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Tigris, Euphrates, and Shatt Al-Arab River System: Historic and Modern Attempts to Manage and Restore Iraq's Lifeline

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Abstract

In Iraq, the principal rivers are the Tigris, Shatt Al-Arab and Euphrates. From their headwater sources in the mountains of eastern Türkiye, these rivers descend through valleys and gorges and flow into the uplands of Syria and northern and central alluvial plain of Iraq. The Euphrates and Tigris Rivers confluence to form the Shatt Al-Arab river at Al-Qurnah which flows into the Persian Gulf. From sources in the Zagros Mountains other tributaries join the Tigris from the east. The Tigris and Euphrates rivers flow in a southeastern direction through the central plain and discharge into the Mesopotamian Marshes, which include permanent marshes, lakes, and riparian habitat. The rivers and their tributaries drain an area of 879,790 km^2 which includes almost the entire area of Iraq as well as land in Syria, Türkiye, Kuwait and Iran. The region has historical importance as part of the Fertile Crescent region and where Mesopotamian civilization first emerged. The post war reconstruction efforts in the Yusifiyah township, an important food production region for Baghdad, illustrate the importance of these water resources. In addition, the advent of soil tunnels by Iraqi insurgents within the riverine corridors will make reconstruction of this resource more complex. The primary objectives of this study are to assess lessons learned, manage, and restore the Tigris, Euphrates, and Shatt Al-Arab river system lifeline in Iraq.

Keywords

Mesopotamian, Shatt Al-Arab, Iraq, Tigris, Euphrates, Baghdad, Soil Tunnels, Yusifiyah

1. Introduction

1.1. Mesopotamia

The Tigris, Euphrates, and Shatt Al-Arab watershed (Figure 1) [1] [2] is shared between Iraq, Türkiye, Iran, Syria, and Kuwait [3] [4] [5] [6] [7]. Since the 1960s, when Türkiye began the GAP (Turkish: **G**üneydoğu **A**nadolu **P**rojesi) project, water disputes have regularly occurred along with associated dam's effects on the environment. Beginning in the 1960s (Figure 1), Türkiye implemented a public-works (GAP) project aimed at harvesting the water from the Euphrates and Tigris rivers through the construction of 22 dams, for hydroelectric energy and irrigation purposes.

During droughts, Iranian and Syrian dam construction contributed to political tension within the basin. The ecoregion is characterized by two large rivers, the Tigris and Euphrates rivers (Figure 2). In the upper watershed the high mountains receive more rain and snow than the lower watershed, which has an arid and hot subtropical climate. Seasonal and permanent marshes in the lowlands are sustained by annual snow melt from the mountains and spring floods. The plain between Euphrates and the Tigris rivers is called Mesopotamia. The

Figure 1. Euphrates and Tigris rivers and watershed (yellow) in Türkiye, Syria, Iraq, Iran and Kuwait. Map created by Cruz Dragosavac.

Figure 2. The location of the Tigris and Euphrates rivers and tributaries in Iraq. Public domain.

earliest emergence of literate urban civilization occurred as part of the larger Fertile Crescent in the Uruk period. Many Tigris tributaries originate in Iran and the Tigris-Euphrates confluence forms part of the Kuwait-Iraq border [8]. There is a large floodplain in the lower basin where the Karun, Euphrates, and Tigris rivers converge to create permanent lakes, marshes, and riparian, including the Shatt Al-Arab River and the Mesopotamian Marshes. The hydrology of these marshes affects the ecology of the entire upper Persian Gulf.

1.2. Soil Tunnels on Tigris River in Iraq

Iraq Tunnels Under the Iraqi town of Sinjar, Islamic State of Iraq and Syria (ISIS) militants built a network of tunnels (**Figure 3**), complete with sleeping quarters, wired with electricity and fortified with sandbags [9]. Olson and Speidel [10] found "*the tunnels*, *which were uncovered by Kurdish forces that took the city in northwestern Iraq after more than a year of ISIS rule. Between 30 and 40 tunnels inside Sinjar were found by the Iraqi Kurdish fighters known as*

Figure 3. Soil tunnel entrance. Reprinted with permission from Editor of Open Journal of Soil Science.

Peshmerga. It was a soil tunnel network inside the city. Daesh (*the Arabic acronym for ISIS*) *dug these trenches to hide from airstrikes and had free movement underground as well as to store weapons and explosives. Two soil tunnels ran several hundred meters, each starting and ending from houses, through holes knocked in walls or floors. This was their military arsenal. The narrow tunnels, carved in the rock apparently with jackhammers or other handheld equipment, are just tall enough for a man to stand in. Rows of sandbags line sections of the walls, electrical wires power fans and lights and metal braces reinforce the ceilings* (**Figure 4**) [10]."

Joseph [9] found "*one section of the tunnel resembled a bunker. In 2017 a brave Kurdistan team explored the aftermath of the east Mosul military operation where Peshmerga discovered several ISIS underground tunnels. In the documentary, the Kurdistan news team led by Ragaz Rasheed visited retaken villages and showed the aftermath of war while interviewing some Peshmerga officers on the front lines. The team showed several ISIS tunnels discovered by Peshmerga. The passageways differed from each other in terms of depth and length. In one of the tunnels, Peshmerga found some ISIS extremists still alive* [9]."

Olson and Speidel [10] reported "*a documentary had been filmed a few months after Peshmerga liberated the area on August 14, 2017, by the jihadist group. These soil tunnels could be constructed in an arid climate with soils* (*Aridisols*) *having a lower permanent water table. The parent material is unconsolidated and overlies bedrock which can be excavated with power drills. ISIS has built extensive networks under cities it had conquered to evade round the-clock air strikes by the United States and its allies and used tunnels to pump oil from captured fields, a key source of funding. Approximately 30 or 40 tunnels were found inside Sinjar, an Iraqi town captured by the jihadists in 2014 and retaken in November 2015 by the Kurdish forces* [10]."

Figure 4. Tunnel with electrical. Reprinted with permission from Editor of Open Journal of Soil Science.

1.3. Colorado and Rio Grande Rivers

Many of the Worlds Great Rivers are drying up including the Colorado and Rio Grande rivers in Southwestern United States [11] [12]. Historical lessons learned in these river watersheds can be applied to other watersheds such as the Tigris, Euphrates and Shatt Al-Arab watersheds. Modern and Native American civilizations have been forcing the unsustainable use of the Colorado River Valley land resources for centuries. Olson and Lang [11] suggested "*much can be learned from past Native American cultures that created irrigation systems to offset low rainfall. These lessons learned can be applied to our modern civilization. We can learn a lot from their previous behavior and experiences and could apply the lessons learned to our current disappearing Colorado River situation. Little of the Colorado River water flow reaches the international border with Mexico near Yuma, Arizona* [11]."

"In addition, there is also a need to restore border security for the Lower Rio Grande, an international border river. It will require a lock and dam system and increased river flow for the Rio Grande to ever recover. The increased flow needs to be achieved by adding water from feeder lakes and a water pipeline. An aggressive conservation effort, in urban areas and on irrigated agricultural lands, and a balanced approach to water management which must include efficiency measures [12]."

The primary objectives of this study are to assess lessons learned, manage, and restore the Tigris, Euphrates, and Shatt Al-Arab river system lifeline in Iraq.

2. Iraq Natural and Cultural Resources Findings

Critically endangered fish species endemic to the Batman and Ambar rivers, Turkish tributaries of the Tigris, include The Batman River loach (*Paraschistura chrysicristinae*). The species (**Figure 5**) is endangered by drought, habitat fragmentation and from the construction of the Batman Dam (**Figure 6**). The Batman

Figure 5. Batman River loach. Photo credit: Shoal Drawing, Corryn Wetzel.

Figure 6. Batman Dam in Türkiye. Photo credit: Rehman Abubakr.

River loach had not been observed since 1974 and was thought to be extinct until a 2021 expedition netted 14 fish living above the Batman Dam [13].

In southern Iraq, the Mesopotamian Marshes (Figure 7) were historically the largest wetland ecosystem of Western Eurasia. The aquatic vegetation includes rushes, reeds, and papyrus, which support numerous species. The Tigris and the Euphrates River valleys are very fertile. Marshy land is home to water birds, some spending the winter in these marshes living off the lizards, frogs, fish and snakes and others stopping while migrating. Other animals found in these marshes are endemic rodent species, water buffalo, gazelles and antelopes and small animals such as the jerboa. The wetland Iraq babbler (*Argya altirostris*) and Basra reed warbler (*Acrocephalus griseldis*) are endemic to the Mesopotamian Marshes (Figure 8).

Figure 7. Location of Mesopotamia (green) in Iraq. Public domain.

Figure 8. Mesopotamia marshes. Reprinted with permission from editor of Open Journal of Soil Science.

2.1. Ecology

An important food fish that lives in the coastal waters and spawns in the lower reaches of the basin is the The Hilsa shad (*Tenualosa ilisha*). Other ocean species occasionally travel the lower reaches of the rivers such as bull sharks (*Carcharhinus leucas*) [4] [13]. The abundant species of barbs (*Barbus*) can reach up to two meters in length. For thousands of years, some species have been important food sources for residents. Many species move seasonally between the marshes and rivers for spawning, feeding, and overwintering [14].

Richardson, Hussain, *et al.* [15] reported "*the Iraq began in the 1950s, to rec-*

laim land for agriculture and oil exploration. Saddam Hussein extended this work in the late 1980s and early 1990s, as part of ecological warfare against the Marsh Arabs, a rebellious group of people in Baathist Iraq. However, with the breaching of the dikes by local communities after the 2003 invasion of Iraq (**Figure 9**) *and at the end of a four-year drought, the process has been reversed and the marshes have experienced a substantial rate of recovery. The permanent wetlands now cover more than 50% of pre-1970s areas, with a remarkable re-growth of the Hammar and Hawizeh Marshes with some recovery of the Central Marshes* [15]."

2.2. Ecological Threats

Iraq suffers from soil salination and desertification partially caused by thousands of years of agricultural activity. Plant life and Water are sparse. Saddam Hussein's government water-control projects drained the inhabited marsh areas east of An Nasiriyah by diverting or drying up streams and rivers (**Figure 10**). There are also inadequate supplies of potable water for water buffalo. Under the Ba'athist regime the Shi'a Muslims were displaced. The loss of the natural habitat poses a threat to the area's wildlife populations.

An extensive natural wetlands ecosystem, the marshlands, were developed over thousands of years in the Tigris-Euphrates basin which once covered 15 - 20,000 square kilometers [14]. In the 1980s, this ecoregion was put in grave danger during the Iran-Iraq War. BBC [16] reported "*that the Mesopotamian Marshes, which were inhabited by the Marsh Arabs, were almost completely drained. Although they had started to recover after the fall of Ba'athist Iraq in 2003. However, drought, intensive dam construction and irrigation schemes upstream have caused them to dry up once more* [16]."

According to the AMAR Charitable Foundation and the United Nations Environmental Program [17], "*between 84% and 90% of the marshes have been destroyed since the 1970s* (**Figure 10**)*. In 1994, 60 percent of the wetlands were*

Figure 9. United States military crossing the Tigris River in Al Hindiyah, Iraq. Photo credit: John Moore, Associated Press.

Figure 10. Drainage of swampland. Public domain.

destroyed by Hussein's regime—drained to permit military access and greater political control of the native Marsh Arabs. Canals, dykes and dams were built routing the water of the Tigris and Euphrates Rivers around the marshes, instead of allowing water to move slowly through the marshland. After part of the Euphrates was dried up due to re-routing its water to the sea, a dam was built so water could not back up from the Tigris and sustain the former marshland. Some marshlands were burned, and pipes buried underground helped to carry away water for quicker drying. The drying of the marshes led to the disappearance of the salt-tolerant vegetation. The plankton rich waters no longer fertilized surrounding soils and cannot support 52 native fish species, the wild boar, buffalo, red fox, and water birds of the marsh habitat [17]."

2.3. Water Disputes

Beginning in the 1960s (Figure 1), Türkiye implemented a public-works (GAP)

project aimed at harvesting the water from the Euphrates and Tigris rivers through the construction of 22 dams, for hydroelectric energy and irrigation purposes. Although the water dispute between Syrian and Türkiye was more problematic, the GAP project was also perceived as a threat by Iraq. The tension between Iraq and Türkiye about the issue was increased as a result of Türkiye and Syria's participation in the UN embargo against Iraq following the Gulf War. However, the water dispute between Syria and Türkiye had never become as significant an issue [18].

Reuters [19] found "*the 2008 drought in Iraq sparked new negotiations between Iraq and Türkiye over trans-boundary river flows. Although the drought affected Türkiye, Syria and Iran as well, Iraq complained regularly about reduced water flows. Iraq particularly complained about the Euphrates River because of the large amount of dams on the river. Türkiye agreed to increase the flow several times and beyond its means, in order to supply Iraq with extra water. Iraq has seen significant declines in water storage and crop yields because of the drought. To make matters worse, Iraq's water infrastructure has suffered from years of neglect and conflict* [19]."

Türkiye, Syria and Iraq agreed to restart the Joint Trilateral Committee on water for the three nations, in 2008, for better water resources management. Iraq, Syria, and Türkiye signed a memorandum of understanding on September 3, 2009, to develop joint water-flow-monitoring stations and to strengthen communication within the Tigris–Euphrates Basin. On September 19, 2009, Türkiye formally agreed to increase the flow of the Euphrates River to 450 to 500 m^3/s, but only for a month. Iraq agreed to provide petroleum to Türkiye in exchange for help curbing Kurdish militant activity within their border region. One of Türkiye's last large GAP dams on the Tigris, the Ilisu Dam (**Figure 11**), was the source of political strife and was strongly opposed by Iraq [20].

2.4. Mesopotamia

Seymour [21] noted "*Mesopotamia is a historical region of West Asia situated*

Figure 11. Ilisu Dam in Türkiye. Photo credit: EsraGurcay.

within the Tigris, Euphrates, and Shatt Al-Arab river system, in the northern part of the Fertile Crescent. Today, Mesopotamia is primarily in modern Iraq [21]." In the broader sense, the historical region included present-day Iraq and parts of Iran, Syria, Kuwait and Türkiye [22] [23] [24].

The Akkadians and Sumerians (including Babylonians and Assyrians) each dominated Mesopotamia from c. 3100 BC, the beginning of recorded history to 539 BC the fall of Babylon in, when it was conquered by the Achaemenid Empire. Mesopotamia was next conquered by Alexander the Great in 332 BC. Mesopotamia became part of the Greek Seleucid Empire after the death of Alexander the Great.

Milton-Edwards [25] stated that "*Mesopotamia is the site of the earliest developments of the Neolithic Revolution from around 10,000 BC. It has been identified as having inspired some of the most important developments in human history, including the invention of the planting of the first cereal crops, the wheel, and the development of mathematics, cursive script, agriculture and astronomy. It is recognized as the cradle of some of the world's earliest civilizations. Around 150 BC, Mesopotamia was under the control of the Parthian Empire. It became a battleground between the Parthians and Romans, with western parts of the region coming under ephemeral Roman control. In 226 AD, the eastern regions of Mesopotamia fell to the Sassanid Persians. The division of the region between the Roman* (*Byzantine Empire from 395 AD*) *and Sassanid Empires lasted until the 7th century Muslim conquest of Persia of the Sasanian Empire and Muslim conquest of the Levant from Byzantines. A number of primarily Christian native Mesopotamian and neo-Assyrian states existed between the 1st century BC and 3rd century AD, including Osroene, Adiabene, and Hatra* [25]."

2.5. Geography of Mesopotamia

In Upper Mesopotamia (**Figure 12**) the Tigris river flows through the region of modern Mosul. One of the traditional types of structures, Mudhif (reed house) structures (**Figure 13**), have been built by the Marsh people of southern Mesopotamia for at least 5000 years. A carving of a mudhif, dating to around 3300 BCE, was discovered at Uruk [26].

The land between the Euphrates and Tigris rivers encompasses Mesopotamia, both of which have their headwaters in the neighboring Armenian highlands. These rivers are fed by numerous tributaries (**Figure 2**), and the entire river system drains a vast mountainous region. The steep banks of the Tigris made traveling difficult. Most overland routes in Mesopotamia usually follow the Euphrates. The climate of the region is semi-arid with a vast desert expanse in the north. However, there are 15,000-square-kilometer region of marshes, lagoons, mudflats, and reed banks in the south. In the extreme south, the Tigris and Euphrates unite and flow into the Persian Gulf via the Shatt Al-Arab River.

Broadbent [26] noted "*the arid environment ranges from the northern areas of rain-fed agriculture to the south where irrigation of agriculture is essential.*

Figure 12. Tigris River valley and buildings. Photo credit: National Geographic Society.

Figure 13. Mudhif structure in marshes. Photo credit: Karin Kloosterman.

This irrigation is aided by a high water table and by melting snows from the high peaks of the northern Zagros Mountains and from the Armenian Highlands, the source of the Tigris and Euphrates Rivers that give the region its name. The usefulness of irrigation depends upon the ability to mobilize sufficient labor for the construction and maintenance of canals, and this, from the earliest period, has assisted the development of urban settlements and centralized systems of political authority. Agriculture throughout the region has been supplemented by nomadic pastoralism, where tent-dwelling nomads herded goats and sheep (*and*

later camels) *from the river pastures in the dry summer months, out into seasonal grazing lands on the desert fringe in the wet winter season. The area is generally lacking in precious metals, building stone, and timber, and historically has relied upon long-distance trade of agricultural products to secure these items from outlying areas. In the marshlands to the south of the area, a complex water-borne fishing culture has existed since prehistoric times and has added to the cultural mix* [26]."

Thompson [27] identified "*periodic breakdowns in the cultural system which have occurred for a number of reasons. The demand for labor has from time to time led to population increases that push the limits of the ecological carrying capacity, and should a period of climatic instability ensue, collapsing central government and declining populations can occur. Alternatively, military vulnerability to invasion from marginal hill tribes or nomadic pastoralists has led to periods of neglect of irrigation systems and collapse of trade. Equally, centripetal tendencies amongst city-states have meant that central authority over the whole region, when imposed, has tended to be ephemeral, and localism has fragmented power into tribal or smaller regional units. These trends have continued to the present day in Iraq* [27]."

2.6. Mesopotamian Marshes

The Tigris, a major source of water for irrigation in the desert region, played a key role in the transition from the hunter-gatherer lifestyle to agriculture with animal domestication. The desert conditions in the region make irrigation necessary for crop survival. The Tigris has been dammed to harness hydroelectric power. However, damming in Türkiye, has raised environmental concerns. The Mesopotamian Marshes have been damaged extensively because of the upstream damming, and the original size was reduced by 86%.

The concept of sustainable development for the 9 million people (in 2005) living in the Southeastern Anatolia region of Türkiye is called the Southeastern Anatolia Project (GAP). GAP is a multi-sector integrated regional development project. The aim of the GAP is to eliminate regional development disparities by raising incomes and living standards. GAP contributed to the national development targets of economic growth and social stability by enhancing the employment generating capacity of the rural sector and productivity. At the end of 2010, the total cost of the project was over 100 billion Turkish lira (TL) (2017 adjusted price). Only 30.6 billion TL of this investment was realized, and the real investment (corrected value) was 72.6% [28] [29]. The project area located in the basins of the Euphrates and Tigris and in Upper Mesopotamia covers nine provinces (Adryaman, Batman, Diyarbakir, Gaziantep, Kilis, Siirt, Şanlıurfa, Mardin, and Şırnak).

Current activities under GAP include sectors like hydroelectric power production, irrigation and agriculture, forestry, rural and urban infrastructure, health, and education. Water resources development envisages the construction

of 22 dams and 19 power plants (nine plants, corresponding to 74% capacity of total projected power output, were completed by 2010) and irrigation schemes on an area extending over 17,000 square kilometers. Seven airports have been built and are currently active including the biggest GAP cargo airport in Şırnak, Türkiye.

2.7. Agriculture in Mesopotamia

The Hadji and Samara Muhammed culture with irrigated agriculture spread southwards from the Zagros foothills about 5000 BC [30]. In the early period down to Ur III temples owned up to one third of the available land. Over time private and royal holdings increased in frequency. The official who organized the work of all facets of temple agriculture was described by the word "ensi". Villeins are known to have worked most frequently within agriculture, especially in the grounds of temples or palaces [31].

Roux [32] determined "*the geography of southern Mesopotamia is such that agriculture is possible only with irrigation and good drainage, a fact which had a profound effect on the evolution of early Mesopotamian civilization. The need for irrigation led the Sumerians, and later the Akkadians, to build their cities along the Tigris and Euphrates and the branches of these rivers. Major cities, such as Ur and Uruk, took root on tributaries of the Euphrates, while others, notably Lagash, were built on branches of the Tigris. The rivers provided the further benefits of fish* (*used both for food and fertilizer*), *reeds, and clay* (*for building materials*). *With irrigation, the food supply in Mesopotamia was comparable to that of the Canadian and American prairies* [32]."

"*The Tigris and Euphrates River valleys* (**Figure 6**) *form the northeastern portion of the Fertile Crescent, which also included the Jordan River valley and that of the Nile. Although land nearer to the rivers was fertile and good for crops, portions of land farther from the water were dry and largely uninhabitable. Thus the development of irrigation became very important for settlers of Mesopotamia. Other innovations include the control of water by dams and the use of aqueducts. Early settlers of fertile land in Mesopotamia used wooden plows to break-up the soil before planting crops such as onions, barley, turnips, grapes, and apples. Mesopotamian settlers were some of the first people to make wine and beer. As a result of the skill involved in farming in the Mesopotamian region, farmers did not generally depend on slaves to complete farm work for them, but there were some exceptions. There were too many risks involved to make slavery practical* (*such as the escape/mutiny of the slaves*). *Although the rivers sustained life, they also destroyed it by frequent floods that ravaged entire cities. The unpredictable Mesopotamian weather was often hard on farmers. Crops were often ruined so backup sources of food such as cows and lambs were also maintained. Over time the southernmost parts of Sumerian Mesopotamia suffered from increased salinity of the soils when irrigated without proper drainage, leading to a slow decline and reduced trade* [32]."

2.8. Trade

The Indus Valley civilization including Mesopotamian trade began as early as the third millennium BC [33]. Mesopotamian civilizations traded with ancient Egypt starting in the 4th millennium BC [34] [35]. For much of history, Mesopotamia served as a trade center. The Volga trade route from north to south between the Eastern Europe and Baghdad and an east to west route between Mediterranean world and Central Asia. Vasco da Gama pioneered (1497-1499) the sea route between India and Europe. In 1869, the opening of the Suez Canal impacted these east-west and north-south trade routes [36] [37] [38].

2.9. Geography of Mesopotamian Marshes

The Marshes (**Figure 14**) are located in Mesopotamia. Modern day Mesopotamia is now part of Iraq, southeastern Türkiye, southwest Iran and parts of eastern Syria (**Figure 10**). These marshes lie primarily within southern Iraq and sections of southwestern Iran. Originally the Mesopotamian Marshes covered an area of 20,000 km^2. The Central Marshes lie between the Tigris and Euphrates, Hawizeh Marshes are to the east of Tigris and the Hammar Marshes lie south of the Euphrates. About 90% of the marshes had been drained before the 2003 Invasion of Iraq.

The marshes lie on a flat alluvial delta. During the last 300 km Tigris drops 24 m and the Euphrates falls only 12 m in elevation. The Tigris and Euphrates to formed distributaries on the alluvial plain. The Euphrates flows often terminated into the Hammar Marshes near Nasiriyah. Near Amarah, the Tigris distributes flows into the Hawizeh and Central marshes (**Figure 15**). Downstream of Amarah, several Tigris tributaries, originating in Iran, permit the flow to increase, and become a river again. The three marshes (**Figure 10**) once provided a connected environment, particularly during flooding events [37].

2.10. Central Marshes

The Central Marshes, namely the Majar Al-Kabir and Shatt Al-Muminah, south of Amarah receive water from the Tigris's distributaries. The Euphrates serves as Central Marshes southern boundary and the Tigris serves as the marshes' eastern border. The 3000 km^2 Central Marshes consist of several permanent lakes including Umm al Binni lake and reed beds. The Hawr Umm Al-Binni and Al-Zikri lakes are the most notable lakes (**Figure 16**) and are only 3 m deep [37].

Figure 14. Confluence of the Tigris, Euphrates and Shatt Al-Arab rivers. Public domain.

Figure 15. Muhif in Marshes on the Shatt Al-Arab River. Mesopotamian Marshes at night, southern Iraq; reed house (Mudhif (reed house) in the water). Public domain.

Figure 16. Marshes and Mashoof (narrow canoe) on the Shatt Al-Arab River. Public domain.

2.10.1. Hammar Marshes

The Hammar Marshes are mostly fed by the Euphrates. These marshes lie south of the Euphrates and extend west to Nasiriyah, and south to Shatt Al-Arab and Basrah. The Hammar Marshes area is 2800 km^2 area of permanent marsh and lake. However, during period of flooding marshes can expand to 4500 km^2. During flooding events on the Tigris, water from the Central Marsh can overflow and supply Hammar Marshes with water. The largest water body within the marsh, Hammar Lake, has a 120 km by 250 km surface area with depths ranging between 1.8 m - 3 m. During dry summer periods, large portion of the marshes' and lake's shore and islands are exposed and can be used for agriculture [36]. Water buffalos (Figure 17) are common in the marshes. An Akkadian king's seal of a scribe shows the sacrifice of water buffaloes [38].

Figure 17. Water buffalo. Public domain.

2.10.2. Hawizej Marshes

The Hawizeh Marshes lie east of the Tigris in Iraq with a portion in Iran. The Iranian marshes is fed by the Hawr Al-Azim (Karkheh) River. The Tigris distributaries Al-Kahla and Al-Musharrah supply the Iraqi section with much less water than the Karkheh River. During spring flooding, the Tigris can flow directly into the marshes. The marshes are drained via the Al-Kassarah. This flow through river prevents the Al-Hawizeh marshes from becoming a closed saline basin.

The marshes are 80 km long (south to north) and 30 km wide and cover a total area of 3000 km^2. The northern and central sections are permanent and the southern part is seasonal. Moderately dense vegetation in 6 m deep lakes can be found in the permanent areas [39]. During the draining the Hawizeh Marshes was the least effected of the marshes and later facilitated the reproduction of fauna, flora, and other species in Hammar and Central marshes [40].

2.11. Marshes Ecology

The marshes (**Figure 8**) are a flooded savannas and grasslands ecoregion, also known as the Euphrates-Tigris alluvial salt marsh [41]. The ecoregion includes both a wetland on the lower Karun River in neighboring Iran and the Mesopotamian Marshes and the Shadegan Ponds [42]. The marshes are integral to filtering out waste and pollutants before they reach the Gulf and coastal health [43] [44]. This function was significantly degraded after their draining [43]. The marshes also serve as nursery and spawning sites for coastal shrimp and fish species [41].

Richarson *et al.* [45] [46] found "*the seasonal and permanent marshlands are dominated by aquatic plants*, *including reeds* (*Phragmites australis*), *cattail rushes* (*Typha domingensis*), *and papyrus sedge* (*Cyperus papyrus*). *Riparian forests of poplar* (*mainly Populus euphratica*), *tamarisk* (*Tamarix pentandra and Tamarix meyeri*), *and willow* (*mainly Salix acmophylla*) *occur on islands and river banks* [45] [46]."

The marshes demarcate a range limit for a number of bird species and are

home to 40 species of bird. Flamingos, herons, and pelicans inhabit the marshes. The marshes were once the stopover for many other migratory birds and as they traveled from Africa to Siberia. At risk are 90% of the world's population of Basra reed-warbler and 40% to 60% of the world's marbled teal population that live in the marshes [47]. Also at risk are the African darter and sacred ibis [48]. The Mesopotamian crow, a subspecies of the hooded crow, is found in this part of southern Iraq [49]. The Bunn's short-tailed bandicoot rat, the Indian crested porcupine, and the marsh gray wolf are extinct [50]. The draining of the marshes resulted in a significant bio-productivity decline. Following the overthrow of the Saddam Hussein (**Figure 18**) regime, by the Multi-National Force the ecosystem has begun to recover after water flow to the marshes was restored [51]. Recent surveys have confirmed that Eurasian otter and the endemic *maxwelli* subspecies of the smooth-coated otter both still survive [52].

2.12. Inhabitants of the Marshes

Rojas-Burke [53] found "*Ma'dān live in secluded villages of elaborate reed houses throughout the marshes, often only reached by boat. Fish, rice cultivation, water buffalo and other resources are also used in their daily lives. In the 1950s, there were an estimated 500,000 Marsh Arabs. This population shrank to about 20,000 following the draining and Saddam's violent reprisals, and between 80,000 and 120,000 fled to neighboring Iran*" [53]. Following the 2003 Iraq invasion, Marsh Arabs have begun to return to the marshes (**Figure 9**) [54]. Many Marsh Arabs destroyed the dikes and dams that Saddam had built [55]. The Iraqi government has provided support via Iraq Cultural Health Fund for Marsh

Figure 18. Saddam Hussein portrait. Public domain.

Arabs efforts to protect traditional cultural practices [56]. Marsh Arabs struggle to obtain healthcare, clean drinking water, and adequate nutrition and remain one of Iraq's most underserved populations [44] [57] [58] [59].

Many Marsh Arabs are once again forced to relocate as the marshes become increasingly polluted and saline [59]. For those who stay, their traditional lifestyle is threatened [58]. The marshes supplied 60 percent of Iraq's fish; however, that number has dwindled to less than 10%. This is driving some Marsh Arabs to marsh perimeters, where they grain farm, since they lack portable water for raising water buffalo [45].

2.13. Draining and Subsequent Restoration Efforts

In the 1950s, the draining of Mesopotamian Marshes began with the Central Marshes (**Figure 10**). The drainage was gradually accelerated as it affected the two other main marshes until the 2003 invasion of Iraq. The draining of the marshes was intended at first to reclaim land for agriculture and later for oil exploration. Intensified agriculture later served as a punishment for Shia Arabs in response to the 1991 uprisings in Iraq. The draining of the marshes was exacerbated by upstream dam construction in Syria and Türkiye and due to dams, dykes and other diversion structures constructed within Iraq [50].

Lewis *et al.* [57] noted "*the British engineers worked with the Iraqi government*; *Frank Haigh developed the Haigh Report in 1951. His report recommended a complex of canals*, *sluices*, *and dykes on the lower portions of both the Tigris and Euphrates. These water control structures could be used to drain marshes therefore creating profitable farmland. In 1953*, *construction began on the Third River or Main Outfall Drain and later the Saddam River which would drain water from the Central Marsh under the Euphrates and through a canal* (**Figure 19**) *eventually into the Persian Gulf. Work on the Third River and other draining projects*, *particularly for the Hawizeh Marsh*, *quickly progressed in the 1980s during the Iran–Iraq War in order to afford Iraqis a tactical advantage in the marshes*" [57]. Part of the Hammar Marshes was also drained in 1985 to clear area for oil exploration [60] [61].

Shia Muslims in southern Iraq rebelled, after the 1991 Gulf War, against Saddam Hussein who in turn crushed the rebellion and further accelerated the draining of the Hammar and Central marshes in order to evict Shias that had taken refuge in the marshes [37] [57]. The 565 km Third River was completed in 1992 with the exception of the Nasiriyah Drainage Pump Station (**Figure 20**). Two other canals were constructed parallel to the Third River and to the south. The Mother of Battles canal was constructed to divert the flow of the Euphrates south of and below the Hammar Marsh. Second, the 240 km Basrah Sweetwater Canal (Loyalty to Leader Canal), originated in the lower Euphrates region and collected water from the terminus of the Gharraf River. The water was diverted away from the Central Marshes and below the Hammar Marshes passing under the Euphrates and flowing towards Basrah [37] [62]. In addition, the Glory River

Figure 19. Prosperity River drainage above central marshes. Picture of canal and Euphrates. Photo credit: Special inspector general for Iraq reconstruction.

Figure 20. Nasiriyah Drainage Pump Station. Photo credit: special inspector general for Iraq reconstruction.

was constructed to divert water from the Tigris's southern-flowing distributaries. The water was diverted parallel and east to the Tigris until the flow reached the Euphrates at its confluence with the Tigris near Qurna [37].

Before the 2003 invasion of Iraq [54] the marshes had lost 90% of their size during the previous decades. Only 35% of the Hawizeh Marshes remained and the Hammar and Central Marshes were nearly drained. After the invasion, returning locals and locals destroyed dikes. The combined efforts of the Iraq government, U.S. agencies, United Nations and record precipitation in Türkiye helped begin the restoration of the marshes [63] [64]. Approximately 58% of the original marshes had been re-inundated by 2006 [65]. The Nasiriyah Drainage Pump Station (**Figure 21**) was completed in 2009, allowing the Third River to be used for agricultural drainage [66]. The marshes were reduced to 30% of their original size, as a result of continued upstream dam construction and operation in Türkiye, Syria and Iran and recent drought [63]. Türkiye has built at least 34 dams on the Euphrates and Tigris rivers, threatening marsh recovery [58] [67] [68].

Figure 21. Baghdad Green Zone. Photo credit: Iraq News Agency.

In 2008 approximately 75% of the marshes were restored. By the spring of 2015 the marshes had receded to 58% of their average pre-drained level. As the water level fell, salinity increased to 15,000 parts per million in some areas, up from 300 to 500 ppm in the 1980s. Bruneau and Al-sudani [59] noted "w*hen the river water levels were high, the low-saline Tigris washed over the marshes, cleansed them, and pushed the salty residue into the saltier Euphrates, which flows along the western edge. But now the Tigris is so low that the Euphrates provides most of the water in the marshes* [59]." The government prioritizes providing water to cities, such as Baghdad (**Figure 21**), along the Tigris and Shatt Al-Arab, resulting in reduced flow to the marshes [69].

2.14. Threats from Climate Change and Pollution

Region temperatures have risen over 0.5 degrees Celsius per decade, causing drought in Iraq and neighboring countries whose waters flow into the Euphrates and Tigris [70]. Combined with upriver dams, this reduction in water, because of upstream dams has caused the three primary marshes to fragment into 10 smaller marshes [62]. Massive amounts of untreated sewage and other pollutants are dumped into the Tigris and Euphrates. These pollutants, move downstream and into the marshes, further degrade the water quality [32] [57] [69].

2.15. Shatt Al-Arab River

The Shatt Al-Arab [1] is a river formed at the confluence of the Euphrates and Tigris rivers near the town of Al-Qurnah in southern Iraq. The southern end of the 200 km Shatt Al-Arab River (**Figure 22**) constitutes the Iraq-Iran border down to its mouth, where it flows into the Persian Gulf. The Shatt Al-Arab (**Figure 23**) varies in width from about 800 m at its mouth to 232 m at Basra. The Tigris and Euphrates originally emptying into the Persian Gulf via a channel further to the west. Kuwait's Bubiyan Island is part of the Shatt Al-Arab delta [2].

Figure 22. Shatt Al-Arab at Basra. Photo credit: Nabil Al-Jurani.

Figure 23. Ships on Shatt Al-Arab. Photo credit: Juergen Braker.

The Karun, a tributary, joins the river from the Iranian side, deposits large amounts of silt into the river. The silts necessitated continuous dredging to keep the river navigable [3] [4].

In the mid-1970s, the Mesopotamia region had 17 - 18 million date palms, an estimated one-fifth of the world's 90 million palm trees. By 2002, more than 14 million of the palms had been killed by combined factors of salt, pests, and war. This count includes around 5 million in Iran and 9 million palms in Iraq. Many of the remaining trees, 3 - 4 million, are in poor health [5].

In the late 1960s, Iran developed a strong military and took a more assertive stance in the Near East under Shah Mohammad Reza Pahlavi [15]. Iran abrogated the 1937 treaty in April 1969 and Iranian ships stopped paying Shatt Al-Arab tolls to Iraq [18]. The Shah argued that because most of the ships that used the Shatt Al-Arab (**Figure 23**) were Iranian the 1937 treaty was unfair to Iran. Almost all river borders around the world ran along the thalweg [70]. Iraq

threatened war over the Iranian move. On 24 April 1969, an Iranian tanker escorted by Iranian warships (Joint Operation Arvand) sailed down the Shatt Al-Arab. Iraq, being the militarily weaker state, did not challenge [14]. The Iranian abrogation of the 1937 treaty by Iran marked the beginning of a period of acute Iranian-Iraqi tension that was to last until the Algiers Accords of 1975 [16] [70].

Attempts by the United Nations to intervene and mediate the Iraqi-Iranian dispute were rebuffed. Baathist Iraq claimed the frontier, agreed to in 1937, was still the legitimate frontier. In the early 1970s, Iran became the main patron of Iraqi Kurdish groups fighting for independence from Iraq. In 1974 with the open support and encouragement of Iran, the Iraqi Kurdish peshmerga rebelled against Iraq. The Peshmerga fought a conventional war, instead of waging a guerrilla war, against Iraq which led to very intense fighting [70]. Iraq and Iran almost went to war, in the winter of 1974-75, over Iran's support of the Kurds in Iraq [70]. The Iraqis decided against war, given Iran's greater population and military strength. To end the Kurdish rebellion, Iraq chose to make concessions to Tehran [70]. In March 1975, the Shah of Iran and Vice President Saddam Hussein of Iraq signed the Algiers Accord. Iraq recognized a series of lines, as the official border, closely approximating the thalweg of the waterway. In exchange for which Iran agreed to end its support of the Iraqi Kurds [70]. The Algiers Accord caused much bitterness in Iraq over what was seen as Iranian bullying [16] [70]. However, the Algiers Accord saw Iran cease supporting the peshmerga as the Iranians closed the frontier, causing the Kurdish rebellion to promptly collapse [70]. The British journalist Patrick Brogan [70] wrote that "*the Iraqis celebrated their victory in the usual manner, by executing as many of the rebels as they could lay their hands on*".

President Saddam Hussein of Iraq abrogated the 1975 treaty, in 1980, before Iraq invaded Iran. The main thrust of the military movement occurred across the Shatt Al-Arab River and adjacent floodplains, which was the stage for most of the military battles between the two armies. The Shatt Al-Arab River was Iraq's only outlet to the Persian Gulf, and thus, its shipping lanes were greatly affected by Iranian attacks.

In 1986, Iraq's shipping activities came to a halt after Iran captured the Al-Faw peninsula. Iraq shipping had to be diverted to other Arab ports such as Kuwait and Aqaba, Jordan. The Iraqi offensive was started on 17 April 1988 and resulted in Al-Faw peninsula recaptured after three days of fighting [70]. The Iraqis began a sustained drive to clear the Iranians out of all of southern Iraq began once Al-Faw was retaken [70]. In May 1988, the Iraqis expelled the Iranians from Salamchech and took Majnun Island. The Iranians showed all the signs of collapsing morale during the spring of 1988 fighting [70]. Brogan reports from the front, both at outside Basra and Faw, indicated that the Iranian resistance was surprisingly weak. The Iranian Army that had shown such courage and élan early in the war now broke in a rout and fled before the Arabs [70]. The Iranians seemed worn out and tired by the nearly eight years of the

war. They "*put up very little resistance*" to the Iraqi offensives during the 1988 battles [70]. At the end of the Iran–Iraq War (**Figures 24-26**), both sides once again agreed to treat the Algiers Accord as binding.

2.16. Karun River in Iran

The 950 km Karun is the only navigable river in Iran. The Karun forks into two branches, the Haffar and Bahmanshir before flowing into Arvand Rud (Shatt Al-Arab). As a result of Iran's construction of new dams on the Karun and tributaries, these dams (**Figure 25**) increased the salinity levels in the Shatt Al-Arab. Salinity destroyed farm areas and threatened livestock in Basra area of Iraq. Civilians were forced to evacuate [71] [72] [73]. The dams are often delayed because of fear of submerging archaeological sites [72]. The Karun and tributary dams have a significant effect on the ecology of the river and sediment transport.

Figure 24. Iraq tunnels under Sinjar. Photo credit: Kristian Skeie.

Figure 25. Karun-3 dam in Iran. Public domain.

Figure 26. Iraq gas flaring. Photo credit: World Bank.

2.17. Climate Change in Iraq

Climate change is thought to be affecting Iraq's economic, environmental, political, and security challenges worse. Intense droughts, rising temperatures, declining precipitation, intense droughts, salinization, desertification, and the increasing prevalence of dust storms have undermined Iraq's agricultural sector. Additionally, Iraq's water security is based on the declining Tigris–Euphrates river system. National and regional political uncertainty will make mitigating the effects of climate change and addressing transnational water management very difficult. Any climatic changes such as reduced precipitation, increasing temperatures, and increasing water scarcity will likely have serious implications for the state of Iraq for years to come [74]. Per person Iraq greenhouse gas emissions are above the world average [75]. In 2019, Iraq accounted for 0.5% of world carbon dioxide emissions and 8% of world methane emissions [76] and [77]. Greenhouse gas emissions per person are above the world average [75]. Being a country that produces massive amounts of oil, Iraq is also one of the top 3 highest gas-flaring nations (**Figure 26**) in the world [78].

In Iraq, climate change has resulted in "*prolonged heat waves*, *erratic precipitation*, *higher than average temperatures and increased disaster intensity*," according to a 2018 report by the Expert Working Group on Climate-related Security Risk [79]. Very heavy rains contributed to flooding and soil loss after a drought between 2007 and 2009 [80]. Temperatures can exceed 50 degrees Celsius [81]. Baghdad is experiencing an earlier onset of 48 degree C days. As participation and water levels fell, the increasing salinity of the water supply has become a concern in southern Iraq, especially in Basra (**Figure 18**) [79].

2.18. Agriculture

In 2018, after Iraq's years of drought land under cultivation was reduced by half. Cultivation of irrigated crops such as corn, cereals, and rice were suspended by the government. Production losses were estimated at 39 million dollars [82]. In

2019, an unusually wet winter caused widespread flooding on the Tigris and Euphrates rivers and "*restored freshwater marshes of southern Iraq*" [83].

2.19. Security Risks, Power Grid Failure, Food Spoilage, and Heat Illness

On August 6, 2022, Iraq's power grid failed in Basra, Dhi Qar and Maysan due to temperatures reaching as high as 51 degrees C. A public holiday was declared until the following Tuesday, the beginning of the religious festival of Muharram [84]. Expert Working Group on Climate-related Security Risks [84] noted "*when agricultural livelihoods are disrupted, local residents in ISIS-liberated areas may become dependent on terrorist groups for access to resources. Demonstrations and clashes over water rights have occurred in southern Iraq* [85]." In July 2022, electricity blackouts were exacerbated by a reduction in power supplied by Iran and attacks on power lines by militants. Protests were held in Sadr City, and Baghdad where residents were left without air conditioning in 50 degrees C heat [86].

3. Results

3.1. Reconstruction in South of Baghdad

Humanitarian aid implemented by the US military in Iraq reinforced stability and quickening the peace after the War. The US military, in five years, spent over 2.8 billion dollars on aid projects through the Commanders Emergency Response Program (CERP) [87] [88] [89]. One township, Yusifiyah, where Task Force 3-187 was able to completely transfer their area task of responsibility back to Iraqi control. The use of CERP funds was an enabling factor [89] [90]. Task Force 3-187 was not an aid organization but was focused on waging counterinsurgent operations. The US Army Field Manual 3-24 "*Counterinsurgent operations strive to restore order, the rule of law, and…the host nation.*" Yusifiyah, Iraq is a predominately rural area of approximately 600 km^2. Canals perforated the fields of cucumber, okra, tomato, eggplant, and potato. Orange groves and date palms are abundant along the Euphrates and villages with uneducated population, which in Iraq means favorable conditions for hiding insurgent soldiers and weapons caches. Terrorists used Yusifiyah for staging attacks due to the proximity to Baghdad. When Task Force 3-187 arrived in late 2007 they found the region lacked essential services and a history of violence. After 14 months of counterinsurgent operations, including $32 million dollars of humanitarian aid, Yusifiyah control was transferred to the Iraqi Army and Iraqi government. Task Force 3-187 was comprised of 900 soldiers with attachments of civil affairs team, psychological operations team. The Task Force Commander structured his meeting time to include lunches, dinners, discussions with tribal leaders (**Figure 27**). These meetings formed the foundation of the "Sahwa" movement or an awakening where trial leaders began allying with Coalition Forces. The Task Force conducted both security and reconstruction at the same time. The Task Force lacked development and reconstruction expertise and could not actually

Figure 27. Sheik meeting for Yusifiyah canal. Photo credit: David R. Speidel, U.S. Department of Agriculture.

fix infrastructure, but they could finance by contracting out the infrastructure work. These efforts were not without challenges.

Eight tribal members of the new representative council were killed by Al Qaeda. The Task Force's initiative to clean irrigation canals with American funded projects was met with resistance by the district government Irrigation Director. He claimed the Ministry of Irrigation would clean canals if three local sheiks agreed to support the director. This delayed the canal cleaning earlier in the year, but when the operational U.S. Commander responded to the local landowner's request to save the town from running out of water, he enlisted the aid of the 187th's Embedded Provincial Reconstruction Team 4 (e/PRT4). This did save thousands of American dollars and provided water in time for the next planting, when the ePRT4, by convincing the sheiks, over a dozen, to work with their government to maintain, now several years overdue, their canal. Water was thus provided in time for fall crop establishment and serviced the town's drinking water needs. The Task Force decided, following CERP principles, to use small and fast projects, to use local contractors instead of employing large contracting firms. The large firms would have in turn subcontract the work at inflated project costs and complicated the management. Most projects were contracted with contractors who lived in Yusifiyah.

What can be learned from Task Force 3-187. The Army develops better local leaders who could work with their aid organizations, rather than just assigning large projects to the aid community [88] [89]. 1) The US Army relies on leaders trained at national service academies, Officer Training Courses, leadership schools and real-world experience to develop their leaders. 2) The Task Force 3-187 success was partially due to small dollar projects which improved project oversight, allowed for quicker access to funds, and decreased the possibility of corruption. 3) The Army was willing to focus on the meeting the real needs of Iraqi society including improved water, electricity, education, and culture. 4) To

prevent Yusifiyah from becoming dependent on American aid the control was transferred to the Iraqi Army and government.

3.2. The Land between the Tigris and Euphrates and the Art of Negotiation

Speidel [88], an U. S. Department of Agriculture Agricultural Advisor for the 2007-08 PRT program, managed by the Department of State, and staffed with members from eight federal departments [90]. Speidel, assigned to review a water resource management reconstruction project in Iraq in which producer stakeholders were involved in the decision-making process (**Figure 27**). The following lessons can be learned. In post-2003 Iraq, a breakdown in relations between Iraqi Government water engineers and landowners, who controlled access to a key canal and pump station # 2 (**Figure 28**), resulted in the inability to maintain water facilities and the canal infrastructure (**Figure 29**). The lack of maintenance had reduced the flow of water to a city, 30 km from either the Euphrates or Tigris River, to an intolerable level, threatening the populace's drinking water. Twenty five percent of the district's water converged at this one point [91] Secondary canals that supported a fertile valley of farmland between the Euphrates and the Tigris Rivers (**Figure 30**) had already dried up. To overcome these obstacles, a social science approach using the cultural imperative of the third pillar of Islam, called Zakah, which entails giving charity to those in need, was employed [88]. Individuals from the agricultural section of the U.S. Provincial Reconstruction Team encouraged the indigenous landowners to work in cooperation (**Figure 27**) with the chief water engineer and his staff from the Mahmudiyah, Iraq District water department to find a solution to the problem. Instead of government/military directive, the power of persuasion resulted in water flowing within six weeks.

Figure 28. The secured Yusifiyah Pump Station #2 and feeder canal supplies water from the Tigris River. Photo credit: David R. Speidel, U.S. Department of Agriculture.

Figure 29. The Yusifiyah Tigris River feeder canal. A view from Pump Station #2. Photo credit: David R. Speidel, U.S. Department of Agriculture.

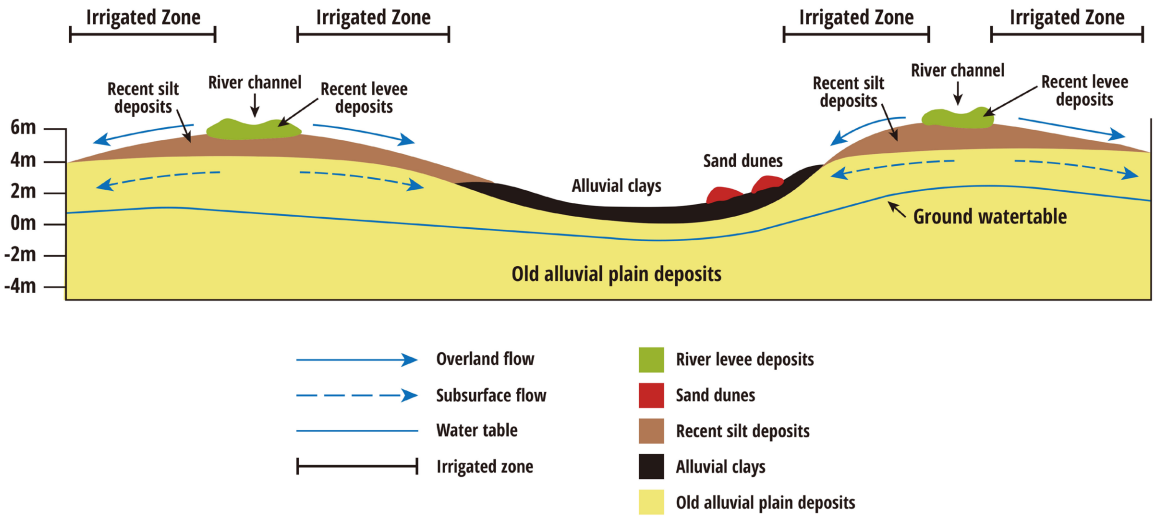

Figure 30. Diagrammatic cross section of Mesopotamian alluvial plain soil formation and landscape [88]. Drawing by Cruz Dragosavac.

4. Summary

The limited water resources for irrigation, human and livestock consumption, shipping and transportation, exacerbated by climate change, population growth, war impacts on water infrastructure have made political stability increasingly precarious. Current efforts to manage a dwining resource with increasing salinity and pollution concern and population demands are severely challenged. Helping local people solve their problems needs to be a humanitarian priority.

Türkiye implemented a public-works project (the GAP project) aimed at harvesting the water, beginning in the 1960s, when from the Tigris and Euphrates rivers the issue of water rights became a point of contention for Türkiye, Iraq and Syria. Turkey constructed 22 dams, for hydroelectric energy and irrigation purposes. The GAP project is perceived as a threat by Iraq. The 2008 drought in Iraq sparked new negotiations between Turkey and Iraq over trans-boundary river flows. Iraq complained regularly about reduced water flows especially about the Euphrates River because of the large number of Turkey dams on the river. Turkey agreed to increase the flow several times. Often Turkey attempted to supplied extra water to Iraq even beyond its means. Iraq has seen significant declines in crop yields and water storage because of the drought. To make matters worse, Iraq's water infrastructure has suffered from years of conflict and neglect. Türkiye formally agreed to increase the flow of the Euphrates River to 450 to 500 m^3/s on September 19, 2009, but only for one month. In exchange, Iraq agreed to trade petroleum with Türkiye and to help curb Kurdish militant activity in their border region. One of Türkiye's last large GAP dams on the Tigris, the Ilisu Dam, was strongly opposed by Iraq and the source of political strife.

Between 1980 and 1988, conflicting disputes over navigation rights and territorial claims between Iran and Iraq were among the main causes of the Iran–Iraq War. After 1988, the pre-1980 status quo was restored. The Iraqi cities and major ports of Al-Faw and Basra are situated along this river as are the Iranian cities and major ports of Khorramshahr and Abadan.

5. Conclusions

The primary objective of this research was to document the settlement history in Iraq on the Tigris, Euphrates, and Shatt Al-Arab rivers which became Western Asia's pathway for invasions, wars, settlement, conflicts, navigation, and trade in the Tigris and Euphrates basin has put the river system at risk for more than 2500 years. The Tigris and Euphrates rivers have had a huge environmental, economic, and social impact on four West Asia countries. However, with five countries sharing the river system it has been difficult to mitigate and manage the threats and risk to the Tigris, Euphrates, and Shatt Al-Arab rivers and its water quality. Environmental risks include pollution, military activities, gas and oil production, industrial and urban wastewater, over-fishing, desertification, population growth, climate change, threats to food supply, urban development, watershed dams in neighboring countries, shoreline erosion, saltwater intrusion and flooding.

Iraqi Government policies can affect challenges from climate change, recovery from war damage to irrigation infrastructure. The challenges from the Türkiye GAP program and the unknown dam construction by Iran are much more difficult. The Kurd people's desire for self-rule adds another dimension to the challenges. Outside assistance by governments with interests in regional stability should be considered. A regional approach which addresses the best use of the

resources from all countries' interests, and the environment using local funds, sciences and national policies will improve the chance of success by allowing the Iraqis to solve the Iraqi problem. How outside nations can shape such a solution will require long term investment of intellectual resources over funds or military influence. Helping with small steps to build trust and enduring longer-term commitments of advisors and overlapping replacement with new advisors has been a proven method.

There is a need for governmental policies and integrated management of the environment, to secure self-sufficiency, environmental security, and food security for the state of Iraq. A balanced approach to water management is needed and must include efficient measures and aggressive conservation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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