled during the 1930s. The eastern boundaries of the block plans were adapted to the center of the river courses. This process was based on large-scale field surveys. 1:2500 field sheets show in detail the two banks of the rivers, indicating the international mandatory boundary in the center of the river courses. The boundaries of the block plans did not change during the armistice period (1949–1967) in spite of the actual changes in the courses of the two rivers, up to 500 m from the original mandatory water course, and in spite of the fact that the topographical maps showed the changes in the courses of the rivers and changed the delineation of the ADL accordingly. Thus, during that period, in certain cases the boundaries of the block plans were located hundreds of meters to the east of the ADL after the latter moved westward, whereas in other cases the ADL moved eastwards, following movement of the course of the river, leaving large unsettled areas west of the river. A similar phenomenon occurred during the years 1967–1994 when the cease-fire lines were shown on topographical maps in locations following changes in the meanders of the rivers up to hundreds of meters westwards or eastwards, whereas the boundaries of the block plans remained in their original position (of the 1930s land settlement).

The 1994 Israel-Jordan Peace Treaty defined the international boundary in the actual centers of the rivers, leaving deviations of hundreds of meters between its location and the location of the boundaries of the land settlement. Owing to the unstable character of river courses and the practical attitude of avoiding crossing river boundaries, there was no attempt to stabilize the international boundaries by enforcing the 1930s land settlement boundaries on the changing water courses of the rivers. The security reality contributed to this trend, since security roads and security fences were constructed along the upper level of the river valleys, preventing free civilian access to the rivers, thus reducing local utilization of river waters.

Following the drying of the lower Jordan and the lower Yarmuk as a result of large water utilization projects, our analysis shows that during the years 1994–2014 the course of the lower Jordan River was very stable, showing only slight changes of about 10

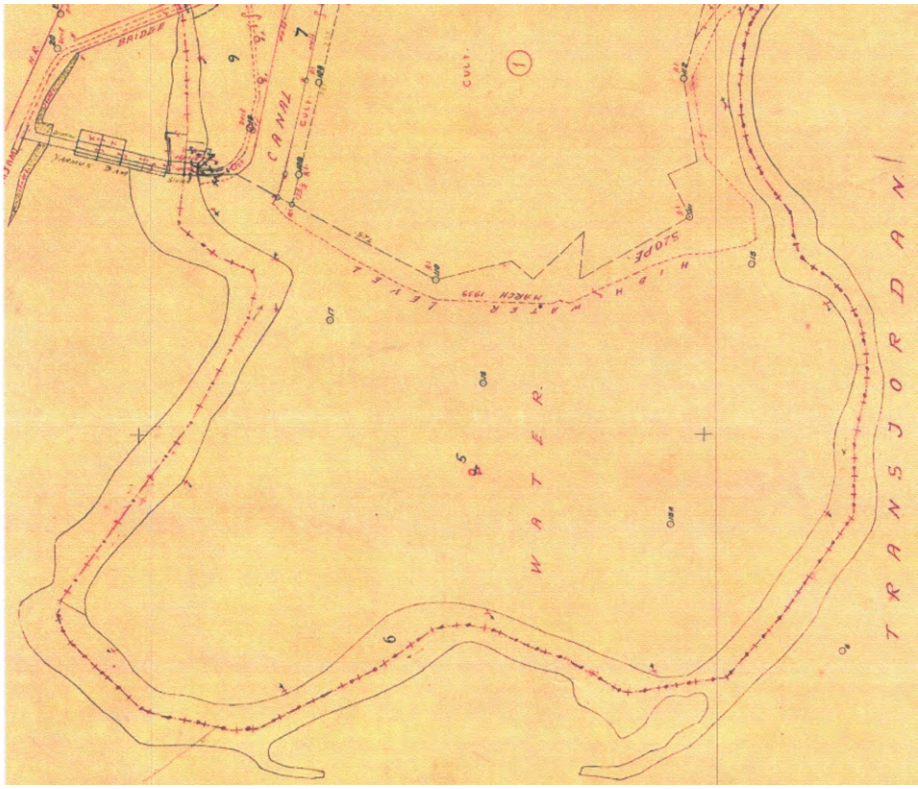

Figure 5: *The international mandatory boundary in the Yarmuk River on a 1939 cadastral field sheet.*

meters. The stabilization of the lower Jordan, augmented by additional supportive justifications, stimulated an initiative to fix the international boundary line in the two rivers and to adapt the land settlement boundaries to the fixed international boundary in the rivers. The supporting justifications, among others, are as follows: the successful joint fixing of the coordinates of the international boundary in the Yarmuk River east of Naharayim/Baqura in 2000, due to man-made changes along the river; the successful adaptation of the land settlement boundaries in the Negev (southern Israel) and the Dead Sea area to the international boundary; man-made changes along the courses of both rivers, which annul the natural behavior of the two rivers, turning their flow to be influenced and regulated by man-made activities.

The easiest task regarding this issue is adapting the block plans along the Yarmuk to the international boundary in the Yarmuk River east of Naharayim, since the boundary in this section has already been jointly fixed in coordinates by the JTE in 2000 as a result of constructing a dam on the Yarmuk near Adassiya. This adaptation of the land settlement block plans in this section is in process at the Survey of Israel and the Land Registry. However, the situation in the other sections, where the international boundary has not yet been fixed is different. The lowest part of the Yarmuk, only 3–4 km long, before its confluence with the Jordan River, actually represents a fully man-made environment, regulated by the Adassiya and Naharayim dams. The human intervention in this area began in the late 1920s, when a hydro-electrical power station – the Naha-

rayim Power Station – was constructed. The works included (1) constructing a dam on the Yarmuk River; (2) digging a large water basin on the Yarmuk water course before the dam for constructing a water reservoir as part of the power station complex, connected by a canal to the Jordan River in order to augment the insufficient flow of the Yarmuk water during the dry season; and (3) constructing the main building of the power station with the supporting canals. The original water course of the Yarmuk before the

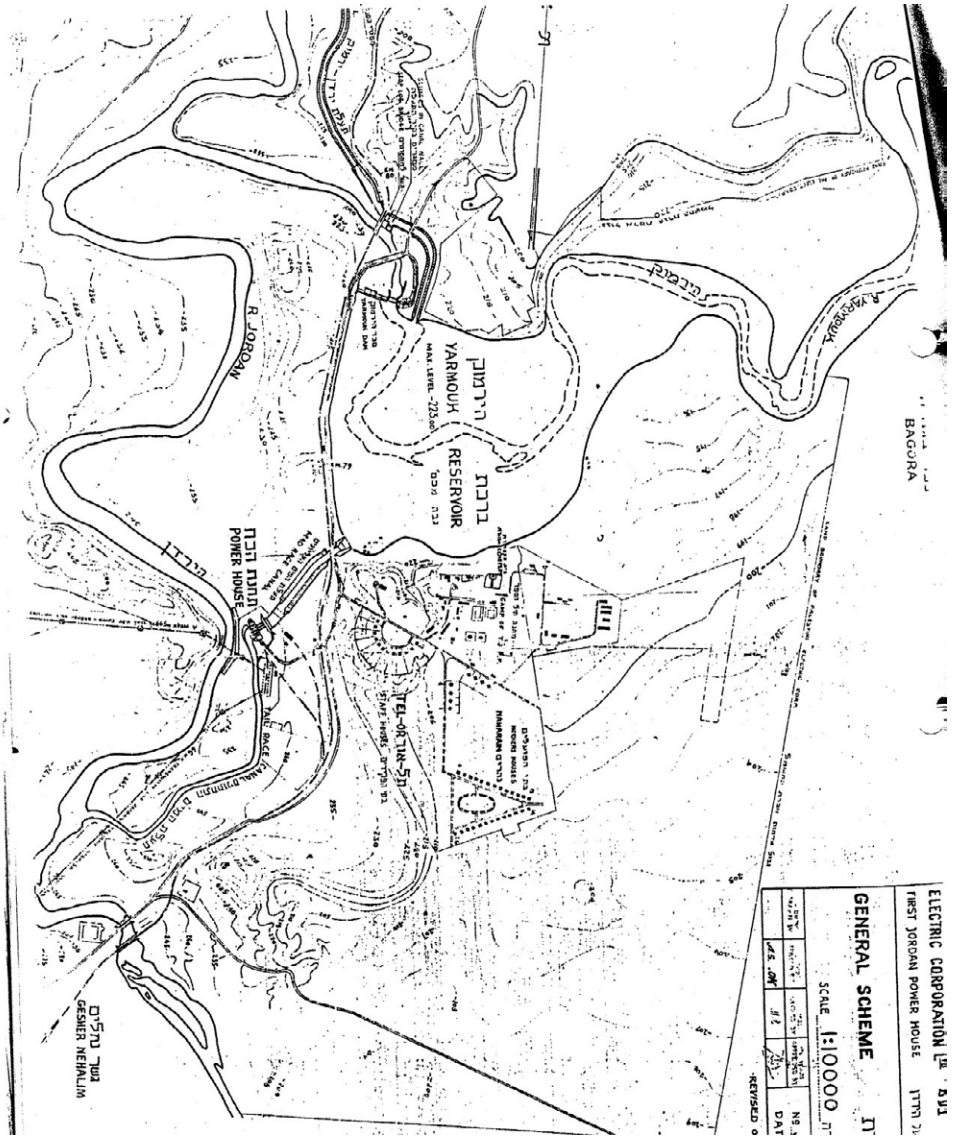

Figure 6: *The course of the Yarmuk River in the Naharayim basin on the map of the power station.*

constructions had been surveyed and is shown on a large-scale map of the power station, as well as on the 1939 original British Mandate block plan which showed the old water course bisected by the international boundary line, which was followed by the boundary of the cadastral block (Figure 5). Topographical maps of the area showed the location of the old course of the Yarmuk River inside the Naharayim Basin (Figure 6). The 1949 ADL was delimited on topographic maps differently, following the situation of forces before the GAA, cutting the basin along a diagonal straight line, not fitting the international mandatory boundary and the cadastral boundary (Figure 3). The 1967 cease-fire line followed the ADL. The 1994 international boundary was delimited according to the actual location of the river, which had been created after 1949, after the power station was abandoned and the water in the Naharayim Basin had dried up (Figure 4). A dedicated annex was assigned to a special area in part of the area between the international boundary and the old ADL line. According to the agreement the Naharayim special area was under Jordanian sovereignty and under Israeli private long-term use. After the peace agreement Jordanian farmers cleared the dense bushy flora inside the Naharayim basin, south of the actual river course, stabilizing the southern bank of the river, and they cultivate the lands up to the river, so that the only possible movement of the river is toward the Israeli side (Figure 8).

Analyzing the situation in the area regarding the delimitation of the international boundary, one can see that it is clear that since the construction of the Naharayim dam in 1927, many substantive man-made changes have influenced the water flow of the Yarmuk in the Naharayim area, stopping its natural behavior, and forcing it to be a completely man-controlled water course. Thus, regarding the accretion principle, and following the wording of the 1994 peace agreement concerning man-made changes in the course of the river, the only option in this area is to fix the international boundary line and to adapt the land settlement to it. The only question is where should be the reference for fixing the boundary line. One option is to fix the boundary in the center of the water course of the Yarmuk River before the construction of the dam in 1927 and before the digging of the Naharayim Basin, since these changes have changed the natural behavior of the river in the area. This line also coincides with the land settlement boundary in the area, which has not been changed since the original land settlement in the 1930s until today. Such a determination complies with the international principle that does not accept river boundary changes caused by man-made interventions in the natural course of a river. The weakness of the implementation of this option today is that the construction of the Naharayim dam and the Naharayim Basin was before the Israel-Jordan Peace Treaty. This may raise a legal question: did the peace treaty initialize a new situation, overruling earlier man-made changes in the course of the river? The second option arises as a fallback, in case that legally the peace treaty had initialized the reference boundary line. In such a case the alternative option is to fix the boundary line in the Yarmuk River at Naharayim according to the delimitation of the boundary line in the 1994 Israel-Jordan Peace Treaty. This refers to the remaining 3 km section in the Yarmuk River, from the international boundary in the Yarmuk which had already been fixed due to the construction of the dam on the Yarmuk near Adassiya in 2000 (Figure 7), until the confluence of the Yarmuk with the Jordan River.

A theoretical third option is to leave the boundary line in this area unfixed, depending on natural and gradual changes (accretion); however, this option of the peace agreement does not have any significance in this area anymore and is actually void, after being overruled by the instruction of the peace agreement that: “Artificial changes in

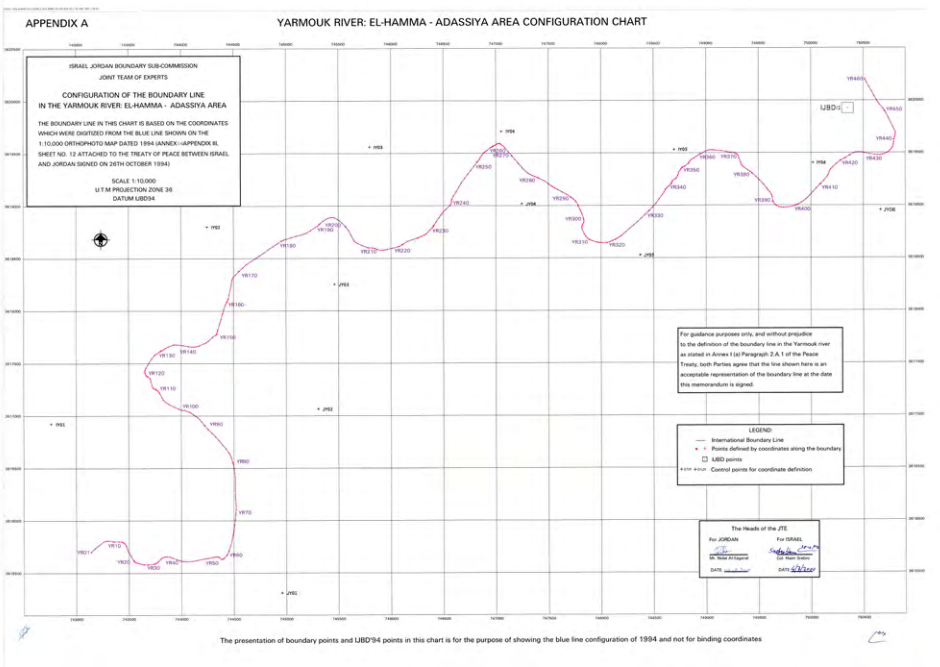

Figure 7: *The fixed international boundary in the Yarmuk River (in 2000) east of Naharayim.*

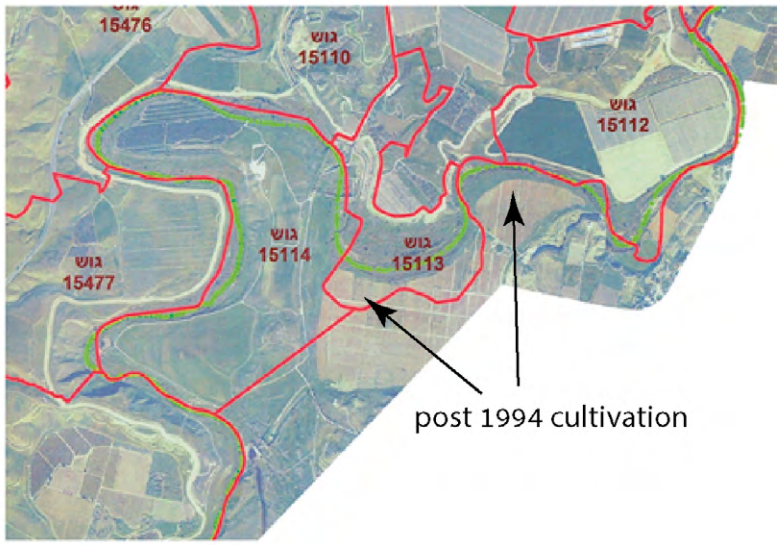

Figure 8: *The Naharayim area in 2014. The new (post 1994) cultivated areas cover the Naharayim basin south of the 1994 boundary. (The green dotted line shows the 1994 international boundary. The red lines show the original cadastral boundaries).*

the course of the rivers shall not affect the location of the boundary unless otherwise agreed." (Israel-Jordan Peace Treaty, Annex I(a), chapter 2.A.). Several reasons lead to this conclusion: (a) the water flow in this short boundary section is completely influenced and regulated by two dams on the river – the Naharayim and the Adassiya dams – and there is no regular and natural flow of the Yarmuk River in this area; (b) all of the Yarmuk water is used before the Adassiya Dam, so that the natural Yarmuk is actually dry in this section, west of the dam. Today, the actual shallow flow in the Yarmuk river bed in this section consists of sewage and drainage of the lands of two villages (Massada and Sha'ar Ha'Golan); (c) the Jordanian lands on the south side of the river course have been prepared and cultivated after the 1994 peace treaty, by uprooting the dense flora and artificially stabilizing the south bank to avoid the sweeping away of the cultivated soils. These are artificial changes that should not change the course of the boundary according to the Israel-Jordan Peace Treaty (and according to international customary law).

From this analysis one can learn that the boundary line in this short section of the Yarmuk River can be fixed by coordinates following one of two options: either following the center of the course after the September 1, 1922 boundary definition and before the 1927 construction of the Naharayim Dam and the Naharayim Basin or following the delimitation of the international boundary in the 1994 peace treaty. Following such fixation of the international boundary, the domestic boundaries of the land settlement block plans should be adapted to the fixed international boundary.

4 THE INFLUENCE OF CHANGES IN THE JORDAN RIVER COURSE ON THE INTERNATIONAL BOUNDARY

The international mandatory boundary between Palestine and Trans-Jordan was determined in an Order of the British High Commissioner on September 1, 1922, in the center of the Jordan River, from its confluence with the Yarmuk River until its estuary to the Dead Sea. Detailed surveying of the upper part was done several years afterwards for constructing the electrical power station at Naharayim. During the 1920s and the 1930s cadastral field surveys were conducted along the upper part of the Jordan Valley, from the Sea of Galilee to the area of Bet Shean, to support land settlement in the area (in the scale of 1:2,500). The beginning of the surveys, close to the time that the international mandatory boundary was determined, can serve for defining the initial reference line of the Jordan River at the beginning of the British Mandate. Great Britain governed both sides of the river. Both banks of the river were shown on the field survey sheets and the international boundary was marked in the center of the course of the river. The Jordan River south of the Bet Shean Valley until the Dead Sea was mapped during the early 1940s on a 1:20,000–1:25,000 scale. These maps show the Jordan River and the international boundary along its course. German and Australian WWI aerial photographs cover limited parts of the river but they are not vertical, are of poor quality and are inadequate for comprehensive analysis. British military aerial photographs at the end of WWII are useful for partial monitoring of the river's course.

In spite of the fact the determination of the 1922 international boundary referred to geographical natural features (like the Dead Sea and the Jordan and Yarmuk rivers), the determination did not refer to possible changes in these features over time. Such an issue was raised in 1927, following a significant change in the course of the Jordan

River, due to a flood transferring a large strip of land (about 800 m) from the west side of the river (Palestine) to the east side (Trans-Jordan). The question whether the change in the river leads to a change in the boundary line was raised by the Chief Secretary of the Government of Palestine in a letter to the Principal Secretary for the Colonies in London. He wrote that he knows that due to the sudden change in the course of the river, according to international law the boundary should remain in the old abandoned water course, but clarified that the Government of Trans-Jordan preferred to follow the actual new water course, and indicated the practical advantage of such an approach. Clarifying the preference of following the river because of difficulty of re-establishing the former course of the river, he asked if there are precedents in other places of the world "for retaining an international boundary in the center or 'thalweg' of a river that have shifted its course" (Toye, 1989) in order to justify such a decision by the Government of Palestine. The Foreign Office clarified its policy that where there are no special circumstances, the rules of accretion and avulsion should prevail[10]. The Army Council considered that "there should be a little difficulty in re-establishing the position occupied by the course of the river at the time of demarcation" (in 1922). In his response to the Government of Palestine, the Secretary of State for the Colonies cited the guiding principles and considerations. In addition, as requested, he also referred to "a few cases where a river had been diverted from its original channel and the boundary also has been changed in such a manner as to make it follow the new course". On September 12, 1927 the High Commissioner (HC) for Palestine and Trans-Jordan informed the Secretary of State for the Colonies that "with the concurrence of the Trans-Jordan Government, I have decided to adopt the 'thalweg' of the River Jordan as the Boundary between the two territories. 2. This decision will involve periodical minor changes in the boundary, as the 'thalweg' of the river shifts, but will probably prove to be the most practical solution to the question."

One should consider that both the Secretary and the HC tried to minimize the description of the Jordan River changes in their letters, in order to justify their view of choosing an easy practical decision rather than following the international law. The first one referred to "the narrow gorge through which the river flows". The latter referred to "minor changes in the boundary". In fact, the width of the lower level of the Jordan Valley through which the river flows (Geon Ha'Yarden – the Zor) ranges up to 1.2 km, and the changes in the course of the river deviate up to 500 meters.

The water course of the lower Jordan continued to change up to deviations of 500 m during the next decades. Figure 9 shows the courses of the upper section of the river in the 1930s, the 1960s and the 1990s. The significant differences between the river courses are seen clearly. The aerial photo in figure 10 provides a visual presentation of old abandoned river courses. Part of the changes was gradual, but most of them resulted from strong sudden floods during very rainy seasons, like in 1927. The continuous process of drying of the water sources of the Lower Jordan decreased the changes in the water course of the river from hundreds of meters in the past to several meters. Figure 11, which shows the water courses in 1994 – the time of the peace treaty – and in 2014, reflects the stabilization of the water course. Most of the differences between these years are less than 10 m, with a few exceptions of 10–15 m, which may be related to human interpretation of the center of the river. Furthermore, in addition to the contribution of the dense flora, which has developed due to the slow flow, to the stabiliza-

10 Prescott and Triggs (2008) indicate that territorial changes that are results of a flood or the formation of new islands are considered as avulsion.

Figure 9: *Boundary changes following changes in the Jordan River (in red – 1930s land settlement boundaries; +++ on the background map – the ADL in 1962; the green line – the 1994 international boundary).*

tion of the river course, also man-made activities have contributed to stabilizing the water course. These include construction of barriers and fences to protect cultivated lands adjacent to the river course. The fences on the Jordanian side, which are based on rigid stones, are more influential.

The man-made changes are sufficient for the two sides to agree on fixing the boundary line according to the 1994 peace treaty line. The minor changes in the water course since 1994 support such a recommendation. In addition, no change is anticipated in the water sources of the river, since the water has to support the water requirement of the growing population on both sides, which has already multiplied by more than

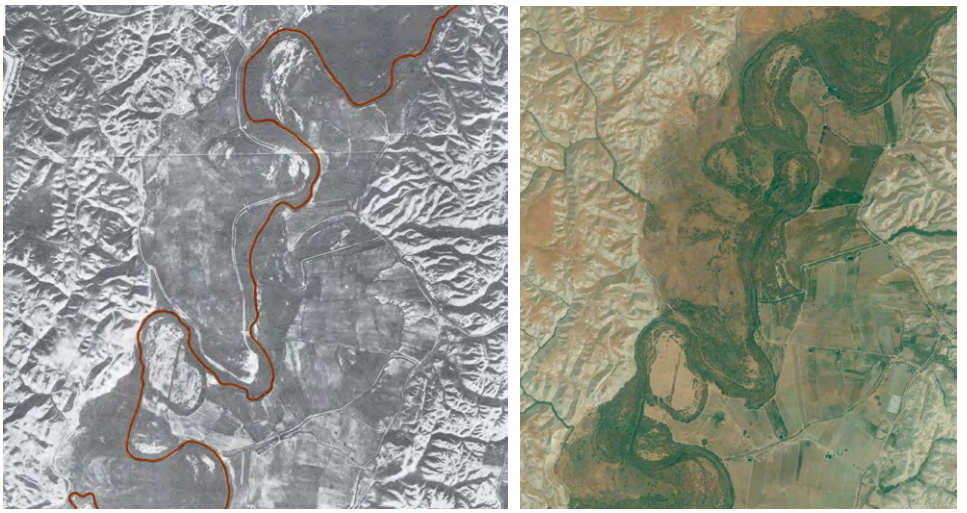

Figure 10: *Changes in the Jordan River's water course and abandoned river beds in 1994 (left) and 2010 (right).*

ten times since the beginning of the British Mandate (1920), and continues to grow rapidly. On this basis, we recommend that both sides fix the boundary line in the river, along the jointly agreed international boundary, delineated in the 1994 Peace Treaty. This should be done jointly, similarly to the fixation of the boundary line in the Yarmuk in 2000. After the international boundary is fixed, the cadastral boundaries should be adapted to the fixed international boundary. Until both sides agree on fixing the international boundary, we recommend (1) defining a line along the maximum range of changes in the water course of the lower Jordan, (which is about 10–15 m on each side), and (2) stabilizing the cadastral boundaries by adapting these boundaries to the limit line of the range of changes, creating a narrow borderline cadastral block – several meters wide – as a buffer block, which will be considered a boundary block, the external boundary of which is defined in the center of the river course, being subject to slight changes in the water course.

5 CONCLUSION AND RECOMMENDATIONS

There is no obligatory international convention regarding river boundaries similar to the UN Convention on the Law of the Sea. As a result, states rely on decisions of ICJ and international tribunals, on customary practice of agreements between countries, and on studies of scholars. The doctrine that a boundary line in a changing river follows the changes in the case of accretion, when the changes are natural, gradual and not perceivable when they are formed and does not follow the changes when they are sudden or when they are a result of man-made activities – has not been accepted as an obligatory principle in international law. This doctrine has been adopted in many cases and fulfils many criteria that check the qualification of principles to be considered as international law. Such cases include the 1911 decision of the tribunal of arbitrators in the Chamizal case, many bi-lateral agreements, including the Israel-Jordan Peace Treaty,

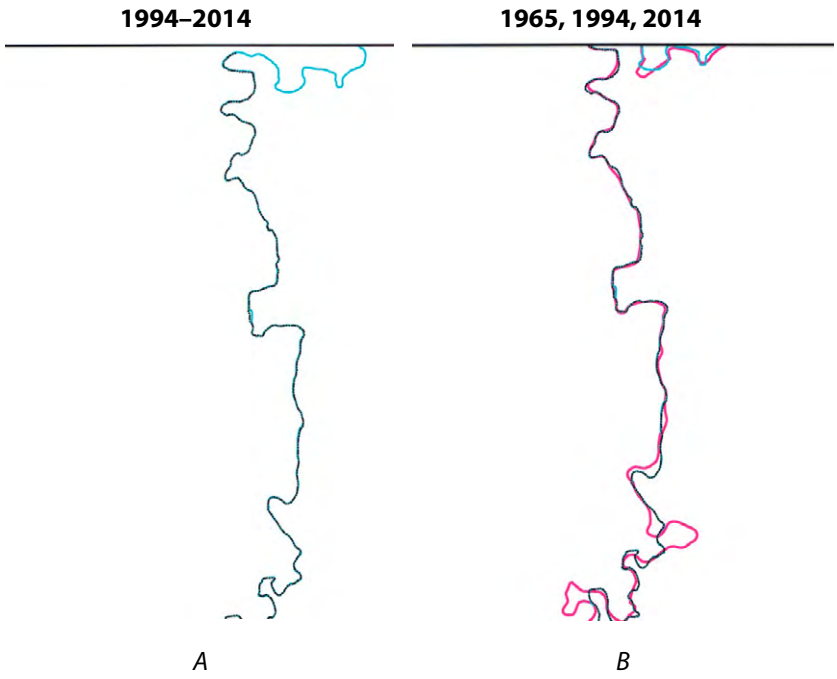

Figure 11: *The stabilized Jordan River's water course 1994–2014 (A). The line in red on the right side shows the river's course in 1965 (B).*

and many law books and scholarly works. However, ICJ did not decide on it unequivocally, and there are countries that do not adopt these principles in their agreements in order to avoid local complications.

A change in a course of a boundary line transfers land from one country to another. This is harmful to the population of the losing side, to the stability of the boundary and to the relations between the two countries. On the other hand, breaking off the connection between the course of the river and the course of the boundary prevents the accessibility of the residents of one of the countries to the river, thus affecting their use of this essential resource. Even if it is concluded that for the sake of stability and legal clarity it is recommended that countries should avoid delimitation of boundary lines in rivers, and with reference to geographic landscape features that are not precise and unequivocal, one cannot ignore the fact that river boundaries make up one third of the international boundaries throughout the world. A relevant global phenomenon that influences the situation of rivers is the dramatic population growth during the last century, which has sharply increased the use of rivers and their pollution. Other influential global developments include climate changes that damage water sources, increasing irregularity of river flows, especially in areas that are on desert edges, characterized by seasonal floods. Lack of water caused many countries, sometimes under the framework of multinational projects, to regulate the flow of water in rivers, to stabilize it by constructing dams and artificial water reservoirs, to stabilize the river banks or to canalize the river bed. Projects of water collection and water use, including pumping out water before it gets to the river, or sometimes along the course of the river, contribute to

the drying out of rivers, and are considered artificial human intervention in the natural flow of rivers, so that most of the boundary rivers cannot be considered as preserving their natural behavior. These artificial changes, rule out the rationale of referring to the natural behavior of the river that stood as the basis of the principle of accretion. If the transfer of soil by the river is influenced by man-made activities, it is not right to grant a country the right to unilaterally influence the flow and course of the river, and as a result to change the boundary line in favor of that country, adding lands to the country's territory on the account of another country.

In light of this situation, it is often right to fix the boundary line in the river between two countries, according to the course of the river on an agreed reference date, and to deal with separate accomplishing agreements regulating other issues connected to the river. Such issues may include accessibility and rights of use of the river waters by the two countries, covering the issue of possible local changes in the river course in reference with the boundary line.

The Israel-Jordan Peace Treaty states that the boundary line in the Jordan and Yarmuk rivers will follow natural changes (accretion or erosion) in the course of the river unless otherwise agreed. Here we have reviewed the courses of the two rivers during the last century, focusing on the changes in the river courses as a result of natural and artificial intervention, including constructing dams and diverting water by canals and pipes under the framework of national water projects. We have shown how these projects have influenced the drying up of the two rivers during the last decades. In addition to blocking the natural water flow of the two rivers, the banks of the courses in which the rest of the water, which is mainly based on sewage and local drainage, are stabilized by farmers who cultivate the adjacent lands and construct fences along the river banks in order to prevent the cultivated lands from flooding.

In principle, the artificial works have created a situation that has turned the relevant peace treaty paragraphs, dealing with changes in the river course (accretion or erosion) into inapplicable conditions. Under the existing circumstances only the peace treaty option of setting the boundary line according to artificial changes is applicable. As a result it is recommended to fix the boundary line in the two rivers by coordinates according to a mutually agreed upon reference line. The existing reference line is the boundary line delineated in Annex I to the October 26, 1994 Peace Treaty. Both sides have already agreed to fix the boundary line along its main section in the Yarmuk River between Hamat-Gader/Al-Hama and Ashdot-Yaakov/Adassiya in 2000, following the construction of a dam on the Yarmuk at Adassiya. The JTE of the JBC set coordinates to the line in this section according to the delineation of the boundary line on the orthophoto of the 1994 Peace Treaty. The JBC formally approved these coordinates and considered them to be part of the annex to the peace treaty. A similar procedure is recommended for the rest of the boundary line in the Jordan and Yarmuk rivers.

From a practical point of view, the changes in the course of the Jordan River decreased from hundreds of meters, when the river behaved as a natural river, to ten meters with several exceptions of up to 15–20 m since the 1994 Peace Treaty. This decrease has occurred gradually since the 1960s, following the construction of large water supply projects on both sides. The consequence of that is that fixing the boundary line will have almost no influence on the reference between the boundary line and the river course.

On this basis it is recommended to fix the boundary line in coordinates according to the delineation of the line in the 1994 Peace Treaty in a joint Israeli-Jordanian process, following the process of fixing the boundary line in the Yarmuk in 2000[11]. This will enable fixing the cadastral boundaries along these rivers, by adapting the land settlement boundaries to the agreed and fixed international boundary. Until such mutual agreement on fixing the international boundary line occurs, it is recommended to delimit a line indicating the range of changes in the Jordan water course (about 10 m) in order to adapt the cadastral blocks to this line, and to leave a border strip, several meters wide, to be defined as a flexible border block, limited by the center of the course of the river, depending on the changes in the course of the river as agreed upon by both sides.

References are at the end of Part I, p. 55.

11 Following the construction of the Adassiya dam on the Yarmuk River.

CHAPTER 3:
BOUNDARY LINES IN LAKES

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Key words: International boundaries, boundaries in lakes, Israel-Jordan boundary

Preamble

Most of the international boundaries related to water bodies are delimited in seas in the maritime part of the world, following UNCLOS 1982 (United Nations Convention on the Law of the Sea), and in rivers in the land areas. However, there are many cases in which the boundaries traverse lakes. This practice took place in spite of the many complications resulting from delimitation of boundaries in lakes. Already in 1945, Stephen Jones recommended in his handbook on Boundary Making (Jones, 1945) to avoid boundary delimitation in lakes.

According to Wikipedia, there are 152 lakes worldwide crossed by international boundaries: 52 of them are in Europe, 26 in North America, 19 in Africa, 15 in South America, and 14 in Asia. The USA has 23 lake boundaries, more than any other country in the world. Of these, 21 are crossed by its international boundary with Canada. Norway has 20 boundary lakes and Sweden has 19.

A few large lakes could fit the maritime boundary delimitation following the UNCLOS rules, which are valid in seas and oceans, however, UNCLOS is invalid in lakes. In these lakes the agreements between the relevant states are binding.

The largest lake on Earth is the Caspian Sea, covering 371,800 square kilometers. Five countries – Kazakhstan, Russia, Azerbaijan, Iran, and Turkmenistan – share its coast lines, each of them for more than a thousand kilometers. Seven boundaries separate their marine areas in the lake. The maritime areas in the lake include territorial water zones and economic zones, as agreed between these countries in a common agreement[12]. The multilateral agreement includes regulation of the rights of use. The boundary delimitation agreements are bi-lateral between respective states. However, not all of them have been agreed upon and signed yet.

The drainage basin of lakes includes rivers and other water sources. Sometimes a large drainage basin of a major river may be the main water supply of a lake. Certain lakes are located in valleys along the flow of a river. In such cases the river enters the lake upstream and departs from the lake downstream. This is the situation with the Jordan River, which flows into the Sea of Galilee; then it departs from it and flows southwards until it enters the Dead Sea. Sometimes there is a series of lakes connected to each other by sections of rivers, like with the Great Lakes between the USA and Canada.

12 Convention on the legal status of the Caspian Sea, August 12, 2018.

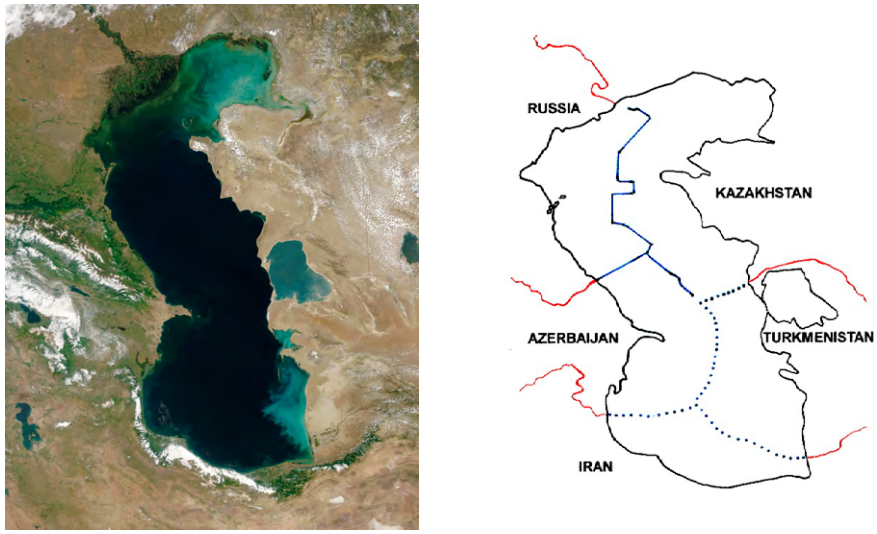

Figure 1: *The Caspian Sea – On the left side: A NASA visible earth MODIS image on Terra Satellite, June 11, 2003. On the right side: A rough scheme of the agreed international boundary delimitation lines and probable theoretical median lines (the dotted lines) in the Caspian Sea. The boundary lines and the probable median lines are not authoritative.*

1 DELIMITING AN INTERNATIONAL BOUNDARY IN A LAKE

Most of the international boundary lines in lakes are delimited along the median line (the center line) of lakes. Others, especially in cases of narrow lakes that are located along navigable rivers, are delimited along the main channels of navigation in the lakes. In the past, boundaries were delimited sometimes in lakes along arbitrary straight lines such as parallels or agreed azimuth lines. Sometimes the boundary lines consist of straight line sections. This is usually the case when the delimitation experts agree to simplify the curve lines, similar to the median lines, by incorporating straight line sections, thus compensating for the discrepancies between the lines.

The median line defines a line, every point of which is equidistant from the opposite shore lines. One of the main problems in delimiting boundary lines that depend on the shorelines is that the shorelines are not stable. They move due to changes in the water levels between high tide and low tide and between seasons, as a result of drought, heavy rains, or snow melting, or even as a result of erosion of the banks of the river.

The definition of the median line in a river, according to the distance from the shorelines, is usually an initial basic step or process, followed by additional steps aimed to achieve an equitable solution between the respective parties. Such steps, in order to make adjustments to the preliminary line, may include dividing the lake into identical parts, taking into consideration islands, taking into consideration local economic interests, or taking into consideration historic or traditional interests.

Whenever a median line is formally defined in an agreement, it should refer to the reference water level.

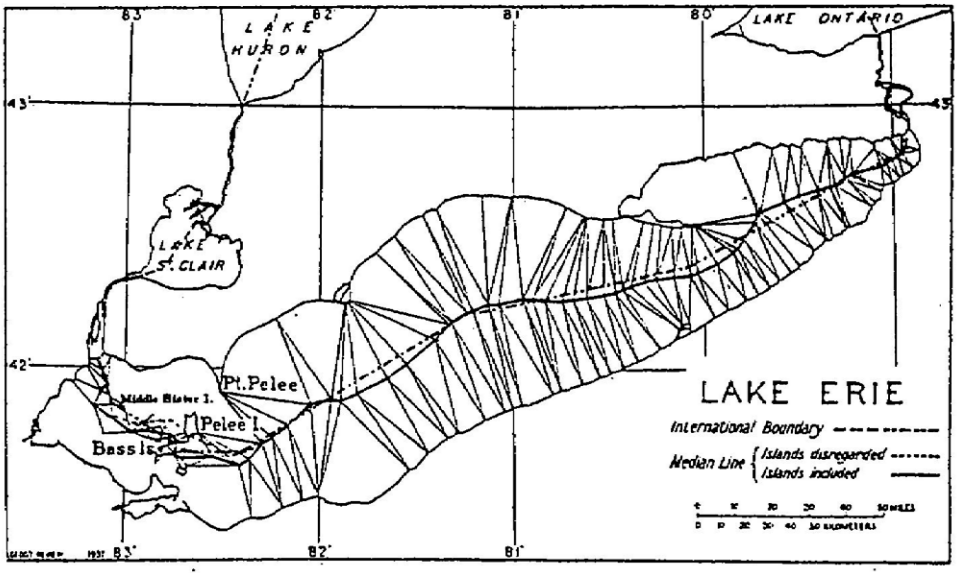

Figure 2: *An example of delimiting a median line in a lake, introduced by Boggs. The line introduced is the international boundary between the USA and Canada in Lake Erie.*

Boggs recommended the following wording when defining a median line in agreements (Boggs, 1940, p.184*): "the median line being a line every point of which is equidistant from the nearest points on the shores of the two respective sovereignties; the shore line being the line of mean high water (mean low water, or other indicated stage of the water)."*

Boggs (Boggs, 1940, p.181) introduced a method of delimiting an international boundary in a lake following a median line (see figure 2).[13]

When a median line is defined as an international boundary in lakes (and rivers) characterized by wide strips of shallow water, the equidistant lines from the median line are sometimes measured, upon agreement by the respective parties, according to prominent points along the margins of the shallow area and not according to the shoreline at the time of a high water rise.

The thalweg is another boundary line sometimes chosen in cases where lakes have a longitudinal shape, and are located along the flow channel of wide rivers used for navigation. The thalweg is usually defined as the line of the deepest points along the channel of navigation.

The Influence of Natural and Artificial Changes on Boundaries in Lakes

One of the main problems regarding the delimitation of boundaries in lakes results from the conflict between the basic requirement for boundaries to be exact and fixed, and to provide stability while considering that lakes are water bodies that do not maintain a permanent size. Owing to severe natural and man-made changes during the last

13 International Boundaries: A Study of Boundary Functions and Problems, S. W. Boggs, Columbia University Press, New York 1940.

half century, this situation is rapidly changing. The most prominent changes are due to climate change and global warming.

According to a research study of two JPL scientists (Schneider P, and Hook S., 2010), who monitored the surface night temperature of 167 large inland water bodies all over the world during the years 1985–2010 (using sensors on satellites), the annual average rate of warming found was 0.045±0.011° (which means over 1 degree during the entire period), and even higher annual warming rates of 0.10±0.01° (which means 2.5 degrees for the entire period). The warming in the lakes in the northern and central parts of the northern hemisphere was higher than the warming of the lakes in the southern part of the northern hemisphere and in the southern hemisphere.

An extreme case showing the influence of global warming on the shrinking and drying process of lakes, which was involved in international boundary delimitation, can be exemplified by Lake Aral (Aral Sea), the fourth biggest lake in the world in the 1960s. The international boundary between Kazakhstan and Uzbekistan was delimited in the Aral Sea. Most of the section of the international boundary line that previously used to pass through the Aral Sea currently follows practically dry land, as is shown in the following illustration, showing the drying process of the lake between the years 1989 and 2014.

Another extreme case showing the influence of global warming and over-utilization of water (for agriculture) can be seen in Lake Chad. The international boundaries of four countries traverse the lake: Chad, Niger, Nigeria, and Cameroon. In the past, this lake was considered as the sixth largest lake in the world (similar in size to Lake Erie) and the largest one in Africa. According to a research study in Madison-Wisconsin University (Coe M.T. & Foley J.A., 2001), using NASA's Earth Observing System Program images, the lake shrank to 1/20th of its original size within 35 years!

Regarding the warming phenomenon, the annual rainfall in the area dropped drastically since the early 1960s. Regarding the over-utilization of water, the quantity of

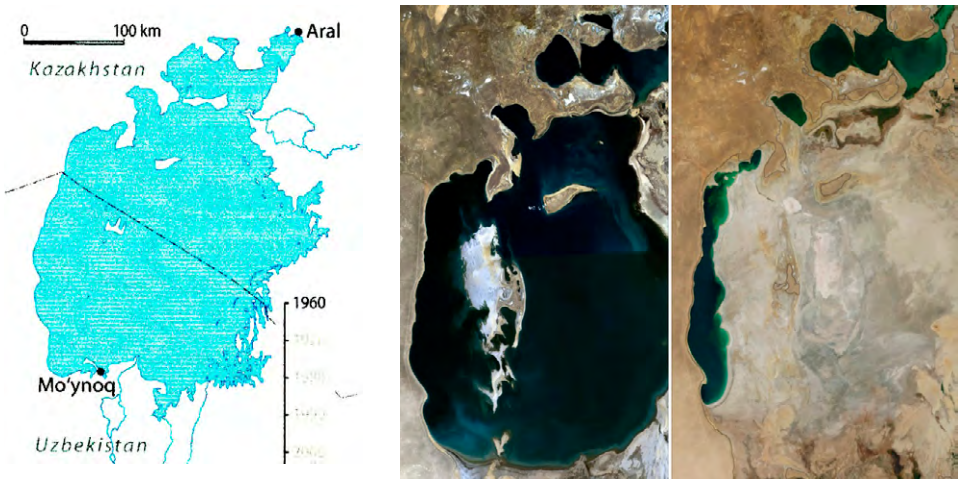

Figure 3: *The shrinking process of the Aral Sea – On the left a chart of the size of the lake in 1960 (from Wikimedia –Author: NordNordWest using Nasa images, US NIMA data, www.unimaps.com). In the middle: A mosaic of LANDSAT images, July-September 1989. On the right: An image of NASA MODIS on TERRA satellite, August 19, 2014.*

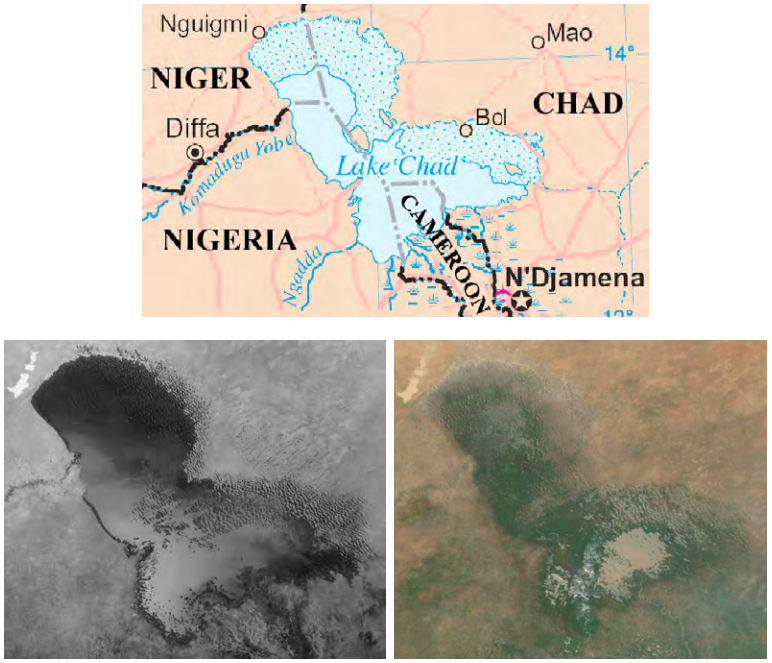

Figure 4: *The drying process of Lake Chad.*

The upper map shows the boundaries between the four countries in the basin of Lake Chad – Wikipedia: https://en.wikipedia.org/wiki/Lake_Chad. The lower left image is a USA Corona declassified image from October 31, 1963, showing the lake in its size in 1963. The lower right image is a MODIS image from September 4, 2002, in which only the southern part (the bright area) remained. (Image by Jesse Allen based on the MODIS Rapid Response Team of NASA GSFC.)

water that was diverted from the lake for irrigation from 1984 to 1993 was three times larger than the lake water used during the preceding 25 years.

The rapid global population growth and the growth of water consumption, either directly or for agriculture, food production, and for industry, has contributed to large-scale projects regarding water all over the world, especially in arid and semi-arid areas. In addition to the natural warming influence, the global water balance suffered a reduction of water sources as a result of man-made artificial changes in lakes and rivers. These activities include the following: 1) Construction of big dams, such as the Aswan Dam and dams on the Euphrates River, which created very large artificial lake reservoirs, enabling regulated and controlled use of water, and avoided the traditional dependence on seasonal and annual climate changes. Such changes, if they are upstream, result in serious implications on the water balance along these rivers, leading to international disputes and conflicts, mainly due to the reduction of water supplied to the states downstream, but sometimes due to water pollution. Lakes and large lake reservoirs may be used to divert part of the water through canals and other water carriers for external use, in a way that may significantly reduce the original water volume.

2) Construction of dams for hydro-electric projects sometimes includes digging and constructing large reservoirs that change the natural original river and lake, which influences the international boundary line. 3) The global population growth and the increased water consumption decrease the water sources and the water volume of lakes, shrinking their size causing their disappearance.

In cases where artificial lake reservoirs along rivers reduce the water flow and water volume of the river downstream, the existence of a lake within a state does not prevent international disputes between this state and the states downstream. In cases where international boundary lines traverse a common lake, the contraction of a lake area directly affects the riparian areas of the lake, since the shrinking is not symmetrical between the areas, but instead, it depends on of the structure of the lake bed and its bathymetric characteristics. For example, the shallow areas are dried first and consequently, the shorelines change appreciably.

Such cases are not only limited to water disputes – sometimes boundary disputes develop as well.

However, these situations can be prevented in advance if the boundary agreement allocates the entire area of the lake to one of the states. In such cases, the rights of access to the lake and the rights of use of its water by the other state can be specified in supplementary or special agreements.

This was the case with the 1920 Franco-British Paris Agreement regarding the boundaries between Syria (and Lebanon) and Palestine (and Trans-Jordan) and Mesopotamia. The boundary between Syria and Palestine had been allocated inside the Sea of Galilee. However, the Joint Boundary Demarcation Commission, which received its responsibility from the Paris Agreement, recommended that the entire area of the lake be included inside Palestine. Finally, the British and French governments approved the boundary agreement in 1923, and adopted this recommendation, so that the Sea of Galilee was included in Palestine.

It is worth mentioning that the Boundary Demarcation Commission took into consideration the problematic situation of the nearness of the Syrian lands to the lake, and the adjacent Syrian population's need to use water from the lake, including fishing. Thus, the commission integrated arrangements for the Syrian use of the lake's water in the boundary agreement itself. In 1926 the two states added a Bon Voisinage Agreement that included special arrangements along the entire boundary line. In order to unequivocally emphasize the inclusion of the entire lake in Palestine, the Boundary Commission stated that the boundary line north-east of the lake will be delimited 10 meters east of its shoreline.

Since the shoreline, like every shoreline, is not a fixed line, but changes as a result of the changing water level of the lake and the local topography, the 10 m line was referenced to a specified height. Taking into account the changes in the water level during high and low water rises, the commission decided that the boundary line will be delimited 10m east of the shoreline of the lake, defined by the high water level of the lake and a dam to be constructed at the exit of the Jordan River from the Sea of Galilee. The construction of such a dam was required for a hydro-electric power station that was planned at that time. Thus, in this complicated way, the commission connected the boundary line to a specified topographic height that fits the upper level of the future dam, which will be the new upper level of the lake, since any water above this height

will spill over the dam. This arrangement theoretically prevented future problems, although the dam was built one decade later.

Regarding the delimitation of the boundary line 10m from the shoreline of the lake, obviously, such a definition is suitable for an office but not the actual field area. The relevant area is characterized by a wavy surface valley, so that similar contour lines are repeated close to the water area. However, the main problem with this delimitation was that it has not proved itself over time, and it did not contribute to maintaining stability in the area. Although during the period of the British Mandate over Palestine the two Mandatory Powers, namely, Britain and France, had preserved the arrangements, the boundary line was geographically unstable and too vulnerable. It did not withstand changes during the times of conflict and war. For example, following the 1948 war, and in spite of the 1947 UN Resolution 181(II) that adopted the international boundary definition under the mandate, the Syrian Army descended from the dominating area of the Golan Heights and conquered the 10m narrow strip. Governing the shoreline enabled the Syrian Military Forces to control a portion of the lake; thus, this clearly shows that such a delimitation does not guarantee stability.

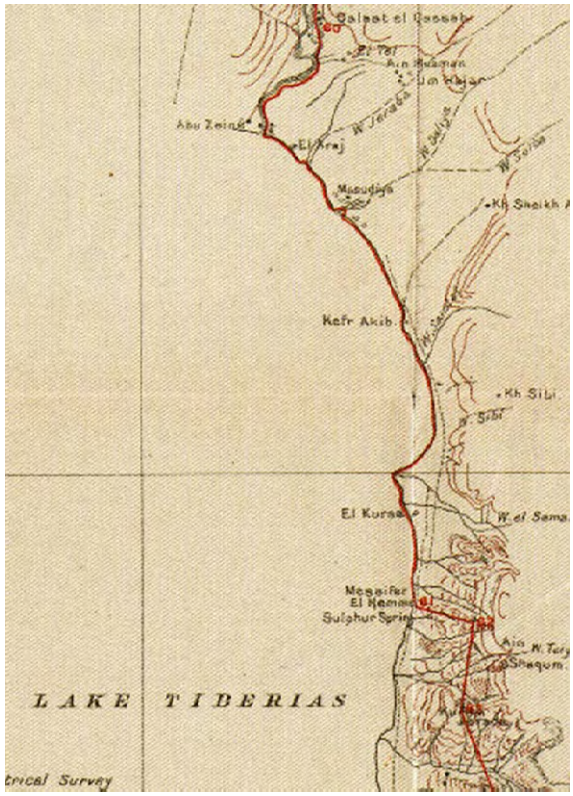

Figure 5: *The delimitation of the 1923 international boundary between Syria and Palestine at a distance of 10m from the shore line of the Sea of Galilee.*

2 THE CASE OF THE DEAD SEA

The case of the international boundary in the Dead Sea, into which the River Jordan flows downstream from the Sea of Galilee, is entirely different from the case of the Sea of Galilee. Since Great Britain was granted the mandate for both sides of the Dead Sea, the choice as to where to delimit the boundary line between the two sides was an internal decision. Furthermore, the international boundary between Palestine and Trans-Jordan was in practice a temporary administrative boundary between two mandated areas that presumably in the future would become independent states. This was why Great Britain decided to delimit the boundary line in the center of the Jordan River, the Dead Sea, the Araba Valley, and the Gulf of Aqaba, so that both Palestine and Trans-Jordan will share the water and the rich mineral resources of the Dead Sea for both populations and as an economic strategy and infrastructure investment.

The British 1922 delimited international boundary in the Dead Sea has preserved stability and it has not been changed throughout the last century, in spite of the fact that the British rule has been replaced by independent states that had been for a certain period of time in a state of war. For the last 26 years this boundary line in the Dead Sea has been part of the international boundary between Israel and Jordan, as agreed upon in the 1994 Treaty of Peace.

Furthermore, this boundary has remained stable in spite of the fact that the lake itself has dramatically changed as a geographical entity, and it keeps changing due to the influence of natural and artificial processes. The Dead Sea, the lowest lake on land in the world, is an example of the dramatic changes that have taken place in water bodies over the world and especially in arid and semiarid areas, due to natural and artificial changes. Therefore, we will elaborate on this case.

The natural and artificial reasons for the significant depletion of water from the Dead Sea and for its reduced size are as follows:

The main natural reason is the global warming, the reduction of precipitation in general and especially the precipitation of rain throughout the drainage basins of the rivers and other water sources that flow into the lake. The other major natural reason is the high rate of evaporation from the large water surface and the surface of the salt pans.

The artificial influencing factors are diverse. Some of them refer to the reduction of water sources; others refer to the exploitation of the Dead Sea water. Among the large influential water projects, one can include two nationwide water projects in Israel and in Jordan, both of which were inaugurated in 1964. One is the Israeli nationwide water carrier, supplying water from the Sea of Galilee to the dry southern part of the country. The other is the Abdulla Canal (The Ghor Canal), diverting water from the Yarmuk River to irrigate the eastern part of the Jordan Valley, Jordan's main agricultural area.

These two major water projects, in addition to regional water projects on both sides that utilize water sources by pumping water or by channeling water to reservoirs, supply water to the fast-growing populations on both sides, and to their agricultural irrigation systems. The combined total population on both sides has increased from several million in the early 1960s to over 20 million people today, in Israel, Jordan, and in the area controlled by the Palestinian Authority. As a result of this process, the Jordan River currently contributes annually to the Dead Sea less than one tenth of the water volume it used to contribute in the early 1960s.

An additional artificial activity that influences the reduction of the Dead Sea water is the utilization of water for the needs of the Dead Sea Works on both the Israeli and the Jordanian sides.

The southern basin of the Dead Sea, which used to be much shallower than the northern one, has dried up and ceased to be part of the Dead Sea. Shallow salt pans were constructed in the area on both sides of the lake. The salt pans are used for water evaporation and for producing valuable minerals, mainly phosphates. The salt pans are at a higher level than the water surface of the Dead Sea, and they obtain their water by pumping the water from the Dead Sea up through canals. The large surface area of the salt pans and the extremely high temperatures in this section of the Dead Sea fault, as already mentioned, the lowest place on Earth, increase the evaporation and loss of water in the Dead Sea.

The reduction of the Dead Sea water sources, the increased evaporation, and the increased utilization of its water have caused a rapid lowering of the water level, reaching a rate of around 1.3 m pa. The accumulative lowering of the Dead Sea water level during the last 80 years is about 40m. The lowering of the water level dries the shallow areas near the shore lines, and contracts the surface area of the Dead Sea. This process is shown in the following table from a study of Israel Oceanographic and Limnological Research cited by Wikipedia:

Year	1930	1980	1992	1997	2004	2010	2016
Water Level (m)	–390	–400	–407	–411	–417	–423	–430.5
Surface (Sq. KM)	1050	680	675	670	662	655	605

Figure 6: *The contraction of the Dead Sea as a result of the lowering of the water level during the years 1930–2016 (Source: Israel Oceanographic and Limnological Research).*

The contraction of the surface of the lake (in the existing north basin) is not symmetrical – it depends on the topography of the bottom of the lake in the shallow areas near the shore lines. Since an international boundary is delimited in the Dead Sea, and since Great Britain delimited this line on September 1, 1922 in the center of the Dead Sea, there could be a severe problem regarding maintaining the international boundary line and utilizing its water for the respective states, if the delimitation remains as a general geographic flexible delimitation, which depends on the unstable location of the center of the Dead Sea.

Three Landsat images shown in Figure 7 visually exemplify the changes in the Dead Sea during the years 1972–2011. The left 1972 image shows that the southern basin is still part of the Dead Sea. Salt pans still do not exist in the eastern Jordanian side. The central 1989 image shows that the Dead Sea has lost its southern basin and that it is only defined by the northern basin. The southern basin has been filled with salt pans on both sides of the boundary line. The right 2011 image shows the expansion of the salt pans, mainly on the eastern Jordanian side. In addition, the northern basin of the Dead Sea has continued to contract, especially in the north-western side, and consequently, the northern shore line has migrated southwards. The movement of the northern shoreline southwards has constrained the Jordan River to break through a new channel southwards toward the new shoreline of the Dead Sea. The new channel continues along the old abandoned bottom of the Dead Sea for kilometers, and con-

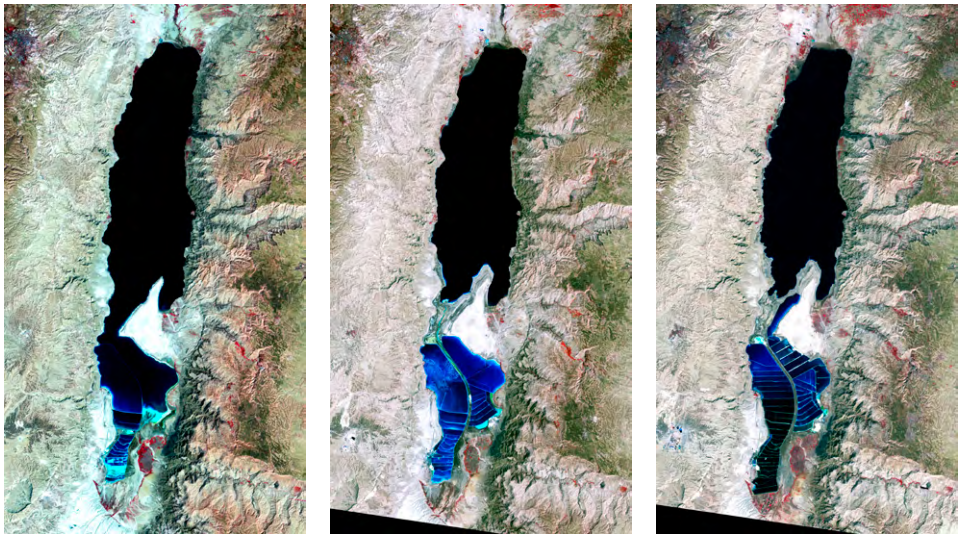

Figure 7: *The contraction of the Dead Sea between the years 1972 and 2011, shown on NASA&USGS Landsat images. On the left: Landsat 1 MSS September 15, 1972; In the middle: Landsat 4 TM August 27, 1989; On the right: Landsat 7 ETMP October 11, 2011.*

tinues to lengthen southwards as the Dead Sea continues to dry up and its northern shoreline shifts southwards.

If the boundary line in the October 26, 1994 Israel-Jordan Peace Treaty would have been delimited in the center of the Dead Sea as it was in 1994, the boundary line would have to been moved up to more than 800 m in comparison to the international boundary in the Dead Sea during the British Mandate. However, Israel and Jordan adopted the delimitation of the international boundary line during the British Mandate as the reference line for delimiting the international boundary of the 1994 Peace Treaty. If the 1994 Peace Treaty would have defined the international boundary in the center of the Dead Sea from the time of the treaty onwards, the boundary in the Dead Sea would require continuous maintenance, improvements, and changes since 1994 in order to deal with the changes in its shorelines in correlation with the lowering of its water level. However, these problems were prevented due to the definition in the 1994 Peace Treaty, which stated that the delimitation of the boundary in the Dead Sea will be fixed following the delimitation in this section of the international boundary under the British Mandate, as delimited on three 1:100,000 maps.[14]

However, the boundary in the newly dried area of the Dead Sea cannot follow the line on the British map, since the new natural channel of the Jordan River does not coincide with the line on the British map. The river channel overruns its original channel opening a new channel in the dried area of the Dead Sea. The Joint Team of Experts, as an official organ of the Joint Boundary Commission, agreed to adopt the river channel as the boundary line and to gradually adjust the boundary line until it meets the boundary line on the British map (close to the estuary of the river into the Dead Sea).

14 1:100,000 Survey of Palestine maps: Dead Sea, sheet 13, 1945; Jerusalem, sheet 10, 1944; Jebel Usdum, sheet 16, 1945.

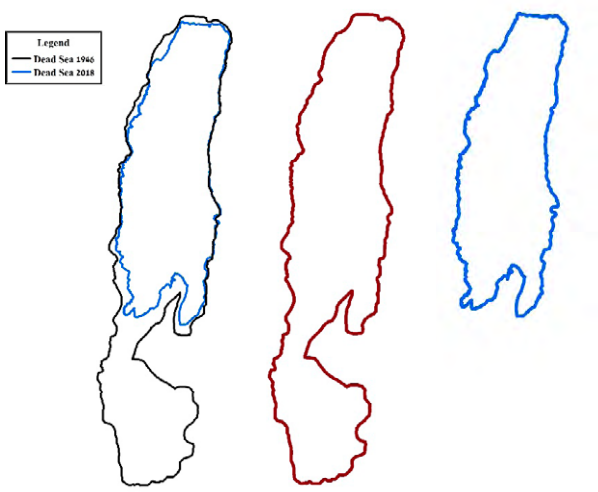

Figure 8: *The Dead Sea during the time of the British Mandate (in black on the left and in red in the middle) and today (in blue).*

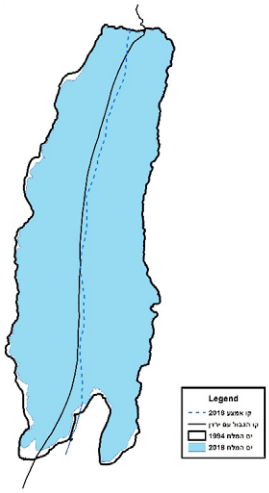

Figure 9: *The Dead Sea in 1994 (black outline) and today (the blue area). The 1994 agreed Israel-Jordan international boundary is shown in black inside the Dead Sea. The dashed blue line shows the current median line.*

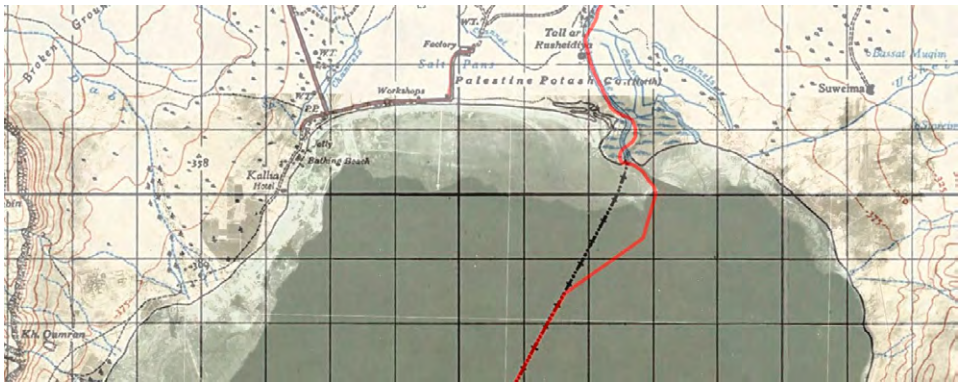

Figure 10: *The boundary line following the route of the Jordan River in the dried area of the Dead Sea (in red) on a 1994 orthophoto in comparison with the line on the 1944 Mandatory map (in black).*

3 CONCLUSION

Global changes, including global warming and rapid population growth during the second half of the 20th century and the beginning of the 21st century, have contributed to the drying of lakes, especially in dry and arid areas. This phenomenon has implications regarding the historical balance between riparian states that share rivers and lakes, regarding the delimitation of international boundaries between them, as well as regarding the right to use the water bodies.

A process of asymmetric drying of the surface of a shared lake continuously changes the median line of the lake and the proportion of an agreed partition of the lake between the respective states. If the relevant parties prefer to fix the boundary lines in order to preserve their stability, it may influence the agreed balance regarding the rights to use the water, and in extreme cases, it may influence the accessibility to the lake. On the other hand, if the respective states prefer to preserve equity or an agreed upon relativeness regarding their rights of use and exploitation of the water of the lake, they must change the boundary line, and thus, affect the stability and functionality of the area, which is the main aim of international boundary delimitation. An alternative option dealing with a dynamic and evolving situation is to fix the international boundary delimitation and to agree on all the rights of use, the practical arrangements, and the preservation of equity separately, in a different agreement, or as a supplemental part of the boundary agreement.

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PART II:
ADDITIONAL ISSUES REGARDING INTERNATIONAL BOUNDARIES ON UNSTABLE GROUND

CHAPTER 4: INTERNATIONAL BOUNDARIES ON GLACIERS – THE ITALIAN "MOVING BOUNDARIES"

Andrea Cantile, Italy

Key words: Italian boundaries; moving boundaries; Italian and Swiss, French, Austrian and Slovenian boundaries.

Summary

This is a brief summary of the general characteristics of the Italian land borders with reference to the length, number of boundary pillars, and the average distances between each of them. Also mentioned are the Italian legislative references, treaties, and international agreements with which the criteria for delimiting and demarcating the borders for each of the four Italian land boundaries have been agreed in the last hundred years.

Moreover, the current criteria in use for maintaining the existing borders are reported. They illustrate the terms of the recent agreements that Italy has concluded with Austria and Switzerland, following the morphological changes in the alpine glaciers. In this regard, it should be noted that the legal requirements and agreements concluded between Italy and Austria, and between Italy and Switzerland have not introduced any form of automation in the management of borders, contrary to what was perceived by the use of the locution "moving border".

In conclusion, some general considerations are proposed regarding the idea of a border, quoting two famous philosophers of the past.

1 GENERAL CHARACTERISTICS OF THE ITALIAN LAND BOUNDARIES

For many people, the land border of Italy has been generically identified with the Alps since the time of the Roman Empire. In fact, the real border between Italy and the neighboring states has changed significantly over time, mainly due to war causes[1] , as well as to other similar cases that have occurred in Europe, "paradoxically [...] the continent with the 'youngest' political border" (Kolosov, 2013, p. 6).

The four border lines that today separate the territory of the Italian Republic from France, Switzerland, Austria, and Slovenia derive from fairly recent definitions. The oldest of them dates back to about a century ago, after the First World War, whereas the other three result from agreements made during or after the Second World War.

Overall, the four Italian land borders now have a total length of about 1913 km and are demarcated by 8,042 boundary pillars[2].

1 A large historical reconstruction of the events that described the definition of the Italian land borders is reported by the monumental work written in four volumes by Vittorio Adami, *Storia documentata dei confini del regno d'Italia: Confine italo-francese*, Roma 1919; *Confine italo-svizzero*, Roma 1926–27; *Confine italo-austriaco*, Roma 1930; *Confine italo-jugoslavo*, Roma 1931. The topic, relating to the post-unitary period up to the First World War, was also recently taken up by Matteo Proto, in *I confini d'Italia. Geografie della nazione dall'Unità alla Grande Guerra*, Bononia University Press, Bologna 2014.

2 Official data of the Italian Geographic Military Institute.

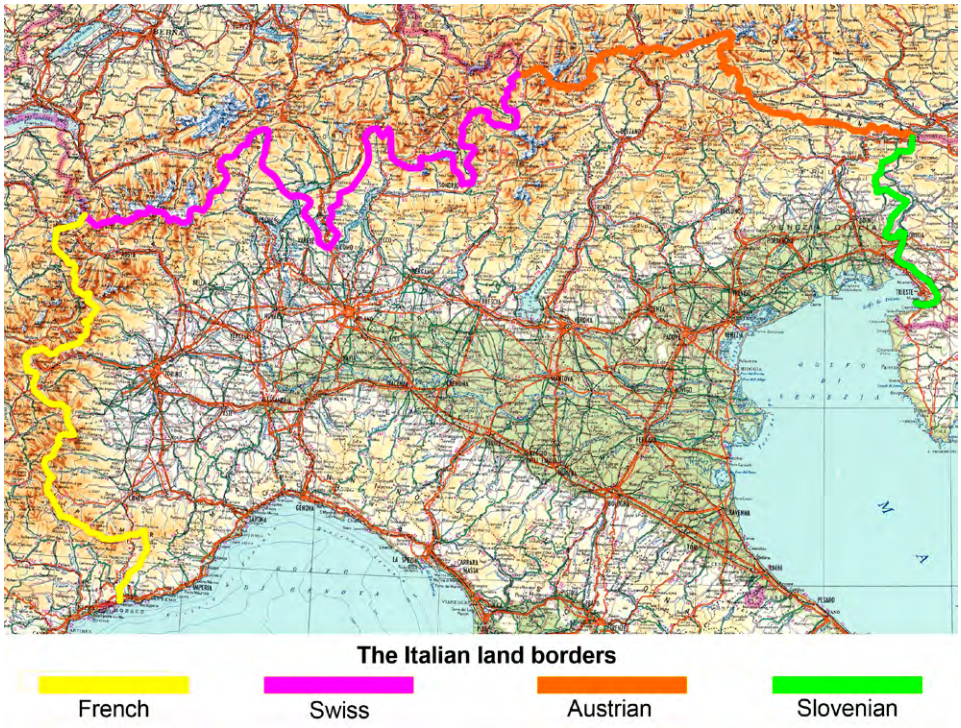

Figure 1: *The four Italian land borders.*

The current border between Italy and France was determined on the basis of the Peace Treaty of February 10, 1947 and its maintenance is regulated by the provisions contained in the "Agreement between the Government of the Italian Republic and the Government of the French Republic on the maintenance of the boundary pillars and the border line", approved by the Italian Parliament with the law of May 15, 1986, no. 231[3]. The border begins today at the mouth of the Rio San Luigi, between Ventimiglia and Menton, and ends at Mount Dolent (3,823 m). It has a total length of 515 km and is demarcated by 697 boundary pillars.

The border between Italy and Switzerland was agreed on, based on the "Convention between the Swiss Confederation and the Kingdom of Italy, [...], signed on July 24, 1941. It was enforced on September 23, 1942, with the law of June 21, 1942, no. 900[4] , which established the determination of the Italian-Swiss border in the stretch between Mount Dolent and Cima Garibaldi or Run Do and the rules for maintaining the boundary pillars of the entire Italian-Swiss border between Mount Dolent and Piz Lat or Piz Lad. The border has an overall length of 745 km, starting from Mount Dolent (3,823 m) and ending in Piz Lad (2,808 m), and is demarcated by 1,274 boundary pillars.

The border between Italy and Austria was drawn by the International Commission for the delimitation of borders, in the years 1920–24, in accordance with the "Peace Treaty concluded between Italy and Austria in Saint-Germain-en-Laye on

3 Gazzetta Ufficiale della Repubblica Italiana [Official Journal of the Italian Republic], no. 43, June 4, 1986, Supplemento Ordinario [Ordinary supplement] no. 127.

4 Gazzetta Ufficiale del Regno d'Italia [Official Journal of the Kingdom of Italy], no. 198, August 24, 1942, Supplemento Ordinario [Ordinary supplement] no. 198.

10 September 1919", approved with the law of September 26, 1920, no. 1322[5] and was enforced on October 1, 1920; it was subjected to a new measurement and supplementary demarcation, carried out by mutual agreement from 1971 to 1981. The border today has a total extension of 430 km, starting at Piz Lad and ending at Mount Oven (1,508 m), and is demarcated by 2,644 boundary pillars.

The current border between Italy and Slovenia was outlined in the aftermath of the Second World War, on the basis of the "Paris Agreement of 1946", of the "Convention between the Government of the Italian Republic and the Federal Executive Council of the Assembly of the Socialist Federal Republic of Yugoslavia for the maintenance of the state border", signed in Nova Gorica on October 29, 1980 and ratified by the law of December 13, 1984, no. 970. This was followed by the "Ratification and execution of the Agreement between the Government of the Italian Republic and the Government of the Republic of Slovenia for the maintenance of the state border, made in Rome on March 7, 2007", approved by the law of November 19, 2010, no. 210[6]. The border has a total extension of 223 km, beginning in Mount Forno and ending between Muggia and Ancarano, and is demarcated by 3,427 boundary pillars.

As indicated above, the demarcation of these four border lines involved the construction of several thousand boundary pillars, of which, to date, 697 are located on the border with France, 1,274 are located on the border with Switzerland, 2,644 are located on the border with Austria, and 3,427 are located on the border with Slovenia. From this it is clear that the distribution of these boundary pillars has a fairly irregular interdistance.

The average distances between each boundary pillar are as follows:

- 738 m along the border with France;
- 585 m along the border with Switzerland;
- 162 m along the border with Austria;
- 65 m along the Slovenian border.

The substantial differences between these borders are generally due to historical and morphological reasons.

In particular, these few data clearly show the average distribution of the boundary pillars between Italy and Slovenia, defined in a historical period known as the "Cold War".

2 MAINTENANCE OF THE ITALIAN BOUNDARIES

Since 1941, Italy has entrusted the borders' care and maintenance with neighboring states to the Italian Geographic Military Institute (IGMI), so that the respective tracks would be well determined and preserved and could always be easily identified throughout their extension. This assignment has been fulfilled and it still complies with the bilateral agreements between Italy and the four neighboring countries.

These agreements provide for the use of special mixed Permanent Commissions, which are charged, each for the country to which they belong, to implement all the necessary provisions for keeping official documents and maintaining borders. For the com-

5 Gazzetta Ufficiale del Regno d'Italia [Official Journal of the Kingdom of Italy], no. 232, October 1, 1920.
6 Gazzetta Ufficiale della Repubblica Italiana [Official Journal of the Italian Republic], no. 290, December 13, 2010, Supplemento Ordinario [Ordinary supplement] no. 273.

position of these Commissions, each state appoints a president and their respective members. For Italy, the IGMI Commander chairs the Italian-Swiss and Italian-Austrian Commissions, whereas a representative of the Italian Ministry of Foreign Affairs chairs the other two Commissions, namely, the Italian-French and Italian-Slovenian. In addition, in this case, the reasons for these differences emerge from the particular historical moment when the official assignment to IGMI took place, in the middle of the Second World War.

In general, the task of these Commissions is to guarantee the maintenance of borders, and to do everything possible to ensure that they are defined unequivocally and are always clearly identifiable on the ground.

More specifically, Commissions must:

"– check the position of the boundary pillars, arranging, where necessary, their accommodation in exact location;
– fix, straighten, lift the boundary pillars that are unsteady, inclined, or collapsed;
– ensure the legibility of the writing of each boundary pillar;
– repair or replace damaged boundary pillars;
– put on site boundary pillars where they are missing;
– materialize border with subsidiary boundary pillars, if it is not found sufficiently clear;
– transforming the direct materialization of the border into an indirect one, and vice versa, where deemed necessary, indispensable, and appropriate;
– move dangerous boundary pillars to a safe position;
– materialize the border on bridges, tunnels, in sections where the border intersects roads or railway bridges and, if necessary, in mines and other plants;
– determine, where necessary, the coordinates of non-materialized border points, in the sections in which the state border is defined in the border documentation by a ridge or watershed line[7]."

Any possible variation in the border line can be performed only following the approval of the parliamentary authority. In Italy, the "Constitution of the Italian Republic", according to the provisions of article 117, letter q, established that the legislation concerning the "protection of national borders" is an exclusive task of the State.

The most significant changes in recent years have been a direct consequence of the melting of glaciers on the Alpine peaks; as a result, the boundary line defined by the watershed was changed with the outcrop of the underlying rocky surface.

3 THE SO CALLED "MOVING BOUNDARIES"

During the periodic reconnaissance of the boundary pillars along the Italian-Austrian and Italian-Swiss borders, several phenomena involving the morphological transformation of some alpine glaciers have been observed, resulting from the climatic variations.

In these areas, where the ridge lines of the glaciers also identified the boundary lines, a discrepancy was therefore caused by the non-coincidence between these two elements. This phenomenon could be ignored, as normally occurs in the valleys, following

7 The actions listed here are taken from the «Agreement between the Republic of Austria and the Italian Republic for the maintenance, measurement and materialization of the common state border», signed in Vienna on January 17, 1994 and approved in Italy on October 31, 2000.

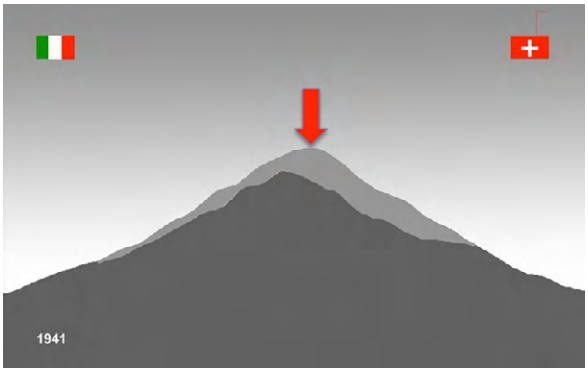

Figure 2: *The red arrow indicates the position of the boundary line on the glacier ridge.*

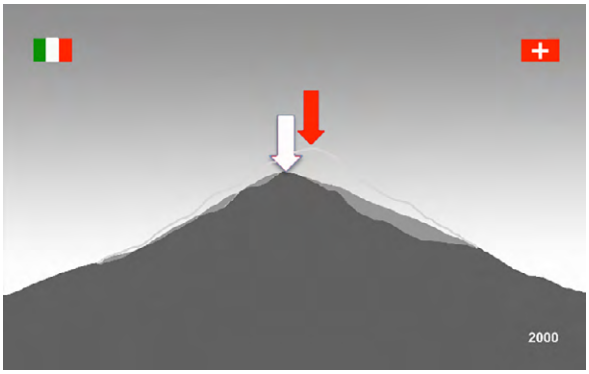

Figure 3: *The white arrow indicates the position of the boundary line after the melting of the glacier.*

the planimetric variation of the borders coinciding with the natural water courses, or it could be subjected to adjustment, as shown in figures 2 and 3.

These phenomena, observed for about a decade, between the 1970s and 1980s, led to a study of a proposal, previously discussed informally with the technicians of the Austrian and Swiss Commissions, on the basis of which, it was agreed on the need to "introduce, within the framework of the existing agreements [...] relating to the common border, a provision with which it is established that the border line coinciding with the glacier ridge can follow the gradual and natural changes of the ridge line, and therefore be considered moving".

The proposal, after obtaining the consensus opinion of the respective commissions, Austrian and Swiss, was followed by an exchange of verbal notes between the diplomatic representatives of the countries concerned and was subsequently presented to the Italian Parliament for the expected approval. The new agreement with Austria was approved by the Italian parliament by a law on December 15, 2005, no. 283, "Ratification and execution of the Agreement between the Italian Republic and the Republic of Austria for the maintenance, measurement and materialization of the common state border, with final Protocol and Attachments, made in Vienna on January 17, 1994 and

the related Exchange of supplementary letters signed in Rome on October 31, 2000"[8]; the agreement with Switzerland was approved by a law on May 29, 2019, no. 72, "Ratification and execution of the Exchange of Notes between the Italian Republic and the Swiss Confederation relating to the 'moving' borders on the ridge or river line, carried out in Rome on May 23 and 26, 2008"[9].

More specifically, for the Italian-Austrian border, article 3 of the law of December 15, 2005, no. 283, which established that:

"(1) The state border, defined in article 1, is stable even if it runs on water.

(2) There where the state border according to the documents referred to in Article 1 paragraph 3 is expressly defined by the river line or the ridge line, follows the gradual natural changes to which these lines are subject. Sudden natural alterations or artificial alterations of the displuvial line or of the ridge line do not involve any change of the border route, however in such cases the Contracting States will proceed to the verification of the border route based on its unmistakable recognition.

(3) For the purposes of this Agreement, 'waterway line' means the line on which runoff water separates on the ground. In this regard, water infiltrations in the lower layers of the soil are not considered. As regards the concept of "land" referred to in this paragraph, in the case of glaciers or perennial snowfields, we mean their surface.

(4) Pursuant to paragraph 2, gradual natural changes of the displuvial line or ridge line are intended in particular:

a) The displacement of the ridge line as a consequence of erosion, as well as

b) The displacement of the waterway line following alterations of glaciers or perennial snowfields; in case of contraction of a glacier or a perennial snowfield, the boundary line will coincide with the displuvial line on the emerging rocky terrain."

For the Italian-Swiss border, the "Verbal Note" attached to the law of May 29, 2019, no. 72 established that:

"1) Where the state border route, based on the documents described in art. 19 of the 'Provisions for the execution of maintenance works on the terms of the Italian-Swiss border from Piz Lat and Piz Lad to Monte Dolent, based on the Convention and related Regulations between Italy and Switzerland, signed in Bern on July 24, 1941' is expressly defined by the displuvial line or by the ridge line, it follows the gradual natural changes to which these lines are subject. On the other hand, sudden natural alterations or superficial alterations of the displuvial line or of the ridge line do not entail any change in the course of the border. In this case, the contracting States will be able to agree on a solution which may also include an exchange of equivalent areas.

2) 'Displuvial line' means the line on which the runoff waters separate on the ground. In this regard, water infiltrations in the lower layers of the soil are not considered.

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8 Gazzetta Ufficiale della Repubblica Italiana [Official Journal of the Italian Republic], no. 6 January 9, 2006 – Supplemento Ordinario [Ordinary supplement] no. 4.

9 Gazzetta Ufficiale della Repubblica Italiana [Official Journal of the Italian Republic], no. 143 June 23, 2009, Supplemento Ordinario [Ordinary supplement] no. 97.

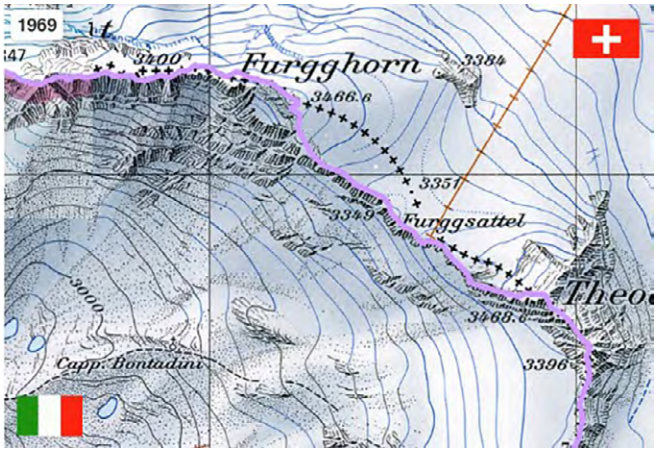

Figure 4: *Example of variation of the current boundary line, highlighted with purple line, compared to that of 1940, indicated by continuous black crosses in 1967 as results on the Swiss Official Map (Source: https://www.swisstopo.admin.ch/it/conoscenze-fatti/limite-territoriale/confine-nazionale/confini-in-movimento.html).*

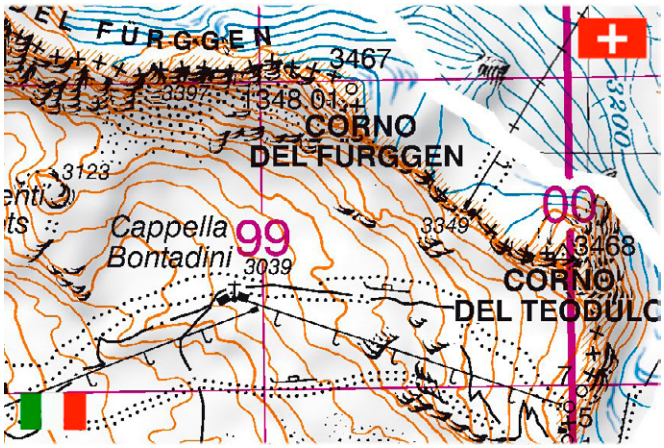

Figure 5: *The same example of variation of the current corrected boundary line, indicated by continuous black crosses, as results today on the Official Topographic Map of Italy 1:50,000, sheet no. 71 – Monte Rosa (2018 edition).*

3) In accordance with the previous point 1), 'gradual changes of the displuvial line or of the ridge line' means in particular the displacement of the growth line as a consequence of erosion, as well as the displacement of the displuvial line following alteration of glaciers or perennial snowfields; in case of contraction of a glacier or a perennial snowfield, the boundary line will coincide stably with the displuvial or ridge line of the emerging rocky terrain, and can only follow the deviations described in the previous point 1)."

Following the sharing of this general principle and its approval by Parliament, this measure then jumped to the headlines when the "moving border" were established

Figure 6: *View on Monte Palla Bianca from the Vedretta della Croda in 1922 (IGMI Boundaries Archive, Florence – Italy).*

Figure 7: *View on Monte Palla Bianca from the Vedretta della Croda in 2012 (Photo by Simone Bartolini – IGMI)*

and caught the attention of scholars (Ferrari *et al*, 2019). In fact, it should be noted that the legal references and agreements concluded between Italy and Austria, and Italy and Switzerland have not introduced any form of automation in the management of their borders, contrary to what was perceived by the use of the phrase "moving border".

Apart from the subtle differences present in the texts of the two agreements mentioned above, the novelty introduced by these rules does not entail "any integration or variation of the regulatory content that in this case regulates the matter", as clearly highlighted in the bill presented to the Italian Parliament (Camera dei Deputati, 2009, p. 2); it only tends to highlight and accept the principle according to which "the boundary route can follow the gradual and natural changes to which the ridge lines or glacier lines are subject for climate-induced variations" (Camera dei Deputati, 2009, p. 3).

To give an idea of the extent of the deviations of the boundary lines from the natural watershed line, observed in recent years in several dozens of cases, it is worth mentioning, for example, the deviation detected in the municipality of Zermatt, in Switzerland, where, during the periodic reconnaissance of the border pillars, in 2000, a deviation in the watershed line was observed between Theodulhorn and Furgghorn, due to the retreat of the corresponding glacier. Following this transformation of the topography in certain places, it was agreed to modify the boundary line between the two neighboring states, and to act similarly regarding the Italian territory. The effects of the withdrawal of the glacier are clearly highlighted by the Swiss Federal Topography Office, Swisstopo, and the Italian Geographic Military Institute, as shown in figures 4 and 5 and in the photos in figures 6 and 7.

4 FINAL REMARKS

At the end of these short notes, it should be noted that the idea of "moving borders", linked to the cases previously illustrated, takes on an exceptional dimension in the collective imagination, even if in fact it results in little or nothing exceptional.

Obviously, the measure appears innovative because of the adjective "moving", which no one would have thought of associating with the term "border".

In the most ancient civilizations the boundaries corresponded with the so-called "zonal border of isolation, consisting of strips of uninhabited and hardly practicable territory, covered by wild or desert areas" (Migliorini, 1948, p. 121). For the delimitation of properties, instead, the border was materialized with a line, associated with the idea of "static", "fixity", "immovability", including a dimension of sacredness, introduced by the Etruscans and amplified by the Romans, with the creation of the god Terminus, in defense of private property, while, among the populations at the time, Julius Caesar reminds us that "civitatibus maxima laus est quam latissime circum se vastatis finibus solitudines habere" [*It is a great merit for cities to have deserted territories around them as widely as possible*] (Caesar, *De Bello Gallico*, VI, 23).

It is perhaps because of this very important tradition, from which the laws of all modern states were inspired, that the provision termed "moving borders" appears even more significant, precisely because it was "born" in the same land where the god Terminus was born and worshiped. The direct heirs of the culture that had elevated the concept of the border on a sacred plan have in fact demolished its sacredness and sanctioned its variability over time.

The Italian geographer Giorgio Valussi had already pointed out that "The border is a purely artificial fact conceived by man and not by nature and therefore subject to change not only its layout, but also its value [...] There is no border predetermined 'ab aeterno', as there is no static border, immobile outside of time" (Valussi, 1972, p. 7). This is proved by the innumerable 'ghost' borders existing in Italy, which even today some people try to revive as zombies, in the name of an undefined and poorly known past.

Nonetheless, the diffusion of the idea of a border that can move over time, albeit very slowly due to the physical changes of the earth's surface, has taken on an exceptional nature.

The aspect that most interests the scientific community is that this principle is limited to other territorial contexts, first of all, the river borders, which by their very nature,

involve much more "moving" than the ridge or watershed. This is true even if in such cases the principle is not applicable because the floodplain of a river, much more than an erosion bed, is not influenced, for example, only by the nature of the soil, the rainfall, and the size of the catchment basin. Importantly, it is also influenced by the presence of buildings or road construction due to the anthropogenic pressure on the territory and, in exceptional cases, it can even be deviated accidentally or with a specific intentionality.

Furthermore, one should not ignore the fact that even today the problem of borders, despite having become over time a necessity for social life, driven by an awareness of the existence of sometimes conflicting interests between neighboring communities, is sometimes addressed by neglecting or ignoring history or using it instrumentally to affirm or deny a particular *status quo*.

In general, however, since borders belong to mankind, we should definitely reject the idea of a border as an entity of separation between communities and strive instead to transform the current borders into administrative limits, aimed only at facilitating the administration and management of the territories, as in the inspiring principles of the Shengen agreement, created within the European Union. However, even this principle, although ideally shared by the vast majority of people, is not easy to implement.

On the theoretical level, thinking of the real construction of a world society of Men, the words of two famous thinkers of the past always remain valid: Thomas More and Charles-Louis de Secondat, baron of La Brède and Montesquieu.

Regarding the treaties between neighboring states, Thomas More wrote in his *Utopia*: "This royal practice of keeping treaties badly there is, I suppose, the reason the Utopians don't make any; perhaps if they lived here they would change their minds. However, they think it a bad idea to make treaties at all, even if they are faithfully kept. A treaty implies that people divided by some natural obstacle as slight as a hill or a brook are joined by no bond of nature; it assumes they are born rivals and enemies, and are right in trying to destroy one another except when a treaty restrains them. Besides, they see that treaties do not really promote friendship; for both parties still retain the right to prey on one another, insofar as careless drafting has left the treaty without sufficient provisions against it. The Utopians think, on the other hand, that no one should be considered an enemy who has done no harm, that the kinship of nature is as good as a treaty, and that men are united more firmly by good will than by pacts, by their hearts than by their words." (More 2016, p. 89).

To this we can also add the thought of the famous French philosopher, Charles-Louis de Secondat, baron of La Brède and Montesquieu, who wrote in his *Pensées*: "Si je savais une chose utile à ma nation qui fût ruineuse à une autre, je ne la proposerais pas à mon prince, parce que je suis un homme avant d'être français, ou bien parce que je suis nécessairement homme, et que je ne suis français que par hasard." [*If I knew something was useful to my nation but ruinous to another, I would not suggest it to my prince because I am a man before being a Frenchman, or because I am necessarily a man and only a Frenchman by chance.*] (Montesquieu 1991, n. 350, p. 285).

Despite the high moral teaching of these thoughts, the need for a practical attitude instead of a theoretical one must still be accepted.

Certain and shared borders still remain an unavoidable necessity, not only in those areas of the world where contrasts and wars still dominate, but also for the peaceful states.

The need to define the sovereignty of a state, to establish territorial competences and precise jurisdictions must still be ensured by the monumentation of the borders, through specific technical-scientific activities that generally involve allocation, delineation, demarcation, delimitation, documentation, and maintenance (Haim Srebro and Maxim Shoshany, 2013, pp. 20–38). Situations such as those that we highlighted along the Italian-Slovenian border, today led us to rationally believe that boundaries with high-density border pillars certainly offer greater guarantees and reduce the possibility of conflicts between two neighboring states.

The idea of "separation" that they inevitably evoke may perhaps in the future be mitigated by their downgrading to the administrative limits of a larger state entity; however, the specter of the possible upsurge of certain tribal behaviors, driven by conflicting interests, can always reawaken the contrasts between "us" and "them" and feed the desire to erect walls.

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CHAPTERS 5–6: THE INFLUENCE OF PLATE TECTONIC MOVEMENT

CHAPTER 5: International Boundaries on a Dynamic Planet: Issues Relating to Plate Tectonics and Reference Frame Changes

CHAPTER 6: Maintaining the Integrity and Utility of International Boundaries in a World of Global Positioning

Key words: International boundaries, reference frames, plate tectonics

Summary

International boundaries, agreed directly between the nation states or through an international commission, are defined and demarcated in a number of ways on land or in marine areas. These include: coordinates expressed in terms of a local or global geodetic reference frame, lines depicted on maps or charts, physical monuments (either on the boundary or with the boundary defined in relation to nearby monuments) or by natural features. Such boundaries, once agreed, accepted and demarcated, can generally be expected to be in place for a very long time – at least decades and potentially centuries. As our ability to define positions (including boundaries) accurately in a global frame improves, we also become increasingly aware that no point on the surface of the Earth can be truly considered to be "fixed" in place – due to pervasive tectonic plate motion. Furthermore, in response to this tectonic motion, the global and local reference frames used for positioning, mapping and coordination change much more frequently than international boundaries are renegotiated. This paper looks at the geodetic and geophysical issues that earth dynamics may impose on the reliable and enduring definition of international boundaries. A case study of the Iraq-Kuwait boundary is used to illustrate these issues. The role that earth dynamics plays in modern geodetic positioning should be considered at an early stage of international boundary determination.

CHAPTER 5: INTERNATIONAL BOUNDARIES ON A DYNAMIC PLANET: ISSUES RELATING TO PLATE TECTONICS AND REFERENCE FRAME CHANGES

Don Grant, Australia, William Robertson & Vincent Belgrave, New Zealand

1 INTRODUCTION

In this paper, we explore issues relating to the impact of plate tectonics on international boundaries that have been defined in terms of a geodetic reference frame. While these issues are usually insignificant in the short term (a few years) there are a number of issues that can potentially cause ambiguity and conflict in the long term if not well managed at the time of negotiation.

Whether or not these issues and ambiguities will become serious over time depends on a number of factors such as the hierarchy of definitive evidence of boundary location; the nature of tectonic motion in the vicinity of the boundary and the form of geodetic reference frame used to gather information and document the boundary location.

2 INTERNATIONAL BOUNDARIES

2.1 Process and Timeframe of Definition

Many international land boundaries have their origins in historic occupation and agreements stretching back a century and more. The authority for establishing international boundaries rests with the territorial parties themselves and bilateral agreement on international boundaries is the norm. The delimitation descriptions can define the boundary in relation to geographical features such as mountains, dividing ranges, hills or valleys, lakes, river and inlets of the sea.

Over time international boundary agreements are refined by demarcation and confirmed by occupation and administrative control. The delimitation and demarcation process is lengthy and demanding even for seemingly small issues. Once the boundaries are finally demarcated and accepted the influence of international boundaries on occupation, settlement and administration will last for centuries.

2.2 Forms of Survey Definition

The practice of accurately surveying and mapping international boundaries has only become common in the nineteenth century. The Canada-USA boundary in the first half of the 1800s and boundaries of the old British and Spanish Empire colonies are some examples. These boundary determinations include the identification of natural features and demarcation with boundary monuments defining the boundaries. More recently geodetic datum have been used to tie survey positioning to a unique geodetic reference frame. A new boundary datum provides a neutral and up-to-date reference system.

The Iraq-Kuwait Boundary Datum (IKBD), Israel-Egypt Boundary Datum (IEBD92), Israel-Jordan Boundary Datum (IJBD94), Eritrea-Ethiopia Boundary Datum (EEBD) and Cameroon-Nigeria Boundary Datum (CNBD) are all examples of the establishment of an independent geodetic boundary datum separate from the datum of each party. The legal boundary along the Iraq-Kuwait border is defined by the coordinates submitted to the Secretary General of the United Nations. This boundary is also marked with substantial monuments but the coordinates held by the UN are definitive. Similarly, the Eritrea-Ethiopia Boundary is defined by the coordinates provided by the Eritrea-Ethiopia Boundary Commission on the completion of its work.

The pre-eminence of monuments as the definition of boundary positions is now being brought into question by superior coordinates and measurements and changing needs. For maritime boundaries, coordinates are the norm and these can vary greatly in reliability and in the ease of reinstatement.

This wide range of descriptive, surveying and mapping definitions of international boundaries have served the practical purposes of their times. However, in a world of globalization and efficient national development, every nation needs to ensure and maintain the integrity of its borders. This need is particularly evident where international boundaries divide significant resources such as oil fields, water resources, fertile lands etc.

2.3 Positioning Challenges Ahead

The role of clearly defined territorial boundaries in enabling positive international relations and effective governance and resource management are well established. However, the demands for security and integrity on international boundaries are escalating through the application of new technology and increased scientific knowledge of the dynamics of global tectonic movement. These advances present a number of challenges that need to be addressed in the demarcation and maintenance of international boundaries.

The assumptions of the past, that international boundaries were established on a stable earth, are well superseded by increasing knowledge of the tectonic plate movement and deformation. This tectonic movement can impact on the international boundaries, particularly where coordinates provide the legal definition of a boundary. The annual rate of tectonic plate movement is of positioning significance and over decades or centuries it accrues to a readily observable amount.

3 PLATE TECTONICS

3.1 Developing Theory of Plate Tectonics

The idea of "Continental Drift" – later Plate Tectonics – developed through the 20th Century. It began as a controversial and speculative theory (Wegener, 1929) with no obvious mechanism for causing the proposed movements. Now it is a fully formed model of earth dynamics confirmed by geodetic, seismic and geological evidence (Oreskes, 2008).

The impacts on cadastral boundaries within a country are increasingly recognized and can be managed by the government. For example, in New Zealand, the legal response to movements of property boundaries resulting from the Canterbury earthquake sequence is encapsulated in the Canterbury Boundaries and Related Matters Act 2016.

The broad acceptance of plate tectonics as a working model of solid Earth dynamics, overwhelmingly supported by both geodetic and geological evidence, means that it is clearly recognized that movement not only occurs episodically on fault lines at the time of major earthquakes but also continuously, slowly and imperceptibly to most observers.

3.2 Magnitude of movements

The movements of tectonic plates are typically several centimetres per year. This may seem to be an insignificant problem for international boundary determination. However, expressed as several metres per century – then the potential problem can more easily be seen. At the time a modern international boundary is defined, especially on land, the negotiating parties will usually seek to have the boundary surveyed and defined. An accuracy of several centimetres may be sought in which case it may take only a few years of tectonic plate movement to exceed the survey threshold.

Depending on how the definition of the boundary has been expressed in the agreement, it would be possible for tectonic plate movement to have the effect of causing the agreed boundary line to appear to inexorably creep across the land as a steady encroachment, small but increasing year by year. One party to the agreement may become aggrieved by this apparent encroachment while the other party may be in no rush to resolve a situation that slowly works to their advantage.

As an example of potential value associated with boundary location, statistics on the Rumaila oilfield (http://www.rumaila.iq/english/the-oilfield.php), which crosses an

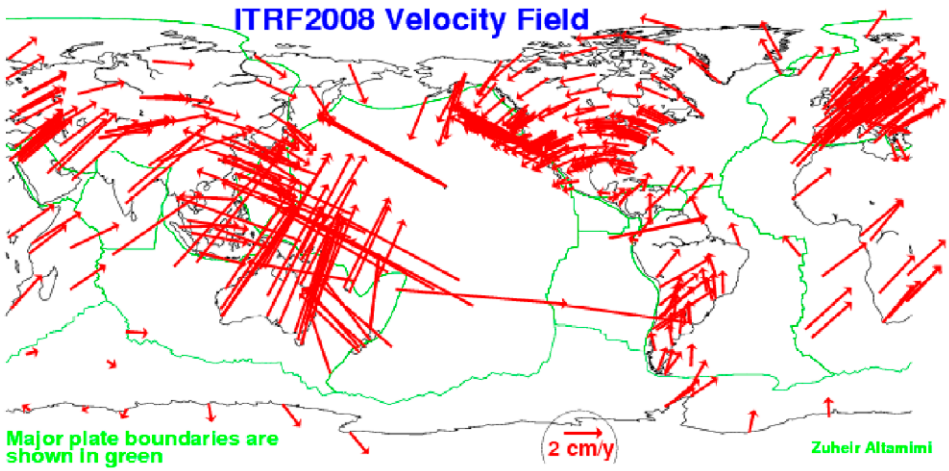

Figure 1: *Velocities of geodetic observations stations in terms of ITRF2008 (retrieved from http://itrf.ensg.ign.fr/ITRF_solutions/2008/ITRF2008.php).*

east-west section of the Iraq-Kuwait boundary indicate reserves of 17 billion barrels of oil in a field that extends 80km north south. Assuming a value of US$50 per barrel gives a rule of thumb value of over US$10M for every metre of boundary movement in the north-south direction.

The ITRF2014 plate motion model parameters (Altamimi et al, 2017) can be used to calculate to horizontal motion of the Arabian tectonic plate in the vicinity of the northern boundary between Iraq & Kuwait. At a latitude of 30.1° and longitude of 47.5° E the east and north components of velocity in terms of ITRF2014 are = 0.028m/yr; = 0.029m/yr; giving a total velocity: V= 0.041mm/yr with an Azimuth of 44°.

The only mechanism to resolve this situation would be to renegotiate a boundary that had been thought to be resolved. A better approach would be to consider this scenario at the outset and define the boundary in such a way that future disputes are avoided.

3.3 International Boundaries Potentially Affected by Plate Tectonics

3.3.1 Marine Boundaries

It can be seen in Figure 1 that the great majority of tectonic plate boundaries are in deep ocean areas where accurate positioning and physical occupation is problematic. However even in these cases, international maritime boundaries can be affected. For example, ocean boundaries may account for extensive oil reserves in basins with a resource sharing agreement based on the area allocated to each country. An example of this is the 1989 treaty between Australia and Indonesia. (http://www.austlii.edu.au/au/other/dfat/treaties/1991/9.html)

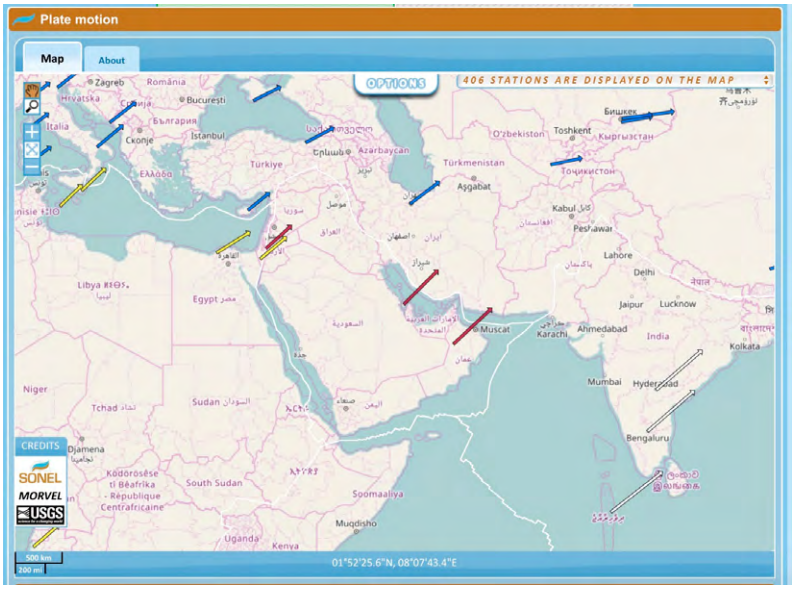

Figure 2: *Complex relationships between the boundaries of the Arabian tectonic plate (plate boundaries shown in white) and international boundaries in the region (shown in purple). (Retrieved from http://www.sonel.org/-Horizontal-land-movements-.html)*

3.3.2 Land Boundaries

Some international boundaries on land also cross tectonic plate boundaries (Figure 2). Over time, straight lines could have a slowly developing offset or step in the formerly straight boundary line. This may occur either slowly as a result of gradual tectonic movement of a few centimetres per year, or suddenly as a result of a major earthquake.

We see in Figure 2 that he tectonic plate boundary between the Arabian plate and the Eurasian plate crosses the international land boundaries of Iran-Iraq, Iraq-Turkey and Turkey-Syria while the Arabian and African tectonic boundary crosses the land boundaries of Syria-Lebanon, Lebanon-Israel, Israel-Egypt, Eritrea-Ethiopia and Ethiopia-Djibouti.

4 REFERENCE FRAMES

4.1 International Terrestrial Reference Frames

The International Terrestrial Reference System (ITRS) is managed by the International Earth Rotation Service (https://www.iers.org/IERS/EN/DataProducts/ITRS/itrs.html). This idealized reference system is periodically realized by International Terrestrial Reference Frames. The two most recent frames are ITRF2008 (Altamimi et al, 2011) and ITRF2014 (Altamimi et al, 2016).

These reference frames incorporate a model of tectonic plate motion. The motions of tectonic plates are defined as rotations about a pole of rotation. In the models used to define the ITRFs, no point on earth is considered to be "fixed". No plate is considered to be motionless while all other plates move around it. The ITRF uses a constraint that all plate rotations are averaged to zero, known as the No-Net-Rotation (NNR) model (DeMets et al 1994).

The ITRS and its sequence of ITRFs, starting with ITRF1989, are increasingly relied on for national and international positioning. The importance of the ITRFs was recognized by the United Nations (United Nations, 2016) with a General Assembly Resolution 69/266 on the Global Geodetic Reference Frame (GGRF).

Increasingly, national, regional and global geospatial datasets will be defined in terms of an ITRF. Global Navigation Satellite Systems (GNSS) such as GPS provide positions on Earth in terms of reference frames (such as WGS84) which are kept in close alignment with the latest ITRF. Many historical international boundaries have been specified in terms of national or regional geodetic datums and reference frames. However, in the future, the mapping and geospatial data that underpins international boundaries, and the positioning systems that allow people to locate themselves in relation to international boundaries will see an increasing move towards the use of ITRFs under the umbrella of a United Nations supported Global Geodetic Reference Frame (GGRF).

4.2 National / Regional Reference Frames

4.2.1 Plate Fixed Frames

The ITRF frames are known as dynamic because all points fixed to the surface of the Earth have not only defined positions (coordinates) but also velocities. The velocity at

a point generally reflects the tectonic plate motion in relation to the coordinate reference frame.

Several modern national or regional geodetic datums are based on ITRF but are "plate fixed" datums. These are generated by generating coordinates in terms of an ITRF at a specified point in time – known as the reference epoch. From that time on the coordinates (unlike those of the defining ITRF) remain unchanging.

What this means for a plate fixed datum is that the datum effectively moves as the plate moves. The coordinates of all points in that datum can remain unchanging because those points move along with the tectonic plate.

This has an advantage that there will be no visible movement of an international boundary defined by coordinates over the surface of the Earth.

It has a disadvantage that a plate fixed national datum is subject to periodic review and replacement when it becomes too far removed from the latest ITRF used for positioning and geospatial datasets. This review means that the boundary will continue to be defined in terms of a reference frame that is no longer in general usage for survey or geospatial data.

4.2.2 Definition of Plate Fixed Frames

Plate fixed frames were traditionally defined, in practice, by the fixed coordinates of a number of primary geodetic control stations. Prior to the use of Global Navigation Satellite Systems (GNSS) these coordinates were typically based on one or more origin stations derived from astronomical observations of the stars. Examples of classical astro-geodetic datums or reference frames are New Zealand Geodetic Datum 1949 (NZGD49) and Australian Geodetic Datum 1966 (AGD66).

The advent of the Transit doppler system for satellite positioning provided an alternative to geodetic astronomy. This allowed geocentric coordinates with a few metres accuracy to be determined for primary geodetic control stations to define the datum or reference frame origin. Examples of reference frames that made use of Transit doppler observations are Australian Geodetic Datum 1984 (AGD84) and – in an international boundaries context – the Iraq-Kuwait Boundary Datum 1992.

More recently geodetic datums and reference frames are often based on one of the International Terrestrial Reference Frame (ITRF) realizations of the International Terrestrial Reference System (ITRS). Coordinates of a plate fixed reference frame are observed using GNSS and calculated to be in terms if a specified ITRF at a specified date (epoch). Examples of ITRF plate fixed reference frames are:

- Geocentric Datum of Australia 1994 (GDA94) which is based on ITRF1992 at 1 January 1994 (epoch 1994.0)
- New Zealand Geodetic Datum 2000 (NZGD2000) which is based on ITRF1996 at 1 January 2000 (epoch 2000.0).
- Geocentric Datum of Australia 2020 (GDA2020) based on ITRF2014 at 1 January 2020 (epoch 2020.0)

4.3 Impact on Boundary Positions

The historic option for managing long term boundary positions has been to assume the stability of boundaries over time. This approach works until earth movements are of such magnitude that ad hoc local solutions no longer suffice. The serious disadvantage of accepting historic positioning is that the coordinated positions become increasingly at variance with the modern measuring capability of users. In addition, differential tectonic movement across the boundary line can cause ambiguity and dispute.

If the boundary is defined by the positions of monuments or physical features, then the boundary will, in effect, move with the tectonic plate. This will cause the least disruption to management of the boundary because there will be no apparent movement.

However natural features can move in relation to the local environment and boundary monuments can be damaged or destroyed. In this case, a boundary maintenance program is likely to recommend reinstatement. If this reinstatement relies on historical survey measurements or coordinates, combined with modern global positioning technology, then ambiguities in interpretation and survey conflicts may result.

An alternative is to establish a plate fixed geodetic datum to define the boundary coordinates. This means that the boundary will not appear to move in relation to the local landscape while allowing unambiguous reinstatement of damaged or destroyed boundary monuments using the geodetic datum.

This option however places great reliance on the geodetic datum itself, which must be maintained to ensure that it remains accessible and useable.

As noted above, there are two options for establishing a plate fixed geodetic datum:

1. Establish a geodetic mark based network in general alignment with the ITRF and rely on the defined coordinates of one or more primary control stations to define the datum
2. Specify an ITRF and a reference epoch. For example, ITRF2014 at 1 January 2014.

The utility of option 1 depends on continued protection and maintenance of the geodetic control stations that define the network. Any loss of those stations imperils the whole boundary definition.

Option 2 provides more long term security because the international community protects the definition of International Terrestrial Reference Frames, including precise transformations from each ITRF to the next one. This option requires an accurate connection, ideally at the few centimetre level at least, between the geodetic network used to measure and monitor the boundary, and the ITRF used to define it.

It should be noted that each of these plate-fixed options will, over time, result in the boundary coordinates becoming increasingly out-of-terms with local surveying and mapping systems including geospatial datasets and personal positioning devices. However, provided that accurate transformations are available between the reference frame of the definitive boundary coordinates, and the more commonly used coordinate systems, this issue is manageable.

5 CASE STUDY: IRAQ-KUWAIT BOUNDARY

5.1 Original Geodetic & Boundary Survey

The survey definition of the Iraq-Kuwait boundary is described in Belgrave, 1995, Grant & Olsen, 1994, Grant 1995, and Pinther, 2013.

During the period 1991–1994 a total of 105 boundary pillars (plus one existing) and 28 intermediate boundary pillars were constructed and surveyed along the boundary by surveyors from the Department of Survey and Land Information (NZ) and Swedesurvey (Sweden) along with engineering contractors. The original 1992 specification for boundary pillars was that the true position must be within 200mm of the specified coordinate.

As noted earlier, the coordinates submitted to the Secretary General of the United Nations – define the legal boundary along the Iraq-Kuwait border – not the pillars that were placed with those coordinates. Therefore, the geodetic datum is crucial to the boundary definition.

The geodetic datum Iraq Kuwait Boundary Datum 1992 was an independent datum that established marks on both sides of the boundary. Transit Doppler observations were made at 4 datum stations – 2 in each country. These provided a connection to WGS84 in an average sense with a coordinate accuracy (1σ) estimated at 0.75m in each axis (Grant, 1995). WGS84 is close to, although not identical to, the sequence of ITRFs.

GPS observations then accurately connected the datum stations to each other and to a network of primary and secondary control stations around the boundary. In relative terms, these stations were all accurate to the centimetre level. The boundary pillars were then precisely connected to or set out to be in terms of the primary stations and thus the datum.

At the time of the IKBDC survey, neither the state of surveying technology or the advances in the knowledge of tectonic movement were sufficiently advanced for a precise datum shift between IKBD92 and ITRF (such as could be determined today) to be identified in the boundary definition.

5.2 Maintenance of Boundary Marks

The Commission made recommendations to the Secretary-General of the United Nations to allow for ongoing maintenance of the pillars and markers of the international boundary including the ability to emplace additional markers if required. It was not within the scope of this project to provide an updated reference system for the survey. Nor was it within the scope to assess the global accuracy of the original datum. A project to undertake the maintenance work in 2013 is described in Belgrave, 2015.

All 106 main pillars were visited and inspected for damage. Of these, 72 had missing or damaged centre plaques that required replacing. In addition, 3 main pillars were considered too badly damaged to be repaired and were noted for replacement.

Selected stations in the primary and secondary networks were resurveyed by GPS. The boundary pillars were then connected by GPS survey directly or indirectly to the primary and secondary control networks.

One of the four original datum stations (D12) was located in an abandoned UN camp in the south of the border area and was in surprisingly good condition. A second datum Station (NGN-43) near Kuwait City was not searched but may be still available.

5.3 Implications for the Boundary Datum & Coordinates

The integrity of the Iraq-Kuwait boundary depends on the ability to re-establish the location of the original definitive coordinates. This in turn depends on the ability to reliably re-establish the IKBD92 in terms of which those coordinates are defined.

While re-establishment of the datum was not within the scope of the 2013 maintenance project, nevertheless some conclusions can be drawn:

- Only one of the original 4 datum stations was recovered. A second one may be available. Nevertheless, the location of the datum is at risk of being lost.
- The original 1992 survey specified accuracy at the 200mm level for boundary pillars but the connection between IKBD92 and say ITRF2014 is not known to that level of accuracy. The uncertainty at 95% confidence is approximately 2 metres.
- The 2013 maintenance project has, in effect, used the primary network to re-establish the datum that the primary control mark coordinates were derived from. This was made necessary due to the loss of at least 2 datum stations. This reverse engineering to locate the datum is effective although a further loss of accuracy can be expected.

Since the Iraq-Kuwait boundary was defined and demarcated in 1992, the Arabian tectonic plate has been moving 0.041m/year in a north-east direction with respect to a no-net-rotation Earth-centred, Earth-fixed dynamic reference frame such as ITRF2014 (refer section 3.2). Or conversely, the lines of latitude and longitude in terms of such a frame have been slowly shifting southwest across the landscape. In those 28 years to date, the total relative motion is 1.15m which significantly exceeds the 0.2m accuracy specification for pillar placement. It is fortunate therefore, that a plate fixed datum such as IKBD92 was used to specify the Iraq-Kuwait boundary coordinates.

6 CONCLUSIONS

It is increasingly common for geodetic survey to form part of the definition of modern international boundaries. The form of definition can vary but nevertheless the negotiations for delimitation, demarcation and maintenance should take into account the long-term characteristics of the geodetic datum used to support or define the boundary. This will include consideration of:

- The global rather than local nature of modern geodetic datums
- The ability to define coordinate reference frames with an accuracy of a few centimetres or better
- The impact of tectonic plate motion and other forms of earth deformation on geodetic systems
- The increasing use and security of a Global Geodetic Reference Frame (GGRF).

- The need for program of boundary and geodetic datum maintenance in terms of the GGRF.
- Mechanisms for maintaining alignment between boundary coordinates and other survey and geospatial datasets in use in each jurisdiction.

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CHAPTER 6:
MAINTAINING THE INTEGRITY AND UTILITY OF INTERNATIONAL BOUNDARIES IN A WORLD OF GLOBAL POSITONING

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Summary

International boundaries have a long history of marking the extent of the sovereignty and government of countries. Borders have ebbed and flowed over time, to result in a global assemblage of borders making up today's nation states. The marking of these boundaries have slowly evolved and range from, lines on maps and charts, generalized and descriptive lines of topography to well surveyed and monumented borders. This global patchwork of boundaries served in the past to generally meet each nation's needs. For the 21st century however it is clear that the historic ad hoc approach to surveying and mapping of international boundaries is no longer fit for purpose. At present their accuracy will fail to provide the national accountability that is increasingly a requirement for global and international treaties and national governance. The prevalence and convenience of satellite positioning is substituting the global geocentric geodetic system as the common reference system for coordinate positioning. The International Terrestrial Reference Frame (ITRF) provides a reference system that best relates geodetic positions on the earth's surface through three dimensional (3D) geocentric coordinates and velocities. Thus, international boundary coordinates and mapping positions around the world will become increasingly out of terms, and inconvenient to transform, in relation to future user needs. As well, the durability of demarcation on the ground is problematical in face of the intensification of use and construction along some sectors of international boundaries. The important issue is how international boundaries can best be connected and updated to Global Positioning Systems (GPS) and kept relevant to new surveying and data collection global positioning techniques.

Future GPS use will demand an upgrading and standardization of the present surveying definition of international boundaries because of major technological developments and innovation and global societal initiatives. These include the widespread application of satellite technology, accurate measurement of global tectonic movement and the increasing imposition of global and national accountability for international commitments. The pressures for consistently defined and up-to-date territorial boundaries are growing decade by decade. International boundaries have an important role as a critical parameter of spatial infrastructure and the spatial support for good national and international governance. Unequivocal boundaries will be essential in the future for the development and maintenance of harmonious international relations, collaborative resource use, management and conservation. This chapter looks at the implications of the rapid growth of satellite positioning capability and the advent of increasing global responsibilities of nation states for the accuracy and integrity of their framework of legal boundaries. It accepts the advances and continuous growth in geo-positioning applications. It also considers the increasing role of international boundaries as critical national reference baselines for lay and expert locational applications. To accommodate these growing developments and demands it is timely to take a global overview

of international boundaries and plan for their integration into the global satellite geocentric geodetic system and international legal and policy frameworks. It is however, difficult to determine the size and timing of the upgrading needed. A collaborative expert review of the integrity of international boundaries by FIG is recommended as a first step to a common strategy for the future. Such a review could provide an important FIG input to the United Nations Integrated Geospatial information Framework ((IGiF).

Preamble

International boundaries have throughout their long history represented the highest order of territorial and property rights. They identify the extent of national sovereignty and the finite limits of government authority. The role of international boundaries has long been accepted as a basis for the security, social stability and economic development of a country. The network of international boundaries has evolved through centuries of invasion and colonization. Early recording of international boundaries were in relation to geographic and population features and on early maps and charts with no or limited datum. Where not demarcated they were given descriptive identification along natural features and around or through settlements and towns. Subsequently important boundary sectors have been surveyed and more recently tied to national survey systems or a local or special geodetic boundary datum. Where a new or recent geodetic reference has been used it has been assumed that this would ensure that an accurate and ready re-identification of boundary positions could be available long into the future. Demarcation has varied greatly from well monumented and managed borders to remote frontier boundaries along natural features, or maritime limits delineated on charts of varying reliability. However as a result of centuries of colonial arbitrariness, wars and boundary disputes the current global patchwork of international boundary delimitation and demarcation lines suffers from inconsistency, ambiguity, variable marking, accuracy and reliability.

1 BACKGROUND

International Boundary Treaties and Agreements

Many international boundary treaties have their origins in occupation and agreements stretching back into history. Initially these old agreements were brief, couched in very general terms with an economy of descriptions and graphics. In the 19th and early 20th century abbreviated delimitations were developed through field inspections and reports, exchange of letters and eventually agreement on a final wording. Sometimes authoritative correspondence followed giving clarification of some parts of the original wording in the delimited boundary. Once countries achieved independence the authority for establishing their international boundaries rested with the countries themselves. Bilateral agreement on international boundaries is the basis of establishing agreed boundaries between abutting countries. However, international boundaries established in relation to historic written agreements still often reflect an arbitrary colonial past. For example, the African Union in 1964 accepted the existing colonial boundaries for newly independent countries in Africa. This decision embedded serious anomalies inherent in the ad hoc history of these boundaries. It was a pragmatic decision as the status quo would have been easier to manage at that time rather than the

administrative and political and social challenges of attempting any major redrawing of African boundaries. Where there are long standing disputes final boundary agreements take many years and even when third party arbitration is involved, decades elapse while decades can occur before final acceptance and settlement.

The number and density of international boundaries have grown markedly since World War II. In June 1945, 44 countries signed the United Nations Charter but today there are 193 member countries of the United Nations. Since July 1996 some 168 countries have ratified the United Nations Convention of the Law of the Sea (UNCLOS) with an additional 14 countries signing but yet to ratify this agreement. International trade, collaboration and treaties are all implemented through the commitments of these individual nations and depend on good governance throughout each nation to the full limits of its international boundaries.

The nature and condition of international boundaries vary greatly and some sectors are at various stages of negotiation, delimitation, demarcation and administration and maintenance. Over time international boundary agreements may be refined by bilateral adjustment and demarcation or confirmed by occupation and administrative control and occasionally through further judicial decisions. There are many unresolved international boundary issues often leading to serious tensions between nations. Problems have been particularly evident where international boundaries divide significant resources such as oil fields, water resources, and fertile lands. These difficulties are compounded if erroneous identification or incorrect measurements or coordinates have been used as indicators of the border. Where there are long standing or intractable disputes over a particular boundary section in many of such cases the practice has been to mandate a third party to progress the final agreement. These arbiters can include the United Nations, the International Court of Justice, the Permanent Court of Arbitration and independent Commissions empowered by the countries concerned albeit with strictly defined terms of reference. The decisions of these bodies can relate to demarcation, confirmation of a delimitation or further delimitation of an established agreement depending on their terms of reference. This arbitration assists the countries concerned to move towards settling long standing boundary disputes. However, this can take decades with testing legal and quasi legal and research processes involving the parties. The delimitation and demarcation process is lengthy and demanding even for seemingly small issues. For example at the tri-point of the Iraq-Kuwait-Saudi Arabia boundary junction a tiny discrepancy has taken 30 years to resolve.

Existing Surveying Standards

The means of identifying and surveying boundaries has varied widely from territory to territory and over time in relation to the political, governance and administrative requirements of the Parties involved. Since the 19th century surveying and cartographic techniques have been applied using the techniques of those times. There are many examples of early surveying of international boundaries particularly in the new world of the North and South America. The Canada-USA boundary in the first half of the 1800s and boundaries of the old British and Spanish Empire's colonies are some examples.

More recently geodetic datums have been used to reference boundary coordinates to a special or local geodetic datum. The Iraq-Kuwait Boundary Datum (IKBD), Israel-Egypt Boundary Datum (IEBD92), Israel-Jordan Boundary Datum (IJBD94), Eritrea-Ethiopia

Boundary Datum (EEBD), Cameroon-Nigeria Boundary Datum (CNBD) and Kuwait-Saudi Datum are all examples of the establishment of a special geodetic boundary datum for long term relocation purposes. The legal boundary along the Iraq-Kuwait border was defined by the IKBD based coordinates submitted to the Secretary General of the United Nations by the Iraq-Kuwait Boundary Demarcation Commission (IKBDC) on the completion of their boundary demarcation project. This boundary is also marked with substantial monuments indicating the boundary position. Nevertheless the IKBD coordinates held by the UN provide the legal definition of the boundary.

The Eritrea-Ethiopia Boundary is also defined by the coordinates provided by the Eritrea-Ethiopia Boundary Commission on the completion of its work. At present there are no monuments along this boundary. The coordinate definition of this boundary has now been accepted by both Parties. The EEBD was connected to the International Terrestrial Reference Frame (ITRF) to relate it to the geocentric global satellite geodetic system. This was intended to enable accurate identification and updating of the boundary in the future. For their protection at the time of survey the EEBD datum stations were placed in United Nations camp areas.

The Cameroon-Nigeria Boundary Datum (CNBD) was a special boundary datum established for the surveying of that boundary. It is connected to the World Geodetic System (WGS84). The upgrading of the Kuwait-Saudi Arabia boundary has connected it to the ITRF2011.

For Maritime boundaries coordinates are the norm and these can vary greatly in reliability and in the ease and accuracy of transformation and relocation. The charts relied on at the time of the establishment of these boundaries vary greatly in age and quality of content and accuracy. The reference frames can vary from connections to a land based geodetic datum, old hydro graphic or survey datum or no horizontal datum at all. Nevertheless, well defined maritime boundaries are as important for the allocation of rights and consent to marine resources as international land boundaries.

This wide range of descriptive, surveying and mapping definitions of international boundaries has resulted in a global mosaic of boundaries defined at widely different levels of accuracy, discoverability or capability of reinstatement.

2 GLOBAL CHANGE DRIVERS IN THE 21ST CENTURY

The world is at present faced with some relentless forces for change that will have significant implications for the role and security required of international boundaries in the future. Rapid positioning technology offers new levels of geo-positioning and enables increased and more demanding user positioning needs. In this continually evolving environment the adequacy and the utility of traditional international boundaries to provide and accurate baseline for data collection and resource use becomes more and more problematic. The accurate identification of international boundaries is critical as environmental, resource, and land use consents, regulations and restrictions expand to meet new demands and opportunities. These demands include multiplying user needs and technological applications, climate change responses, population pressure and globalization opportunities and risks. Where international boundaries are near or across significant natural resources the accurate and up-to-date location of international boundaries will be even more crucial to the future optimization of sustainable resource use. The issues covered below all have the potential to test the integrity of in-

ternational boundaries in a way never before contemplated. These portents of change are largely indicative and only time will reveal their impact over the long term. However, adaption to the change ahead will need future planning and foresight and continued monitoring and feedback. The integrity of international boundaries has never been more necessary.

The Pervasive Use of Satellite Positioning

The rapid development of satellite positioning through the profusion of geo-satellites and measurement systems offers large improvements in the accuracy, capability and speed of surveying. Developing Global Navigation Satellite Systems (GNSS) applications provide increasingly accurate positioning for data collection applications to identify and analyze thematic data. They will provide a wealth of remote sensing information including telemetry and real time streaming. This continuing proliferation of thematic and geographic and automated applications extends right around the globe across all countries and their borders. These new developments and augmentation of satellite positioning technology are providing users with higher levels of accuracy and utility. Accompanying this rapid technology improvement are the rising expectations of specialist and citizen users. All are now anticipating high levels of accuracy and utility in the delivery of locational and spatial services. Consequently, it will be increasingly necessary for a wide range of users to be readily able to relate their measurements and positioning to existing positioning and legal frameworks including international boundary coordinates.

Supplementary initiatives and densification are providing increasing levels of accuracy. These include the densification of ITRF, Satellite Based Augmentation Systems (SBAS), Real Time Kinematic (RTK), and mobile receivers. ITRF provides accuracy of a few centimeters or less and maintains this over long global distances. .ITRF positional coordinates are for a particular epoch date and through velocity adjustment can be related to any other dates. Tectonic plate movement and crustal deformation are detectable at the level of accuracy of ITRF positioning. The Japanese national geodetic system demonstrates leading edge practice in the use of satellite geodesy for providing an ITRF connected primary geodetic system, and real time, accurate satellite geo-positioning data to users throughout Japan.

The Satellite-Based Augmentation System (SBAS) now offers increased levels of utility and accuracy for a wide range of positioning applications for a number of industry sectors. It is a system of differential corrections to Global Navigation Satellite Systems (GNSS) positioning delivered from a geostationary satellite. There is global coverage of SBAS apart from the Australian region which has now built a case for government funding of an operational SBAS. This region is the last one to establish SBAS coverage. Because of this time lag it will be able to leap frog other regions in terms of services offered. SBAS will offer a second generation SBAS in the Australia-New Zealand and Pacific region based on Dual Frequencies as well as Multi Constellations (DFMC) and Precise Point Positioning (PPP). The Southern Positioning Augmentation Network (SPAN) will be the first in the world designed for multi constellation and dual frequency operations while still supporting legacy systems. The initial research indicates huge efficiency and financial benefits to industry sectors such as agriculture, resources, construction, roads, maritime, aviation, water utilities rail and consumers. Low cost applications to sub-meter accuracy are planned for hand held devices such as mobile phones. There is also a

good potential increase in accuracy for high end users. This further step in capability will lift user applications for geo-positioning to a new level eventually worldwide.

Real Time Kinematic (RTK) satellite technology has been available for some time to enhance the position data derived from satellite positioning. It relies on a single reference station to provide real time corrections giving up to centimeter accuracy. It places additional local demands by service users for consistency and integrated access to geodetic systems and datums. A prerequisite of RTK is up-to-date coordinates of reference stations. For optimum performance of the RTK network it needs provision for transformation to local systems. RTK networks in geodynamic areas experience constantly changing coordinates and need frequent updates of reference station coordinates with a good quality and consistency of the geodetic framework.

Japan is a leader with its GNSS Earth Observation Network System (GEONET) operated by the Geospatial Information Authority (GSI). This service has over 1300 control stations at an average density of 20k. RINEX data is provided through the internet at 30 second intervals. Earth movement is monitored daily. GEONET serves as a source of up to date, accurate, base geodetic data for national surveying activity throughout the country. With the real time connections to the geocentric geodetic system consistency can be achieved through the adjustments for the impact of crustal deformation and plate movement. The GEONET service has facilitated the densification of the Global Geocentric Geodetic System in Japan. This in turn has enabled the recent "Japanese Geodetic Datum 2000" (JGD2000) to represent the new geodetic reference system in Japan.

The ready availability of sub-meter accuracy, now imminent in the Australia-New Zealand region of SBAS and potentially for all other regions, will provide hand held and Unmanned Aerial Vehicles (UAV) GPS users with high accuracy capability. UAV users need to get to their precise area of operation quickly, safely and automatically. It will be important that they have accurate positioning information and navigation in relation to the precise location of the international boundaries in border areas. Regulations for UAV will need to be exact in defining three dimensional (3D) positioning requirements.

Tectonic Plate Movement and Crustal Deformation

Through satellite positioning crustal movement and deformation can now be measured accurately and consistently in real time. For international boundaries fixed in the past the coordinates of boundary monuments and positions become significantly displaced over time as revealed by GPS. Where there are well demarcated boundaries these present little immediate practical problems but can introduce questioning and ambiguities about the quality of critical international boundary coordinate positions. Where there are only local coordinates or geographic indicators the modern user can lack the transformation information needed to have confidence in them. The consequences for the surveying of international boundaries of both crustal deformation and continuous plate movement for geospatial positioning are becoming increasingly significant over the longer term.

Crustal measurement has been able to be neglected with traditional cadastral and boundary surveying in the past. However, satellite measurement is now making yearly plate movement, evident to users. The annual movement of the tectonic plates varies greatly and ranges of annual movement have been established for the major and minor plates. Wikipedia figures provide some general ranges of annual plate movement.

These average from 6mm for the Somalia plate to 89mm for the Pacific plate, giving an average annual movement for 8 major and 14 minor plates as 33mm per year. High annual rates apply to the Pacific, Australian, Caroline, Philippine and Cocos plates, with lower rates applying to the Eurasian, North American, African, Antarctic plates. Significant differential displacement also occurs in locally deformed areas particularly along tectonic plate boundaries. For the future, tectonic plate movement and crustal deformation requires regular detailed monitoring and modelling across the globe to ensure the continually changing displacements regularly update boundary coordinates.

Globalization

Globalization adds a further requirement for accurate positioning and recognition of borders for the sustainable use of resources and the containment, mitigation, management, and prevention of environmental and health risks. Accurate international boundary location enables efficient regulation, effective governance and effective application of international treaties. As international treaty commitments become increasingly demanding the integrity of national statistics will require consistent application inside each nation's international boundaries. A wide range of thematic and statistical data depend on the integrity of a nation's boundaries for their reliability, consistency and trustworthiness.

The efficiency and good outcomes of international agreements require certitude and confidence about the location of resources and the access and user rights applying to particular transactions and regulations. As well as offering opportunities, globalization also involves the introduction of serious risks such as pandemics. Pandemics particularly test the robustness of borders in relation to maintaining surveillance and security. It is becoming crucial that there is trustworthy global data to support many areas of national and international concern and the achievement of national and international economic, social, environmental and cultural goals.

Environmental and Climate Change Issues

The ongoing rise in earth's temperature through climate change is a burgeoning global issue and it heralds as increasing range of pressures on international boundaries. Together with other related environmental issues climate change is presenting an urgent need for international agreement and effective programs of action. National geographic inventories and accounting are baselines required for such agreements and require continuous spatial identification and positioning inside a nation's external boundaries. As global warming continues, international boundaries will face more direct pressures caused by population and settlement movement, arising from changing rainfall and temperatures, wild fires, sea level rise and other environmental events. All government responses from rescue, evacuation, resettlement and relocation will depend on accurate spatial data for the whole extent of a nation as defined by its international borders.

Population Growth

World population in 2020 is 7.8 billion and is continuing to grow at a projected rate of 80m per year for the rest of the 21st century. The current population growth is putting

huge pressure on the national resources and infrastructure. The implication for food production, poverty, health, education, energy water availability and economic growth are serious challenges to all of the 17 current United Nations Sustainable development Goals.

In times of rapidly increasing populating, efficient national development will require every nation to optimize the sustainable use of its total resources. Clearly defined and recognized boundaries are a basis for confidence building and long term cooperation, in the joint use and management of these resources by the territorial parties concerned. The North Sea oil fields are one example of how well established and accepted international boundaries can be cooperatively managed to allow full use of oil resources. This has allowed the full resource to be utilized irrespective of its location in relation to the international boundaries. There are many areas of resources along international boundaries where precisely defined and recognized international boundaries can enable cooperative use of various resources or infrastructure. Recently accurate definition of the maritime boundary between Cameroon and Nigeria in the Gulf of Guinea has provided certitude for the better use of each country's maritime territory and the collaborative use of cross border resources.

3 CHALLENGES AND POTENTIALITY

International boundaries are increasingly providing important base lines for the collection and integration of a wide range of administrative, social, economic, legal and cultural data. These increasing demands for geo-referencing applications will test the utility and quality of international boundaries in the coming years. With the regard to the emergence of widespread governance requirements there are significant risks of international boundary practice lagging behind current user needs. The integrity of international boundaries over time will depend on the facility to re-establish their definitive location not only on the ground but also in a real time virtual world of satellite coordinates. Thus, the up-to-date tracing of this tectonic movement is becoming more and more critical to maintaining the integrity of international boundary coordinates.

The main implication for international boundaries of this increase in the growth of user applications of accurate satellite positioning, is the need for all international boundary position coordinates to be readily available in a consistent and authoritative transformable format. This means full compatibility with the satellite geocentric coordinate system. If not directly available then the boundary position coordinates need to be easily transformable from their existing format. As well, these coordinates, where required, should be supported by appropriate demarcation. Many existing boundaries have barely sufficed in the past and most are now unlikely to be readily transformable into modern satellite positioning coordinates.

Taking into account the variability and multiplicity of international boundary coordinates there is an exacting task ahead. The permanent stability of international boundary datum stations, monuments and coordinates cannot be taken for granted. This is because of the difficulty of protecting even substantial boundary and datum monuments and marks from damage or destruction over even a decade or two. The removal of datum stations can degrade the connections of a boundary datum and consequently the capability of ready transformation of international boundary coordinates to global geodetic accuracy.

Belgrave reports that this has been the experience with the IKBD92 over a period of just 20 years. The maintenance survey of this boundary only found 1 of the 4 original datum stations. Although it was in good condition it was not sufficient to provide a reference to confirm the original +/- 2cm accuracy of boundary positions in relation to IKBD92. There is now a real risk of that datum being lost. Of the 106 main pillars inspected 72 had missing or damaged center plaques and three main pillars were damaged beyond repair. These were all substantial concrete boundary pillars weighing ten tons each. New connections to the primary control system provided a new geodetic connection but with a significant loss of external accuracy. Thus, the role of the original special purpose datum has been negated through the loss of the essential datum stations over time. The Iraq-Kuwait border area is a small highly defended strip of land but even so this degree of destruction is sobering. The legal coordinates held by the United Nations Secretary General remain internally in terms of the specified +/- 2cm for reinstatement. However, due to the loss of datum stations they are now dependent on connections to a local primary control system. This is a downgrade from IKBD92 with only a 2m confidence in terms of the global geodetic system. According to Wikipedia estimates the Arabian plate has moved between 380 mm to 500mm in 25 years. Thus, there is a major difference between the legal coordinates held by the UN Secretary General and current satellite positioning. This discrepancy needs to be remedied urgently by connection to the ITRF, to validate the integrity of the legal coordinates lodged with the United Nations Secretary General.

Belgrave reports also that in the case of the EEBD the datum stations were located in United Nations camp sites. With the withdrawal of the United Nations Mission from these sites these datum stations could be at risk over the coming years, putting the existing connection of these boundary coordinates to the ITRF in jeopardy. This could cause serious complications for the future identification and demarcation of the legally coordinated boundary, which at present has no ground marking. Both Ethiopia and Eritrea have recently confirmed the Algeria Agreement which required the demarcation of this boundary.

The vulnerability of datum stations can be overcome with a robust connection to the ITRF. This will provide a sound basis for bringing all international boundary coordinates into terms with the modern geocentric satellite 3D system. This can be done through direct connections to international boundary datum or positions. A better alternative would be a national densification of the ITRF through an upgrade of a nation's primary control with connections to key international boundary positions. Such a solution would ensure that the all legal framework boundaries including the external ones are readily transformable into ITRF epochs.

With regard to the role of international boundaries in relation to the challenges of globalization, climate change and population growth, this is highly relevant to the current work of the United Nations. It is now important that external boundaries of countries be included in the current United Nation's legal and policy frameworks initiative. The importance of a better understanding of the definition and importance of authoritative national and international data is a current exercise of the United Nations Global Geospatial information Management (UN-GGIM) section. In particular, its Working Group on Policy and Legal Frameworks for Geospatial Information Management is offering access to an extensive network to help gather examples of best practice, and facilitate information sharing. The Working Group is seeking to establish effective and efficient geospatial management globally, and is implementing an Integrated Geospatial In-

formation Framework (IGiF) as an early international consultative step. IGiF provides a basis and guide for integrating, strengthening and maximizing geospatial information management and related resources in all countries around the world. International boundaries are a key element of the spatial infrastructure that supports the IGiF. All of the databases important to the IGiF such as industry statistics, trade statistics, tourism statistics, big data, development indicators demographic and social statistics, gender statistics, need to be gathered in a legal and policy framework, consistent in format and positioning accuracy with the relevant international borders.

4 CONCLUSION

The past importance of international boundaries to only the abutting countries is now being superseded by their significance internationally. The effectiveness of global opportunities, treaty commitments, inventory and monitoring, all require high quality geo-positioning and accurate areal and locational calculations within each national border. Thus, the integrity of each national border becomes an issue of international confidence and statistical efficacy. Currently, there is a great lack of consistency, and exactness in many international boundaries. Overall, the present ad-hoc assemblage and inconsistency of international boundaries makes them ill-suited to cope with the sea change of new geo-positioning technology and future user needs and demands. The challenges ahead are how the existing discontinuity of the variable survey quality of international boundaries can be reviewed and transformed, so as to better serve users positioning requirements and future needs for effective national and international governance.

In today's global positioning world, the delimitation, demarcation and maintenance of international boundaries can be future proofed by being connected to a regional densification of ITRF. This could well be the densification of ITRF through the national primary control system. It would allow international boundary coordinates to be connected to an epoch of the ITRF and upgraded regularly through the national geodetic system. This would ensure international boundary positions can readily be brought into terms with satellite positioning for all user applications. Taking into account the average movement of tectonic plates in the order of 3.3cm pa, the increasing accuracy of even hand held and UAV based receivers, will ideally require the regular upgrading of all international boundary coordinates every decade. For the future consistency, the ellipsoid, datum and coordinates for calculations, and the long term adjustment to the ITRF, could be a standard requirement in the technical specifications of all international boundary demarcation agreements.

The assessment in this paper of the future impact of global drivers of change is indicative only, and the impact of these changes will need continuous monitoring over time to determine the robustness of international boundaries for future user demands. The examples in this paper are far too isolated to judge the totality of the circumstances applying to international boundaries globally in the future. In these circumstances a desk reconnaissance would be a prerequisite for effective longer term planning. A first step would be a collaborative assessment, of the fitness for future purposes of the existing surveying condition and standards of international boundaries. A comprehensive inventory and data base would provide a sound basis for developing a collaborative strategy for connections and transformation to ITRF. This would involve national survey organizations and provide detailed returns of the present survey status of their interna-

tional boundaries. Follow up analysis and research would assist in the development of strategic advice and recommendations by FIG for the long term survey upgrading and maintenance of international boundaries.

Such a survey would provide sound input into the current UN-GGIM initiative and fit well into the role and organizational capability of FIG through its many national member organizations. Commission 1 Working Group on International Boundaries, Settlement & Demarcation with its established approach and expertise would be a logical leader for this inventory of the survey status of international boundaries and preparation of strategic recommendations. It could use the wider FIG membership. The inventory information could cover, for example, items such as lengths of boundary demarcated, coordinated, connected to a datum (datum identified and rated for geodetic quality and currency), and plans for upgrading international boundary positioning. Such a survey could need further follow up stages for any consequential items. The findings of such a survey would position FIG well to contribute to UN-GGIM, IGiF in relation to the development of an ITRF compatible format for ensuring the currency and authority of international boundary coordinates. This would be a progressive first step in ensuring the future role and integrity of international boundaries as baselines and trustworthy perimeters for legal and policy frameworks, national administration and governance important to international commitments and treaty obligations.

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FIG PUBLICATIONS

The FIG publications are divided into four categories. This should assist members and other users to identify the profile and purpose of the various publications.

FIG Policy Statements

FIG Policy Statements include political declarations and recommendations endorsed by the FIG General Assembly. They are prepared to explain FIG policies on important topics to politicians, government agencies and other decision makers, as well as surveyors and other professionals.

FIG Guides

FIG Guides are technical or managerial guidelines endorsed by the Council and recorded by the General Assembly. They are prepared to deal with topical professional issues and provide guidance for the surveying profession and relevant partners.

FIG Reports

FIG Reports are technical reports representing the outcomes from scientific meetings and Commission working groups. The reports are approved by the Council and include valuable information on specific topics of relevance to the profession, members and individual surveyors.

FIG Regulations

FIG Regulations include statutes, internal rules and work plans adopted by the FIG organisation.

List of FIG Publications

For an up-to-date list of publications, please visit
www.fig.net/pub/figpub

ABOUT FIG

International Federation of Surveyors is the premier international organization representing the interests of surveyors worldwide. It is a federation of the national member associations and covers the whole range of professional fields within the global surveying community. It provides an international forum for discussion and development aiming to promote professional practice and standards.

FIG was founded in 1878 in Paris and was first known as the Fédération Internationale des Géomètres (FIG). This has become anglicized to the International Federation of Surveyors (FIG). It is a United Nations and World Bank Group recognized non-government organization (NGO), representing a membership from 120 plus countries throughout the world, and its aim is to ensure that the disciplines of surveying and all who practise them meet the needs of the markets and communities that they serve.

International boundaries of a state define the territorial limits of its sovereignty and the area where its laws are applicable. 193 UN member states have over seven hundred international boundaries on land and in the sea. Surveyors play a central role in the boundary making process. Stability of boundaries is of utmost importance in peace keeping throughout the world. The International Court of Justice stated that "In general, when two countries establish a frontier between them, one of the primary objects is to achieve **Stability and Finality**" (The Temple Case, 1962).

The lack of clarity in defining international boundaries between states has been one of the main reasons for territorial disputes and ensuing wars. Part of the problems of boundary delimitations resulted from selection of unstable common natural geographic features that have been chosen for delimitation of boundary lines. Such are boundaries in rivers, used for about one third of the land boundaries. Shorelines, lakes and glaciers are other examples. The origin of many natural geographic feature based problems is an outcome of climate changes and global warming. Many others are a result of man-made activities. Another source of instability of boundaries refers to dynamic land moving due to tectonic activities. Unfortunately, the numerous cases of disputes regarding past delimitation of natural boundaries, and especially river boundaries, show big disadvantages of natural boundaries.

This FIG Publication deals with river boundaries, elaborating on the practical case of the Jordan and Yarmuk Rivers. It deals with boundaries in lakes and elaborates on the practical case of the Dead Sea. It deals with the Italian boundaries on melting glaciers and the "moving border" approach. In addition, it deals with issues of instability of boundaries due to tectonic plate movement, including issues of geodetic reference systems for boundary documentation.

This FIG Publication has been initiated and edited by Dr. Haim Srebro, who has already developed methodology of a process driven boundary making model (FIG Publication 59), following almost fifty years of practical experience in boundary making, including boundary delimitation in rivers and lakes. The practical part has been prepared by senior practical professionals, with expertise in boundary delimitation and demarcation. Three of them served as Director Generals of national surveying and mapping organizations (Dr. Haim Srebro in Israel and Dr. Bill Robertson and Prof. Don Grant in New Zealand), one served as chief geographer (Prof. Andrea Cantile in IGMI Italy), and one served as chief surveyor in UN international boundary missions (Vince Belgrave).

This FIG Publication has been prepared under the framework of the FIG Commission 1: Professional Standards and Practice work plan for 2019–2022. It is intended to promote the sharing of methodological knowledge and experience regarding delimitation of international boundaries and to promote peace throughout the world.

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