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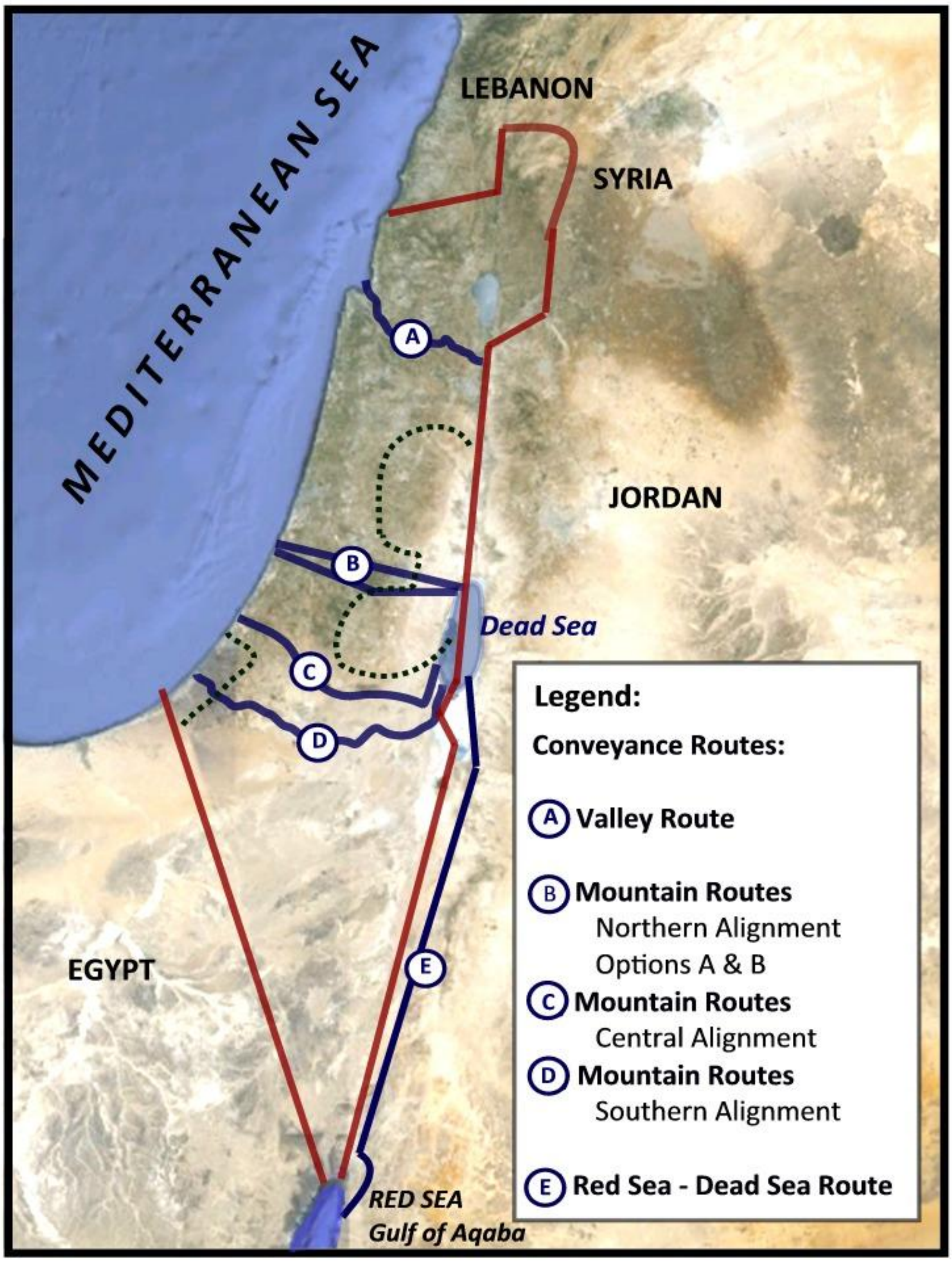
A Pre-Feasibility Study on Water Conveyance Routes to the Dead Sea

Willner, Lipchin, Kronich, Amiel, Hartshorne, Selix



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A PRE-FEASIBILITY STUDY ON WATER CONVEYANCE ROUTES TO THE DEAD SEA

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1 Introduction

"I believe that if we can prove that it is a feasible project, environmentally and economically, it will happen. The political problems can be solved."

Professor Uri Shani, former Israeli Water Commissioner

As Earth's lowest point, home to its own mix of hypersaline waters, and one of the world's few transboundary lakes, the Dead Sea has an undeniable uniqueness that attracts millions of visitors each year and makes it one of the most important environmental resources in the Middle East. Due to freshwater diversions over the last century, the level of the Sea has dropped 36 meters, from a steady state of around -390m below sea-level up until the 1930s to -426 meters in June 2012. This has threatened both tourism and industry at the Dead Sea for Israel, Jordan, and the Palestinian Authority, which jointly share its banks. To solve this issue, many have suggested importing seawater to be pumped into the Sea to restore it back to historic levels. Due to the negative differential between the elevation of ocean water and that of the Dead Sea, such a conveyance could also provide benefits for the three countries: freshwater generation and energy security. The question remains, which sea should the conveyance to the Dead Sea come from: the Red Sea or the Mediterranean Sea?

A potential Red Sea-Dead Sea conveyance (Red Dead) has been extensively studied, and many proposals have come and gone. However, while different Mediterranean Sea-Dead Sea conveyances (Med Dead) have also been proposed in the past, the information is more scattered. This report puts together previous literature on these proposals, principally detailed government documents and interviews from a diverse set of water and energy experts, government officials, and NGO leaders. It describes four different potential Med Dead conveyances from historical, economic, engineering, political, and environmental perspectives. This is followed by a comparative description of the Red Dead route, which has been researched in detail in the past few years. The Med Dead has received noticeably less attention, yet it has been considered for more than a century.

Using a combination of early land surveying and biblical beliefs, British naval officers proposed building a navigable canal from the Mediterranean Sea to the Galilee or Dead Sea as early as the 1850's. The British continued to weigh similar plans for a while, but the construction of the Suez Canal eventually led to abandonment. The Zionist movement in the late 19th century led to further interest in a canal, but for hydroelectricity rather than navigation. This culminated in Theodore Herzl's work *The Jewish State (Altneuland)* when he proposed building a canal to power a manufacturing industry in the Jordan Valley. As an early Israeli nation began to form, more plans began to unfold involving international partners from countries such as Norway and the United States. After Israel gained independence, the prospect of implementing a conveyance seemed to become a real possibility, and several detailed proposals were drafted in the decades after 1948.

In the late nineteen seventies and eighties, TAHAL, followed by BW Engineers, published a series of economic and engineering feasibility studies on potential Med-Dead routes. This included the "Valley Route", a canal through the Jezreel Valley, bringing seawater to the Dead Sea through the Jordan River. Also discussed were more southern "Mountain Routes" which would convey water through a tunnel over the Judean Mountains and directly into the Dead Sea. The most seriously considered involved a sea intake in Gaza, which ultimately led to several UN resolutions condemning the project. Since then, little research has advanced proposals for a Med Dead route. This document draws heavily from TAHAL's reports in 1978 and 1983 and BW Engineers' report in 1984 to give a comprehensive summary of the research on the Med

Dead and updates their engineering and cost/benefit analyses to the current technological, financial, and political situation.

Israel has changed significantly since the early 1980s; the nation has seen the Palestinian uprisings (intifadas), the Russian Aliyah, and the peace agreements with Egypt and Jordan were signed. Changes in demographics have led to new needs and potentially different benefits of a Med Dead conveyance. As the population of the entire region has greatly increased, strains on energy and water resources have become more widespread. Israel's energy problems lie largely in a lack of energy security and diversification. As there is currently no hydropower generation in Israel, a Med Dead conveyance could tap into a new energy resource, introduce pumped storage to create an energy reserve for peak usage, and increase Israel's renewable energy generation. The situation is worse for Jordan and the Palestinian Authority, where most of their energy is imported and fossil-fuel based. A centrally located hydroelectric plant serving all three entities could help diversify energy production in the region and stimulate economic development through initial construction and continued maintenance of the conveyance and associated projects. This could lead to further regional cooperation.

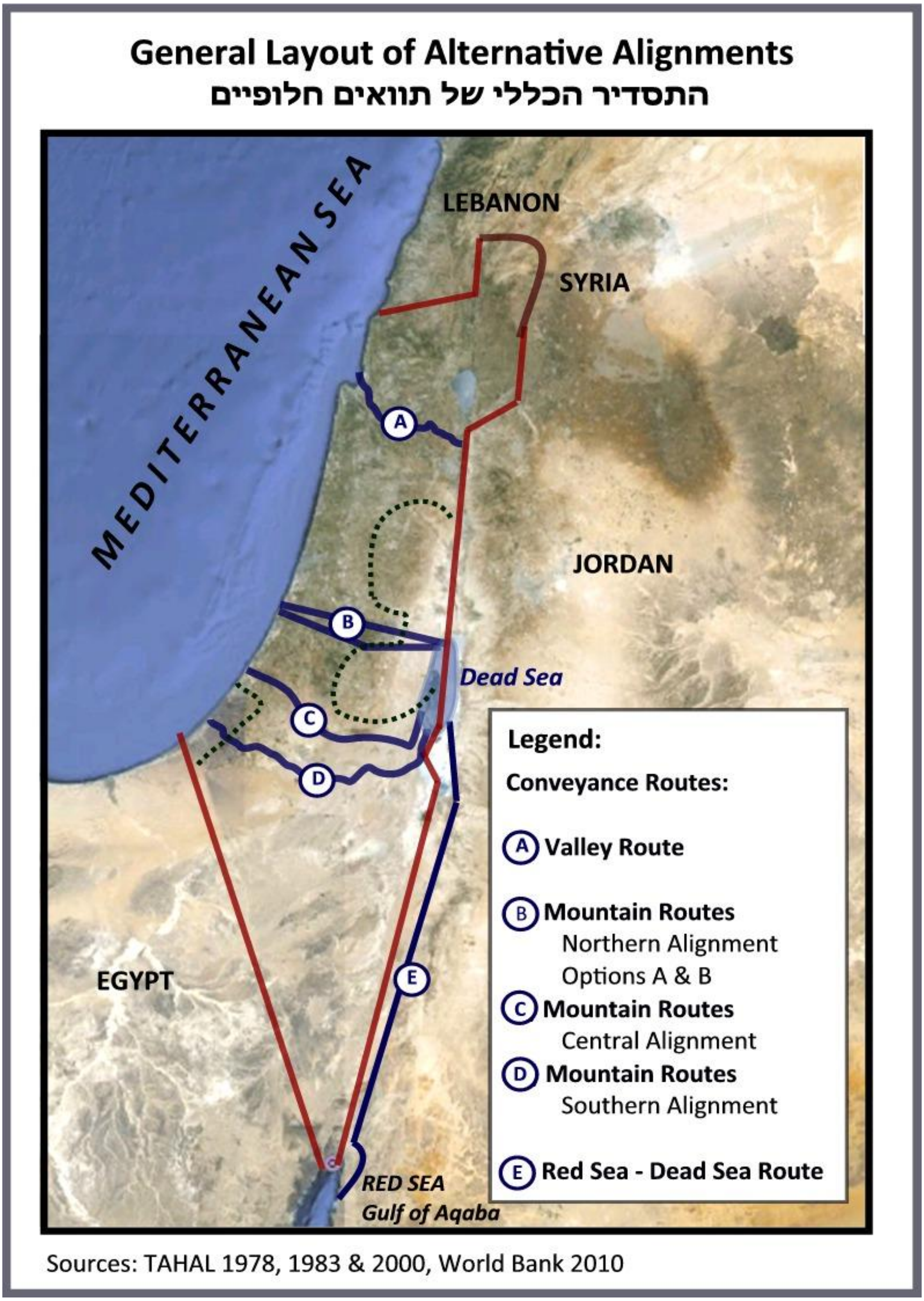
BW Engineers' report identified six factors that would determine the economic feasibility for such a hydroelectric plant: Dead Sea annual evaporation rate and stream inflow, future fuel prices, discount rate, exchange rates, and electricity demand forecasts. For a current proposal, water resources and costs would also need to be examined. One important technological development has been the advance in desalination processes. In the 1970s, desalinated water cost about $2.50 per cubic meter, and in 2003, the cost had dropped to $0.50. The combination of seawater conveyance and hydroelectric power generation would make a reverse osmosis plant possible in locations beyond the coast. As water resources are so scarce in the entire region, this could be of use for domestic, agricultural, and industrial purposes.

An updated engineering analysis of the Med Dead incorporates a desalination plant into the technical layouts of the early 1980s. Section 4 describes how any conveyance route would include: Sea Inlet, Main Tunnel, Regulating Reservoir, Power Station, Outfall Canal, and Pumped Storage, as well as Desalination. If seawater needs to be pumped over mountains, as required by some proposed routes, the design would also need to include: Pumping Station, Pressure Pipeline, Chlorination Facilities, and open trapezoidal Canal with a high point at an elevation of circa 100 meters. The hydroelectric plant would be built on the lowest portion of the Dead Sea basin, on the western side. The desalination plant would necessarily be limited to the Dead Sea region; it could potentially be built anywhere along a conveyance where the water would best be used, e.g. Be'er Sheva. The location of the seawater intake basin depends on the route chosen.

Four Med Dead routes have been promoted in the past. Each has its own benefits and consequences in terms of economic and technical feasibility, environmental impact, and political possibility. The first is the "Valley Route", which would require little pumping to bring Mediterranean water though the Zevulon and Jezreel valleys and into the upper reaches of the Jordan River. Haifa Bay houses several industrial plants, so the addition of this salt water to the river could potentially have far-reaching impacts on the ecology of the valley. The alternative "Mountain Routes" avoid the valley by using a tunnel to convey the seawater over the Judean Mountains and into the Dead Sea. The Northern Alignment intakes seawater north of Ashdod, tunnels water south of Jerusalem and under the West Bank and into the Jordan Valley just north of the Dead Sea. The Central Alignment avoids both the West Bank and Gaza by beginning in Ziqim, jutting southeast, and outfalling near Masada, therefore making it the most feasible politically. The Southern Alignment, which was once the preferred route, now seems less likely to materialize, as it would begin in Gaza, at Qatif. The tunnel involved in the Mountain Routes prevents much ecological damage, but a leak (if the risks are minimized in the planning phase of the system) could pollute groundwater and be difficult to fix. For any route, Valley or Mountain, the environmental effect of mixing seawater with Dead Sea water constitutes a major unknown.

Overall, more research should be carried out on a Med Dead conveyance. Based on an analysis of technical plans and expert interviews, potential routes have been well researched and seems within feasibility. More complicated proposals have been implemented in the past. For example, in the California Aqueduct, water is pumped more than 1,000 km and over 600m of elevation for delivery into Los Angeles. The Gotthard Base Tunnel in Switzerland, when completed, will have more than 150 km of rail tunnels under the Swiss Alps. The components of the various proposed Med-Dead projects fit together from an engineering perspective but an updated economic cost/benefit analysis was inconclusive. However, limiting the analysis to only the factors used by TAHAL seemed to leave out many other potential benefits, such as those in regional development, agriculture, and energy diversification, which cannot be quantified with current knowledge. A Red Dead route has been studied and negotiated for more than a decade, and yet no plan has emerged. As an alternative, there is clear interest in the Med Dead. The next step is exploration.

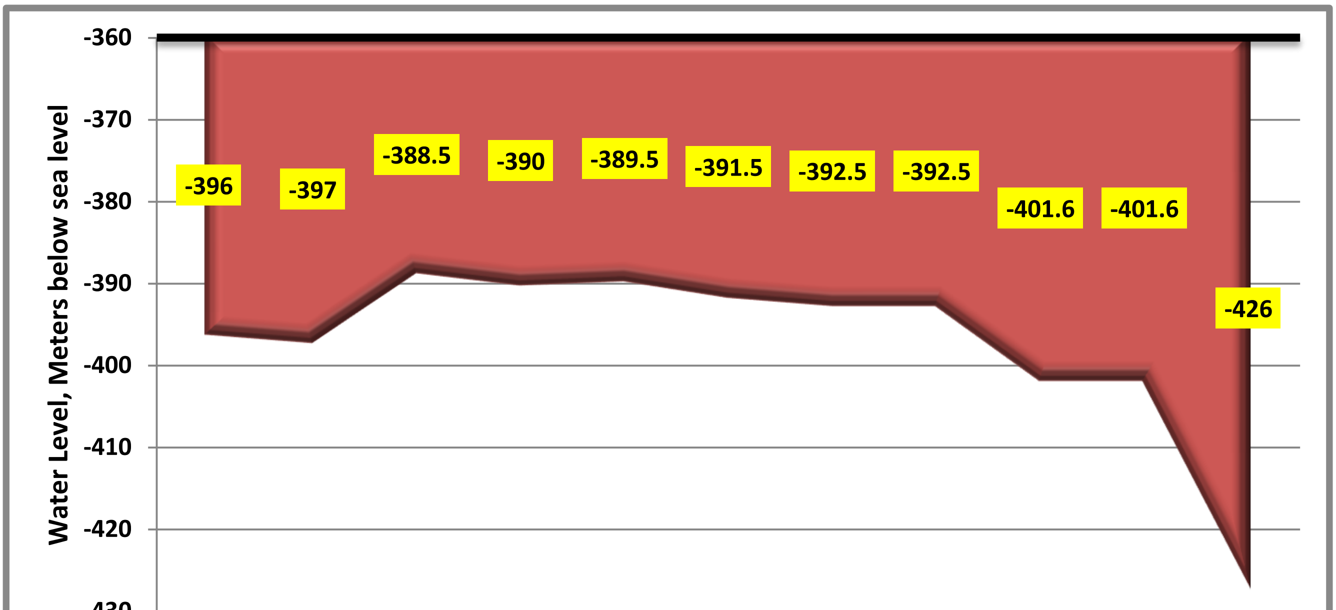
Map 1: General layout of Alternative Conveyance Alignments



2 Historical Review

The Dead Sea is a terminal lake that loses water only by evaporation (see Map 2). Until the 1930s the water level was high and relatively stable at around -390 meters. Since the 1930s the level has been dropping, mainly due to diversions of freshwater in the upper catchment of the Sea of Galilee. These diversions have led to a drastic decline in the water flow of the lower Jordan River that is the primary source of water to the Dead Sea. As the lower Jordan River has dried up, so too has the water level of the Dead Sea declined. The measured sea level of the Dead Sea (Figure 1) in June 2012 had dropped to -426.0 meter (Arab Potash Company Ltd.).

Figure 1: Dead Sea Water Level Trends (TAHAL 1983, Arab Potash Company 2012)



	1840-1883	1884	1896	1897-1932	1933	1936	1937-1957	1958	1982	1983	2012
Level	-396	-397	-388.5	-390	-389.5	-391.5	-392.5	-392.5	-401.6	-401.6	-426

Map 2: Jordan River and Dead Sea Basin

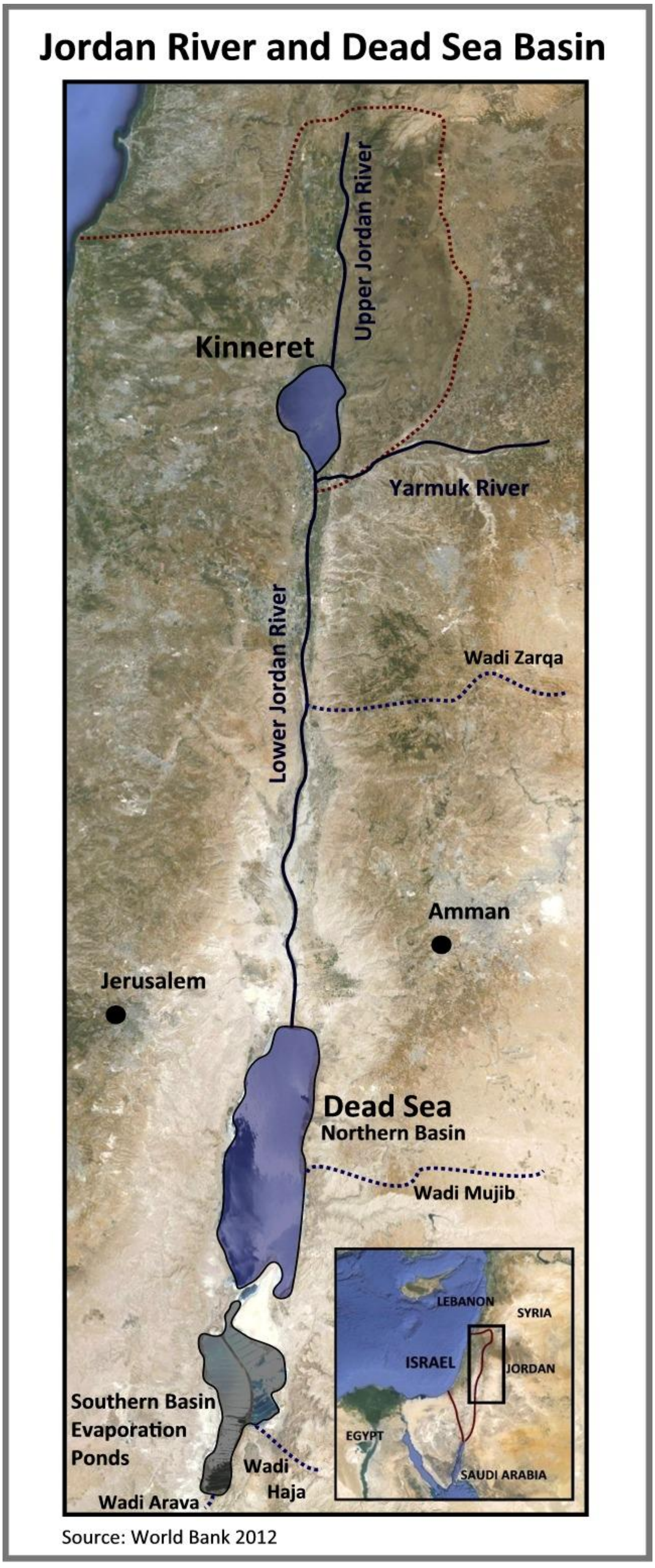
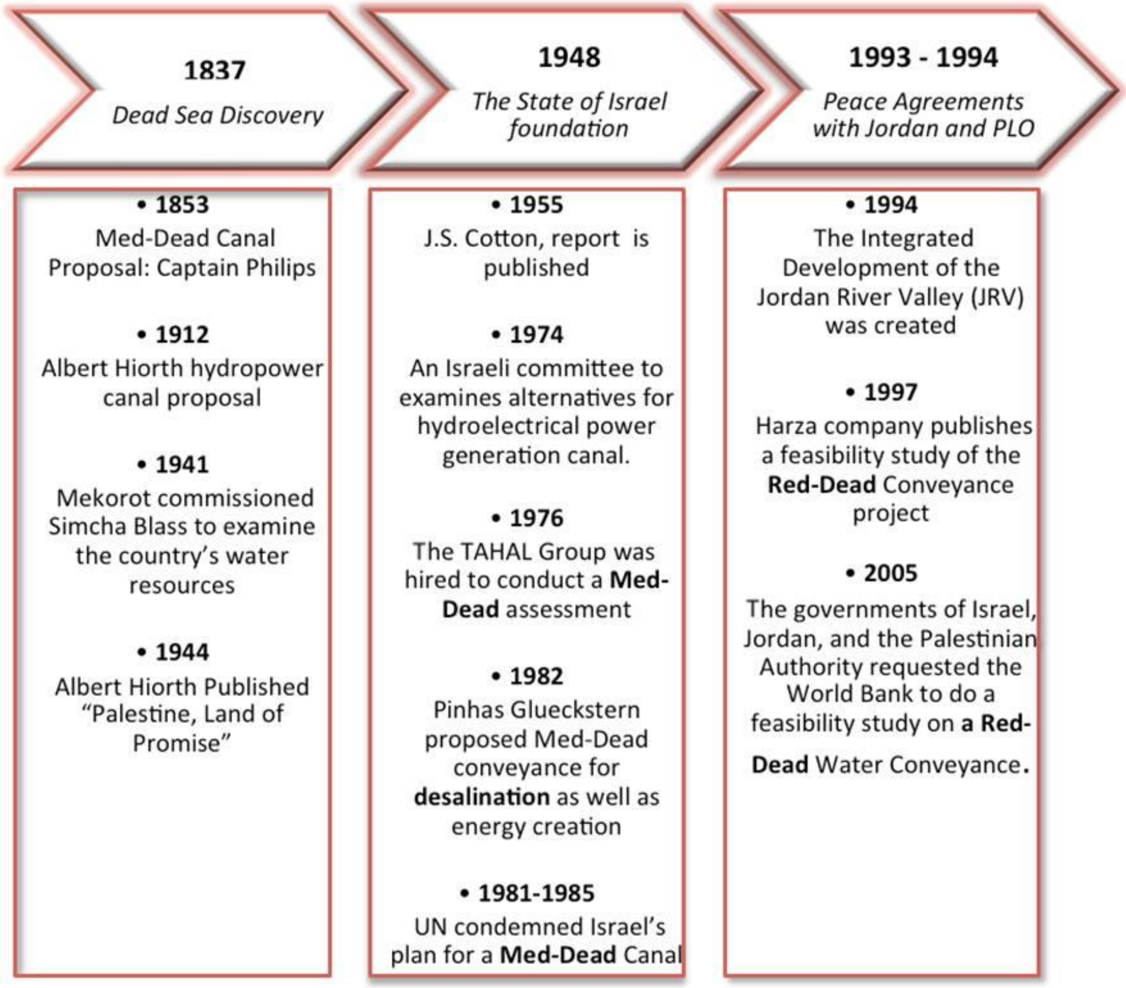


Figure 2: Timeline of proposed water conveyance projects to the Dead Sea (Vardi 1990, World Bank 2012)



2.1 The Evolution of the Med-Dead Sea Conveyance Project

One of the significant geographical features of Israel contributing to the idea of a canal from the ocean to the Dead Sea is the fact that the Dead Sea lies below sea level.

It was Captain Phillips of the British Navy in 1853 who first proposed creating a canal to bring Mediterranean waters to the Dead Sea. He, like many subsequent advocates, used a combination of scientific reasoning and biblical beliefs to recommend the canal's viability for navigation. (see Figure 2 for timeline of the water conveyance projects to the Dead-Sea)

British Naval Officer William Allen, who had originally visited the area in 1850-1851, expanded on Captain Phillips's idea, suggesting the digging of a canal from Haifa to the Jezreel Valley, where water would then flow into the Jordan and then to the Dead Sea. He knew that only a short stretch of land in the southern Arava would have to be dug in order to connect the greatly expanded Dead Sea to the Red Sea.

This was important in the political maneuvering between France and England to gain the upper hand in waterways allowing control of their eastern colonies and markets. The fact that this canal would flood cities such as Tiberias did not seem to be a problem to him.

In 1863, the British government examined the possibility, but it concluded that the digging in the southern Arava would be too deep, the canal too long, and that the Suez Canal project was about to begin, so the idea was shelved (Vardi 1990).

It was twenty years later when the British General Charles G. Gordon suggested the plan again. His design was almost the same as Allen's, and though the Suez Canal was built and functioning under British control, there were both biblical and defense beliefs that he brought into the equation. General Gordon felt the Suez Canal was still too contentious and volatile of a waterway and creating another one would bring more security to Britain.

Starting in 1891 with a representative of Baron Rothschild, as the Zionist agenda began to pick up steam, both Jewish and Christian Zionists began proposing additional ideas. J. Kremensky, a friend of Theodore Herzl, was actually the first recorded person to suggest the creation of a canal from the Mediterranean Sea to the Dead Sea for hydroelectricity rather than navigation. He also suggested chemical factories on the shore of the Dead Sea. In 1897, M. M. Eshelman, a Californian Christian, gave his proposal to Herzl for digging from Acre to Kinneret and from the Dead Sea to the Red Sea for both navigation and hydropower (Vardi 1990).

Max Bourcart, a Swiss engineer, got so involved in the Zionist movement that he changed his name to Avraham ben Avraham. He wrote (1899) to Herzl suggesting a tunnel from the Mediterranean to the Dead Sea for hydro power and a canal from Jaffa to Jericho. Power would be used to pump Kinneret waters to the rest of Israel and the rest of the Kinneret's waters would dilute the Dead Sea to make it useable for fish and the fishing industry. Boucart eventually gave up the idea of the canal altogether, but the influence lived on in Herzl (Vardi 1990).

In his 1902 seminal Zionist work, Altneuland, Herzl suggested ways to improve the future homeland of the Jewish people. One of these methods was the creation of a canal for hydroelectric purposes (Vardi 1990). In Altneuland Herzl (1902) wrote:

> *"Before them extended the Dead Sea spread out like a deep blue mirror, their ears assailed by the thunder of the canal waters, led hither through tunnels from the Mediterranean, rushing down to the depths ... On the northern shore, near where they stood, was a narrow, pointed strip of land extending behind the rocks over which the waters of the canal came thundering down. Below stood the power plant and beyond, as far as the eye could see, numerous large manufacturing plants. The canal had brought the Dead Sea to life!"*

Many Norwegians got involved in the project. Albert Hiorth, a devout Christian, was the first, proposing his idea for a hydropower canal in 1912**,** and he even presented the project at the 11th Zionist Congress in 1913. He remained a strong advocate for the project for 25 years. After the 1912 Zionist Congress, several proposals were presented to the British Government (since they now had possession of the British Mandate) in order to promote the Mediterranean Dead Sea hydropower project. In February 1919, Norwegian C. J. Alfred Hanssen applied to the British Government, as did a group of Norwegians consisting of Moltke Hanssen, A. Helland Hanssen, Olaf Orvig, and Dr. Nassen in April later that same year (Vardi 1990).

These were not the only proposals that promoted the Mediterranean Dead Sea project. Aside from the Norwegians, the British government began to be flooded with proposals as W. K. Weber, an Australian engineer who applied in 1918, and the engineers Robert H. Bicknell and Theodore Stevens who separately proposed their ideas for a conveyance project in 1920, and Pierre Gandillon in 1925 (Vardi 1990).

As mentioned earlier, due to strategic interests, the British had proposed connecting the Mediterranean Sea, Dead Sea and the Red Sea. Not unsurprisingly, David Ben-Gurion said almost the same thing in 1935 about the need for more secure waterways for the future Israeli state should England lose control of the Suez Canal. In a 1947 meeting with President Truman, Chaim Weizmann reiterated this point (Vardi 1990).

One of the most significant events was in 1939, when Walter Clay Lowdermilk, an American soil scientist, visited the British Mandate. He used the Tennessee Valley Authority to model his vision of the Mandate. He even borrowed the name, creating the Jordan Valley Authority. Published in 1944, Lowdermilk's book "Palestine, Land of Promise" outlined his vision. He wanted to use the Jordan waters for irrigation, lowering the Dead Sea, and then using the elevation difference to create hydropower (Vardi 1990).

In 1941, Mekorot, which eventually became Israel's national water company, commissioned Simcha Blass to examine the country's water resources. He proposed a canal from the Mediterranean to the Kinneret, creating a salty Kinneret, but improving the potential for hydroelectricity (Vardi 1990).

In 1943, the Jewish Agency's Bureau for Water Research commissioned E. Boroucov to examine the potential for conveyances. After two years, he proposed two alternatives, the second of which was favored by the Bureau because it involved no expensive tunneling through the rock (Vardi 1990).

1948 saw the first radical change in the canal proposals since hydroelectricity was proposed. M. Feldschreiber suggested creating a canal for hydropower from the Red Sea to the Dead Sea. The energy created would then power a magnesium plant on the Dead Sea. (Vardi 1990)

2.2 The History of the Conveyance since Israeli Independence

With the creation of the State of Israel in 1948, the new government began a slow series of many canal studies (see Figure 3). In 1955, the engineer J.S. Cotton published a report for the government on the country's power system, which included a Mediterranean-Dead Sea canal.

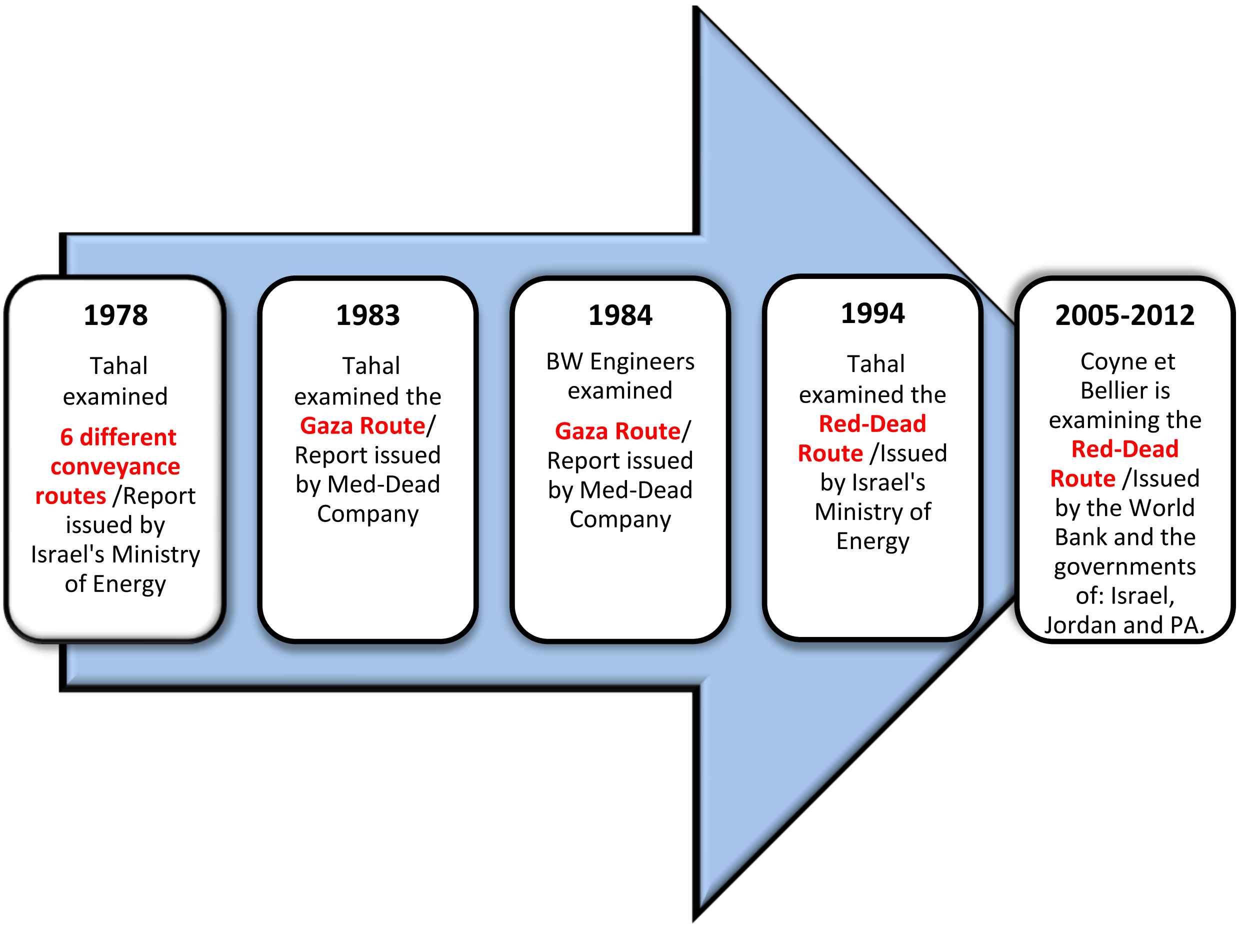
In 1966, Meir Batz, the chief engineer for the Jewish Agency's Department of Land Settlement in the Negev also advocated for a Mediterranean-Dead Sea canal. At about the same time, Professor J. Haversham was reviving an older model and proposed a navigable canal from Eilat to just south of the Dead Sea where hydropower would then be produced (Vardi 1990).

TAHAL, Israel's Water Engineering firm, found both Batz's and Haversham's plans to be economically unfeasible. Not giving up on the idea, in 1973, the engineering firm Finkle and Finkle, on behalf of the Jewish Agency's Department of Land Settlement, examined the Mediterranean-Dead Sea (Med-Dead) and Red Sea-Dead Sea canal proposals in an initial assessment and found the Med-Dead better especially in terms of the length of the conveyance, which is considerably shorter from the Mediterranean Sea.

In 1974, as a result of the energy crisis, the Minister of Energy, H. G'vati, appointed a committee headed by Professor Shlomo Eckstein (then a member of the Board of Directors, Israel Chemicals Ltd.) to examine options for a hydroelectric power generation canal, including several plans with intake all along the Mediterranean as well as the Red Sea. Finding that not only was the Mediterranean-Dead Sea conveyance superior, but also that it might be economically viable, the TAHAL Group was hired to conduct the assessment in 1976 (Vardi 1990).

The committee concluded that the project "seems practicable from an engineering viewpoint and is within the bounds of economic viability". Since this initial committee assessment, further numerous reviews have been conducted. Some of these are represented in Figure3.

Figure 3: Chronology of Conveyance Research



The first proposal to use the proposed Mediterranean-Dead Sea conveyance for desalination, as well as energy creation, came from Pinhas Glueckstern, working for Mekorot, in his 1982 article "*Preliminary Considerations of Combining a Large Reverse Osmosis Plant with the Mediterranean Dead Sea Project*."

He suggested four alternative designs to work a Reverse Osmosis (RO) desalination plant in conjunction with a hydroelectric power plant, using energy recovery systems and maximizing the system's potential, but did not develop any of these designs thoroughly. His preliminary findings suggested that locating a RO desalination plant downhill from the hydroelectric plant would have many benefits. He also noted that, if possible, adding brackish water to the seawater would decrease the energy costs of pumping the water (Glueckstern 1982).

After thorough investigation the committee recommended the Southern Alignment of the Mountain Routes from Qatif, in the Gaza Strip, to Ma'ale Yair as the preferable one in terms of engineering, economic and environmental considerations. The route was chosen mainly due to minimizing the risk of groundwater contamination from potential leakage from the tunnel.

One of the major considerations for the Ne'eman Committee was that most of the conveyance route and the entire hydroelectric power plant would be within the "Green Line[1]".

[1] The Green Line marks the line between Israel and the territories captured in the Six-Day War of 1967

This route was also preferred with regard to the ancillary social and economic benefits that the project could realize. In 1983, TAHAL released a report (continuation of a series of research) stating that ancillary benefits are maximal, with the possibility of supplying cooling water to inland power stations. This would also apply to the other Mediterranean Dead Sea routes. With the Med-Dead routes, the hazards to freshwater aquifers and tectonic and other geological risks are the lowest.

> *"The route from the Mediterranean Sea is much safer because it is not crossing the fault line opposite to the Red Sea Dead Sea route which goes along the Arava Valley. The biggest earthquakes in the history of the region have appeared in the Arava Valley. An important question is can you protect such a project."*
>
> *Eli Raz, Geologist, Biologist and Environmental Consultant, Dead Sea and Arava Science Center*

The committee recommended the establishment of a government company that will engage in all the activities related to the planning and construction of the project, including excavation of the tunnel; building of a hydroelectric power plant; ancillary projects "needed for the development and benefit of the state". It was recommended that the lands required for the project will be registered on behalf of the State. The committee further advised that the operating funds will be drawn from the State budget, while there should be an attempt to mobilize capital from private investors.

A very detailed feasibility study on "*the Mediterranean-Dead Sea Hydroelectric Project*" was completed and submitted to the "*Mediterranean-Dead Sea Company Ltd*" in 1983. This report performed research on the physical, chemical and biological processes that result from contact between the Dead Sea and the Mediterranean waters, and examined the evaporation rates. In 1984 the feasibility of the Mediterranean Dead Sea Hydroelectric Project was further assessed by BW Engineers on behalf of the Mediterranean Dead Sea Company and the Israel Ministry of Infrastructure.

In addition, surveys, measurements, and research were conducted to provide answers to various questions. Electricity demand forecasts and development plans of the Israel Electric Corporation were collected and analyzed. A cost-benefit analysis was included and the benefits from the ancillary projects were identified. Overall, over one thousand man-months were invested in the creation of the scope of the study, enabling leaders to decide whether or not the project was feasible.

The 1983 feasibility study (TAHAL) concluded that the Med-Dead project was both economically viable and feasible from both an engineering point of view. However, following the 1980s oil crises, the State of Israel faced several challenges at the end of 1980s and in the early 1990s, which caused setbacks in plans over the Med-Dead project. Russell Robinson, CEO of JNF explained (August 13, 2012):

> "*On the eve of the Russian Aliyah, the Mediterranean-Dead Sea conveyance was ready to be built. Because of the million new immigrants from the former Soviet Union, the government of Israel switched from dealing with water and energy to dealing with housing."*

Despite the positive cost-benefit balance, the study (TAHAL 1983) emphasized potential economic risks related to high discount rates. These factors eventually caused Israel to abandon the project in the 1980s and 1990s.

2.3 United Nations Intervention

TAHAL recommended the conveyance's intake on the Mediterranean to be in Gaza, which sparked problems immediately (Vardi 1990). Also, Jordan was upset at Israel's unilateral use of the Dead Sea.

From 1981 to 1985, there were five UN General Assembly resolutions and three UNEP Governing Council resolutions that were passed condemning Israel's plan for a Mediterranean Sea – Dead Sea Conveyance. The first General Assembly resolution cited international law (the Hague Convention No. IV of 1907) and noted that the plan, which had not been decided upon, would go through Gaza, which at that time was considered as an occupied territory. From the resolutions it stated the conveyance would:

> *"Cause direct and irreparable damage to the rights and the legitimate vital interests of Jordan and of the Palestinian people" (A/RES/36/150)*

Later resolutions also stated that the plan would inflict:

> *"Serious and irreparable damage to Jordan's rights and legitimate, and vital interests in the economic, agricultural, demographic and ecological fields." (A/RES/37/122).*

Although Israel's plan was unilateral, it had attempted to make the project bilateral with Jordan. In a letter to the United Nations in 1984, Yehuda Z. Blum, Israel's Ambassador to the United Nations, stated that Israel had repeatedly made overtures to the Jordanian government regarding the project, but received only silence in return. Israeli requests for information about Jordan's plans for a Red Sea-Dead Sea conveyance were also ignored (A/RES/39/142). The two countries were without a peace agreement and, of course, still technically at war.

In 1982, when citing its reasons for voting for the resolution, the Greek delegate stated that according to the Hague Convention No. IV of 1907:

> *"The occupant could exercise only a temporary right to administer the territory which it occupied and could make no changes in that territory beyond those necessitated by the immediate needs of the occupation. The construction of the projected waterway could in no way be considered a purely administrative act" (A/RES/37/328).*

2.4 Multilateral Cooperation

The peace talks and subsequent agreements of the 1990s reopened the way for the project. The 1993 Oslo Accords suggested the Mediterranean Sea-Dead Sea conveyance as a project of bilateral cooperation and benefit for Israel and the Palestinians (Israeli Ministry of Foreign Affairs 1993). Since then, there have been updated reports by TAHAL, and the way appeared open, yet plans for the Mediterranean-Dead Sea conveyance never got underway again.

Another plan, however, started to gain interest. While objecting to Israel's use of the Dead Sea for hydroelectricity, as early as 1981 Jordan had studied its own conveyance route (Jordan officially announced its plans in the "United Nations Conference on New and Renewable Sources of Energy" in Nairobi, Kenya, August 1981), connecting the Red Sea to the Dead Sea, though they abandoned it soon after for not being politically and economically feasible (A/CONF.100/NR/61 and A/SPC/38/SR.47).

Israel, too, had made official examinations in the 1970s (TAHAL 1977 and 1978) of the Red-Dead conveyance, but found the Mediterranean route cheaper and more feasible from an engineering point of view. After the 1994 peace treaty between Israel and Jordan, the way opened up for joint, rather than competing, Israel-Jordanian projects (Oren, 1999).

The Integrated Development of the Jordan River Valley (JRV) was created, following the peace agreement between the two countries. The new entity's purpose was to create a comprehensive outline of joint projects in the Jordan Rift Valley that both Israel and Jordan could cooperate on. It included various projects such as agriculture, tourism, infrastructure, and technical innovation (Israeli Ministry of Foreign Affairs 1998).

In 1995, a joint committee consisting of Israeli, Jordanian, and American officials initiated a Red-Dead study, which was managed by the World Bank and funded by the government of Italy. The US-based engineering company Harza was commissioned to create the feasibility study, while Bechtel engineering company and Mekorot analyzed the results of Harza's study (Glueckstern 2006). Yet, the study which was completed in 1997 (Harza JRV Group 1997), went nowhere for years, mainly due to political differences and economic considerations.

In the late 1990s a team headed by Dr. Refael Benvenisti working with Minister Shimon Peres as the Minister of Regional Cooperation suggested to establish the stabilization of the Dead Sea water level as a major objective of the conveyance project (Benvenisti, 2013).

Speaking at the United Nations Summit on Sustainable Development in Johannesburg, South Africa in September 2002, then Israeli Foreign Minister Shimon Peres called for the building of "a water conduit between the Red Sea and the Dead Sea, to save the Dead Sea from death" (Ministry of Foreign Affairs 2002). Finally, on May 9, 2005, the governments of Israel, Jordan, and the Palestinian Authority requested the World Bank to conduct a feasibility study on a Red-Dead Water Conveyance. Their goals were to end the Dead Sea's degradation, desalinate water affordably, and create a symbol of peace between the parties (World Bank Question and Answer Sheet 2011). This is the latest event in the 150 year development of the project. However, the World Bank study did not include the feasibility of a Med-Dead conveyance as a possible alternative to the Red-Dead.

3 Med-Dead Project Benefits

Since a conveyance project was proposed, a large variety of benefits have been touted over the years in support of its construction, yet each time the project was abandoned either due to economic or political reasons. Nevertheless, Israel still has much to potentially gain from adopting such a proposal in the present day. The security and volatility risks of fossil fuel based electricity generation makes hydroelectric power an attractive option.

In addition, such a project could have other benefits with new job and business opportunities. As a major infrastructure project, maintenance and upkeep of the Mediterranean Dead Sea conveyance, desalination and hydro plants alone, would provide new jobs. Further, new opportunities would become available especially in Jordan, Palestinian Authority and the Dead Sea region of Israel, when potable water is provided to dry desert regions.

A comprehensive cost-benefit analysis of the Mediterranean Dead Sea Conveyance project was conducted in 1983 by TAHAL Consulting Engineers Ltd. and was further assessed by a US engineering company BW Engineers in 1984. These studies did not, however, include the non-quantified benefits such as diversifying Israel's fuel sources, ecological benefits of hydropower production, and the merit of refilling the Dead Sea. Also, they did not include the benefits from the ancillary projects.

The long-term strategic significance of a potential Mediterranean-Dead Sea Conveyance Project (Med Dead) can be seen in terms of **energy security**, **water security** and **food security**. The project will have momentous contribution to all these strategic fields. All these areas have strong implications on Israel's **economic security**.

3.1 Water Management in Israel, Jordan and the Palestinian Authority

It is well known that the Middle East is a water scarce region. This region today is at the epicenter of an overarching area of water insecurity that spreads from the Far East to Turkey to North and East Africa. This water scarcity is a major challenge but may also be a harbinger of more widespread cooperation over shared water resources.

"The Blue Peace – Rethinking Middle East Water" (Waslekar, 2011) provides a comprehensive, long-term and regional framework for thinking about water in the Middle East. The idea of "Blue Peace" is to "put forward an innovative approach to engage political leaders, the public and the media in harnessing and managing collaborative solutions for sustainable regional water management, make a path for the evolution of a regional political and diplomatic community in water and create new opportunities for resolving protracted water related conflicts" (Waslekar, 2011).

The challenge is to rethink water in the Middle East, and to treat it as an opportunity for peace and development. While peace is needed for cooperation in water, a collaborative and sustainable approach to water management can build peace.

Transboundary waters connect two or more countries together. The Jordan River is shared by five riparian states – Lebanon, Syria, Israel, Jordan and the Palestinian Authority. The Sea of Galilee offers several connections to both the Upper and Lower Jordan River states. Syria and Israel are involved in a dispute over the Golan Heights and this area can have an effect on both the flow and the security of the Sea of Galilee. In the Upper Jordan River, Israel and Lebanon have had a long standing dispute over the Hasbani River. The Jordanians, Israelis and the Palestinians on the other hand are concerned about the amount of water released from the Sea of Galilee and the effect that this can have on the flow of the Lower Jordan River. (Waslekar, 2011)

Transboundary water issues exist not only between Israel and its Arab neighbors but also between Arab countries themselves. The Yarmuk River, which is shared by Syria and Jordan, has been an issue of dispute, over the amount of water allocated to each country and the amount that is actually being extracted for use. (Waslekar, 2011)

Currently almost 90 percent of the Lower Jordan River is diverted by Israeli, Syrian and Jordanian dams and development projects. The Dead Sea is shrinking by more than one meter every year due to a lack of water supply. This adverse development will continue unless the issue of scarce water resources is seriously addressed and solutions implemented. Thus Mediterranean Dead Sea conveyance project would be a natural way to increase the Dead Sea level, produce potable water for the use of Israel, Jordan and the Palestinian Authority.

The following subchapters introduce and discuss the water situation in Israel, Jordan and the Palestinian Authority.

3.1.1 Water Management in Israel

Israel has an annual renewable freshwater availability of approximately 1,300-1,400 million cubic meters annually as per indications available for 2010. About 60 percent of this comes from groundwater, 35 percent is derived from the Sea of Galilee, which is Israel's only freshwater lake, and an additional 1.5 percent is obtained from the Yarmuk River. The per capita availability of freshwater is expected to decrease in the coming decades. Israel is however supplementing its freshwater availability at a faster rate than any other country in the Middle East with desalinated water and treated wastewater, although both these alternative resources are costly ventures (Waslekar, 2011).

There is a distinct difference in precipitation levels between the northern and southern Israel. The north is generally characterized by heavy rainfall – up to 950 mm of mean annual precipitation in some parts of the Sea of Galilee and Mount Hermon in the Golan Heights. The south, in contrast, is dominated by Israel's vast Negev desert region where rainfall at the Dead Sea and in the Arava Valley can be as low as 25 mm annually. In addition, the last decade experienced several years of drought, which did not ease the water situation in the region.

Two severe periods of drought in the last decade led to serious water shortages in Israel's agricultural sector, which experienced large cut-backs in the water supply. In the short term, however, the situation has eased as the winters of 2012 and 2013 have experienced more rainfall filling the Sea of Galilee closer to its optimal water level, the upper "Red Line".

The Sea of Galilee is fed by several underground springs but its main source of water is from the Upper Jordan River. The total average annual inflow into the Sea of Galilee catchment basin is about 900 million cubic meters, of which roughly 200 million cubic meters serves consumers in northern Israel, about 400 million cubic meters is withdrawn to serve consumers throughout the rest of the country by means of the National Water Carrier, and about 280 million cubic meters is lost to evaporation (Israel Oceanographic and Limnological Research, 2013).

One important issue, when finding ways to solve the growing water shortage, is to deal with the leaking water conveyance system. In Israel water loss through leakages in pipes has been substantially reduced. According to Waslekar (2011), in Israel the water leakage was 11-12 percent as compared to 50 percent in most other Middle Eastern countries. The 10 percent level indicates basically the highest possible level of efficiency, and it is practically impossible to bring down conveyance losses below that 10 percent.

The future of Middle East water management relies on desalination. Israel's strategy of ensuring water security for its population in 2020 is dependent on efficient demand management and creation of wastewater and desalinated water on a large scale. This assumes massive energy consumption and financial investments (Waslekar, 2011). In the coming decade the master plan for desalination aims to produce a total of 1,750 million cubic meters of potable water (Global Water Intelligence, 2011). This will relieve the stress that is currently placed on the ground water resources. Another important role will be on the wastewater treatment which is already highly developed in Israel. In future, this cutting-edge technology can be applied in the surrounding region, firstly in Jordan and the Palestinian Authority.

3.1.2 Water Management in Jordan

The Hashemite Kingdom of Jordan is the fourth most water-deprived country in the world (Waslekar, 2012). Deserts comprise 80 percent of its territory and droughts are a natural part of its climate. The main rivers flowing through Jordan that contribute to its surface water supply are: the Jordan River, two of its main tributaries - the Yarmuk and the Zarqa and the side wadis that flow from the Jordanian highlands.

Jordan is facing a future of very limited water resources; among the lowest in the world on a per capita basis. In 2010 the per capita availability was 85 cubic meters per year and is projected to be 73 cubic meters by 2020.[2] Jordan has an annual renewable freshwater availability of roughly 500-570 million cubic meters. Of this amount, around 250-270 million cubic meters comes from surface water resources, while 250-300 million cubic meters is derived from renewable groundwater resources. Jordan also has fossil water aquifers located in the southeast (Disi, Mudwara and Jafr) that can provide Jordan with around 100-150 million cubic meters of water per year for another 50-100 years. These fossil aquifers are non-renewable groundwater. (Waslekar, 2011)

Demand for water in Jordan, however, is much higher than the availability of freshwater resources. Current demand exceeds freshwater supply by more than 1,000 million cubic meters. In order to make up for the excess demand, Jordan has embarked upon efforts in wastewater treatment, brackish water and seawater desalination and has plans to extract around 100 million cubic meters from its fossil water aquifers. (Waslekar, 2011)

Despite the plans to extract additional freshwater sources, a major effort needs to be undertaken in order to take care of the water supply system leaks. Water losses through water supply system leaks and illegal connections are a major problem in Jordan. According to Waslekar (2011), the government of Jordan has brought them down from 50 percent a decade ago to 35 percent in 2010, though most of the improvement has been around the capital Amman.

In order to fulfill Jordan's growing demand for water in the future, as well as at present, it has had to rely on supplementing its freshwater availability with additional or non-conventional water resources. These resources include desalinated brackish groundwater and seawater, treated wastewater and non-renewable, fossil water resources (Waslekar, 2011). However, pumping from these non-renewable water sources can be controversial because it is not sustainable in a long run. Another long term solution for Jordan is to construct dams and reservoirs to collect water. This is what Israel is already implementing when it collects and stores both rain water and treated wastewater (Keren Kayemeth LeIsrael, 2013). Yet, with Jordan's current dam capacity, an additional five new dams and additional water resources, Jordan will still not be able to cope with a decline in water availability in the future.

[2] The UN suggests that each person needs 20-50 liters of water a day to ensure their basic needs for drinking, cooking and cleaning (World Water Assessment Program, UN Water Statistics, 2013). This however does not include the agricultural and industrial water needs.

In addition to the planned Red Sea Dead Sea pipeline option for desalination and hydropower as options for Jordan's long term water security and strategy, the Mediterranean Dead Sea hydropower and conveyance project would seem to be the only viable option – especially financially – to meet the country's water needs. However, political consensus needs to be reached between the neighboring countries.

3.1.3 Water Management in Palestinian Authority

While the West Bank relies solely on the Mountain Aquifer for its freshwater supply, the Gaza Strip depends on the Coastal Aquifer as its sole freshwater resource, which already suffers from overexploitation. Thus new solutions for finding additional freshwater resources are desperately needed.

Water demand currently exceeds the available supply in the Palestinian Authority which has led to low consumption rates. The Palestinians are estimated to have an access to 158 million cubic meters water per year from the Mountain Aquifer on the basis of median calculations for 1993-2010 using shares allocated under Article 40 of the Oslo Accords (Waslekar, 2011).

The Coastal Aquifer is a shared resource that flows from Israel to the Gaza Strip. The Gazan portion of the Coastal Aquifer has an annual renewable freshwater yield of 57 million cubic meters. Some sources indicate that it is around 35 million cubic meters per year on the basis of median recharge from rainfall (Waslekar, 2011). Israel has been ready to transfer 20 million cubic meters of desalinated water from its coastal desalination plants to Gaza. All the pipes and most of the infrastructure are ready (Israel Ministry of Foreign Affairs, 2012). One would only have to connect the two water systems; Israel and Gaza. As Israel would be ready to share the resources it has with its neighbors to develop the living conditions, which would be beneficial to everyone, the leadership in Gaza has refused. Currently Israel transfers to Gaza annually five million cubic meters of water.

The key problem that the Palestinian Authority in the West Bank face today is the reduction of fresh potable water in the Mountain region. The same can be said about the Coastal Aquifers. In addition, rapid urbanization threatens to reduce run-off and consequently decrease the aquifers' recharge capacity in coming years. Another problem is that about 10 percent of the population in the West Bank lacks network connections to a regular supply of water, and as a result, unconnected communities pay higher price for their water. (Waslekar, 2011)

Internal conflicts and power struggle between the Hamas and Fatah has also made it difficult to develop the water infrastructure in the Palestinian Territories (Waslekar, 2011).

Also, for the Palestinian Authority desalination could be the future source for freshwater. Currently Gaza has small public and private desalination plants that produce a combined total of roughly 3,000 cubic meters of water a day, which is about one million cubic meters annually. Though there is potential for large-scale seawater desalination plants along the Gaza coastline, they have yet to be developed. In addition there are also 20,000 home desalination plants (Waslekar, 2011). For instance, the Arava Institute for Environmental Studies is currently developing such small scale desalination systems that would utilize the high solar radiation as a source of energy (Arava Institute, 2013).

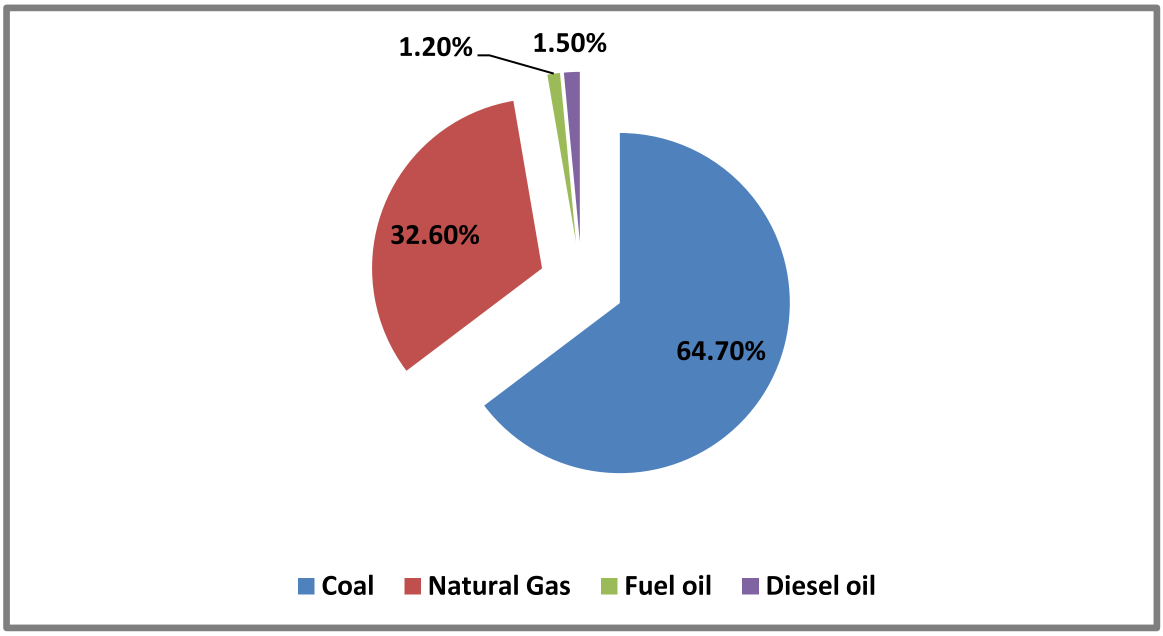
If a peace agreement between Israel and the Palestinian Authority is reached within the next decade, the water supply to the West Bank will increase.

3.2 Power Generation in Israel

In Israel, electricity is generated, transmitted, and distributed by the Israel Electric Corporation – the sole integrated electric utility, and 99.85% owned by the State of Israel. In the decade from 1999 to 2009, the national cumulative electricity demand grew at an average rate of 3.6%. In 2009, 64.7% of the electricity produced by the IEC was generated by coal, 1.2% by fuel oil, 32.6% by natural gas and 1.5% by diesel oil. All fuels used are imported from outside of Israel, with a proportion of natural gas, coming from Egypt (Israel Electric Corporation, 2012).

Israel's electricity is currently generated almost exclusively by thermal power plants (Figure 4). The current system has no hydroelectric resources (conventional or pumped storage) and is not interconnected with any system outside of Israel. Thus, it has been necessary for Israel Electric Corporation to maintain considerable reserve capacity in the form of oil-fired steam plants and gas turbines.

Figure 4: Israel's Energy Production Sources (Israel Electric Corporation, 2009)



The volatility of obtaining natural gas from Egypt cannot be overstated, especially as Egypt supplies 43% of Israel's natural gas, and 40% of the country's total electricity. Eight times in 2011, Sinai Bedouin and terrorists halted the flow of natural gas from the Sinai Peninsula to Israel in protest, resulting in losses amounting to US$1.5 million per day.

Thus, Israel's lack of control over the availability of fuels, and the dependence of desalination plants in operation along the Mediterranean coast on the national grid, means that any disruption in the supply (due to political or other reasons) would impact the state's ability to provide water for residents, agriculture and industries.

Alternatively, recent natural gas discoveries in the offshore Tamar (9.1 trillion cubic feet) and Leviathan (twice as big) fields in the Mediterranean will mitigate the potential for harm by consolidating a greater fuel supply within Israel's borders, and the government is working quickly to develop this resource (Israel Electric Corporation, 2012). In January 2012, Delek Drilling signed a US$5 billion agreement to supply Dalia Power Energies Ltd. with Tamar natural gas for 17 years, and production is set to begin in 2013 (Solomon 2012). A summary of Israel's electricity generation and consumption are presented in Table 1, below. (Lipchin, 2012)

Table 1: Israel's Electricity Landscape
Source: Israel Electric Corporation, 2009

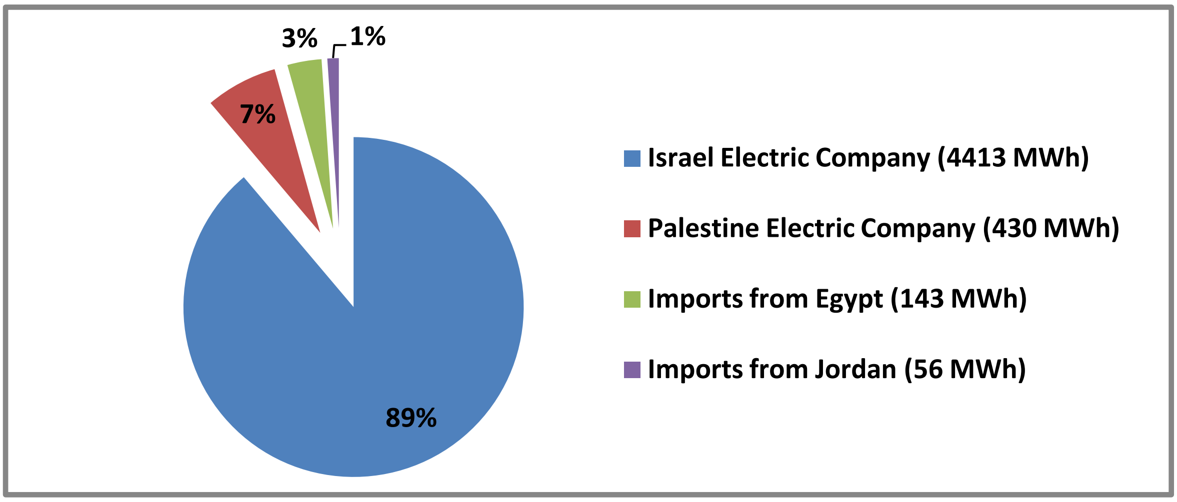
Generating System	**Installed Capacity**	11,664 MW
	Peak Demand	9,900 MW
	Electricity Generated	53,177 Million kWh
Electricity Consumption	**Total Consumption**	48,947 Million kWh
	Average consumption growth (1997-2009)	3.6%
	Total Revenues	18,704 Million NIS (4,955 Million USD)
	Average Electricity Price	0.3821 NIS/kWh (0.1012 USD)
	Total Consumers	2.4 Million
Fuel Consumption (Millions of Tons)	**Fuel Oil**	0.2
	Coal	12.3
	Gas Oil	0.2
	Natural Gas	2.7

3.3 Energy Sector in the Palestinian Authority

Energy in the Palestinian Authority is an incredibly complicated issue. The political and geographic isolation of the Authority makes transporting energy very costly, and there are local resources to generate energy.

The vast majority of fossil fuels consumed in the Palestinian Authority are imported, most originating in Israel with marginal percentages from Egypt and Jordan (Figure 5). Thus, the territories under the Palestinian Authority rely mainly on Israel for its fossil fuel and electricity imports. This is further complicated not only by the political situation but also by the fact that Israel relies predominantly on fossil fuels for its own electricity, as well. The fossil fuels in the Palestinian Authority are principally consumed by the transportation sector. (Abu Hamed et al, 2011)

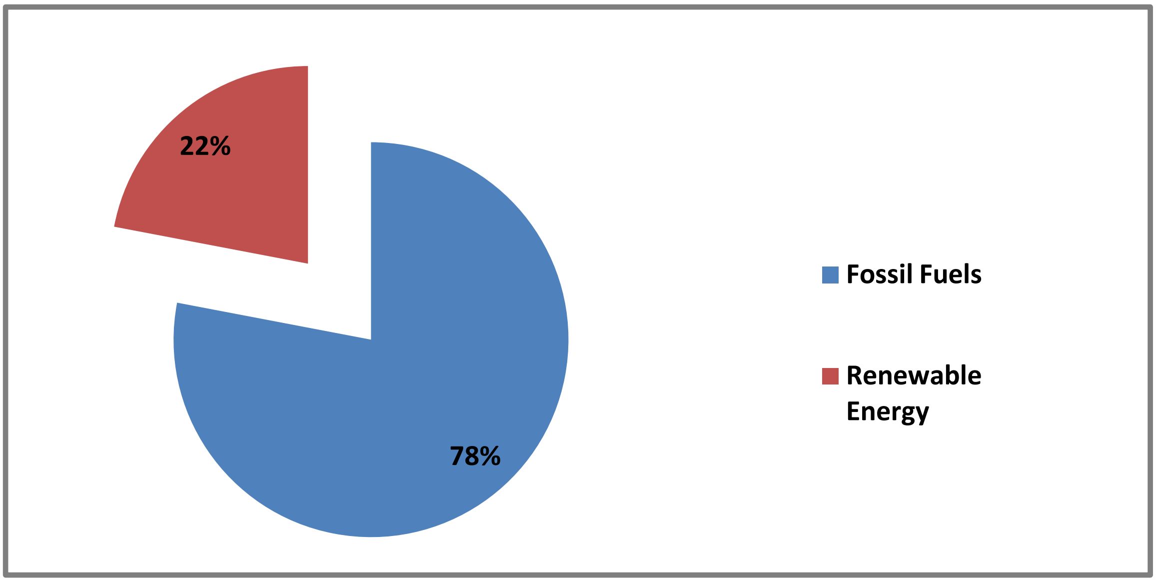
Figure 5: Energy Production Sources in the Palestinian Authority (PCBS 2010)



The only domestic production of traditional power takes place at the Gaza Power Plant, which constituted 7 percent of the energy supply in 2010. Just 1 percent of the Palestinian Authority energy consumption is supplied by the Jordanian electricity grid, which feeds the Jericho area in the West Bank, 3 percent is imported from Egypt and powers the city of Rafah in Gaza.

Dependence on Israeli and other foreign sources is costly in environmental, economic and political terms. The Palestinian Authority has the potential to reduce this reliance by producing its own energy from renewable sources. The first step toward Palestinian energy independence and security would be the development of its renewable energy sources, for both large scale energy production and smaller scale, stand alone systems (Figure 6). These include solar energy, biomass, biogas and agricultural residues. For instance, in the Gaza Strip, the production of energy from biogas would offer the additional benefit of preventing a large quantity of animal waste from entering and polluting the water and groundwater systems, which are already highly contaminated and a source of health problems. (Abu Hamed et al. 2011)

Figure 6: Primary Energy Sources in the Palestinian Authority (PCBS 2009)



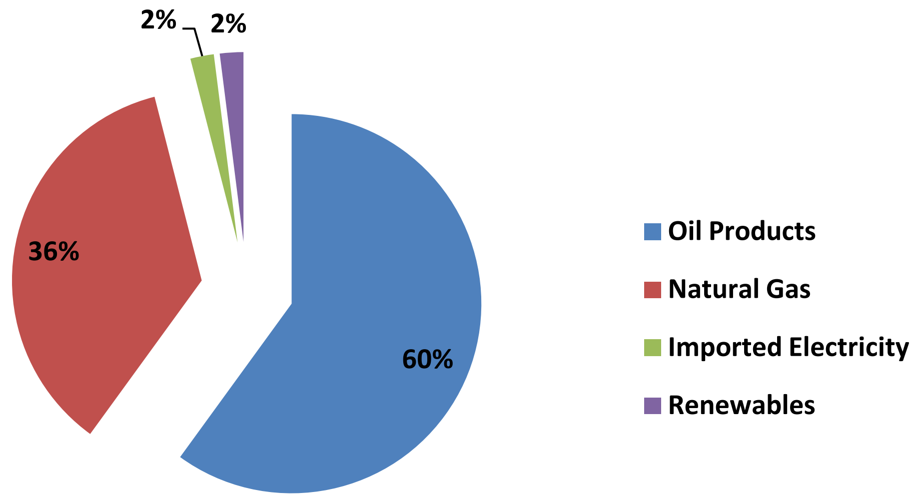
According to Abu Hamed (2011), the lack of a stable, reliable and sufficient energy system is one reason that Palestinian community development and economic development are curtailed, even before accounting for anticipated population growth and economic potential. Also, numerous natural and political characteristics of the Palestinian Authority's small geographic area pose significant obstacles for the Palestinian energy sector.

The land in the West Bank and Gaza is nearly devoid of natural resources for the production of fossil energy. There is no physical contiguity between the Gaza Strip and the West Bank. Gaza's isolation presents technical and political challenges for transporting, storing, importing and exporting energy. (Abu Hamed, 2011)

3.4 Power Generation in Jordan

Jordan has almost no indigenous energy resources and energy imports account for nearly 10 percent of GDP. Due to economic growth and increasing population, energy demand is expected to increase by at least 50 percent over the next 20 years, and therefore the provision of a reliable energy supply at reasonable cost is a crucial element of economic reform. Due to lack of conventional energy sources, Jordan is highly dependent on energy imports. Jordan's energy supply by fuel sources is highlighted in Figure 7. (Jordan Ministry of Energy and Mineral Resources, 2010)

Figure 7: Jordan's Energy Supply by Fuel Sources in 2008



Source: Jordan Ministry of Energy and Mineral Resources, 2010

In Jordan, electricity is generated, transmitted, and distributed by the National Electric Power Company, which is the sole integrated electric utility, while the Jordan Petroleum Refining Company (JPRC) has a monopoly on most of the value chain including importing products, refining, logistics and customer supply.

A great challenge for the Jordanian energy sector is the very high annual growth rate of electricity demand, around 7 percent. In addition, demand growth requires a number of policy initiatives: increased emphasis on energy efficiency; diversification of energy supplies to reduce risk; development of improved energy supply infrastructure; development of the gas industry and increased use of indigenous energy resources. (Jordan Ministry of Energy and Mineral Resources, 2010)

The Jordanian Government completed a Master Strategy of the Energy Sector in 2007 that aimed to confront the challenges that impede implementation of several energy projects. This strategic plan identified the obstacles the Jordanian energy sector faces in its implementation process and its developments. Additionally the study updated the energy demand forecasts on oil, natural gas and electricity up to the year 2020.

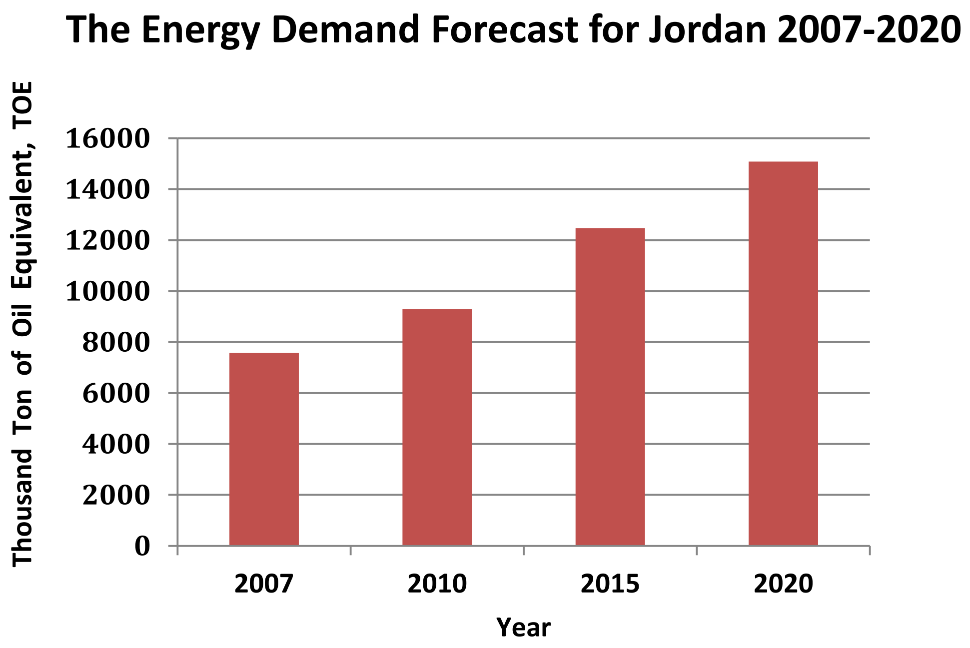
For instance, the rapidly increasing growth (Figure 8) in electric loads requires expansion of several substations operating in the national grid. This is most critical in the central areas of Jordan where the majority of the population is concentrated. The increasing power load requires the setting up of numerous electric substations to feed the new loading stations that emerge and are hard to feed from the existing substations. (Updated Master Strategy of Energy Sector in Jordan, 2007)

Jordan has oil shale resources with estimated reserves reaching as high as 40 billion tons. Jordan is also committed to continued exploration for oil and gas. Additionally, Jordan is committed to increase the share of renewable energy sources to 10 percent by 2020. According to the Ministry of Energy and Mineral Resources plans, a major share of the renewable energy sources is to come from wind power and solar power.

The future energy projects include importing increasing amounts of natural gas from Egypt through the Arab gas pipeline, replacing the crude oil pipeline from Aqaba to the refining site in Zarqa near the capital of Amman.

The energy plans also include consideration of constructing a nuclear power plant with capacity of 60 MW by the year 2020 in order to contribute to electricity generation by about 6 percent in the total energy mix.

Figure 8: The Energy Demand Forecast for Jordan 2007-2020



Source: Master Strategy of Energy Sector in Jordan (2007)

3.5 The Economic Benefits of the Hydropower Project

The Mediterranean Dead Sea Project will have great potential for energy production. Hydroelectric power generated from regulating reservoirs has special merits due to its high dependability and availability. The large difference in elevation between the Dead Sea and the Mediterranean Sea, combined with the development of free capacity in the Dead Sea, create suitable conditions for a hydroelectric project.

> *"Back then the Mediterranean-Dead Sea Conveyance project was cancelled mainly because of economic considerations. The major reason against the feasibility was the high interest rates. In major projects similar to the Mediterranean-Dead Sea Conveyance, like tunnels and dams, the investment is done in the beginning, and therefore the role of the interest rates is critically important."*
>
> *Professor Emeritus Michael Beyth, former Chief Scientist, Ministry of National Infrastructures*

There are several economic parameters that significantly affect the project net benefits in comparison to thermal energy generation alternatives. The parameters include the economic discount rate, exchange rates, world coal and gas costs, the electric load forecast, Israel Electric Corporation (IEC) resource options and expansion plans, and alternative generating resource investment costs.

Table 2: The economic feasibility analysis of the conveyance project depends on:
(source: BW Engineers 1984):

1	**Annual evaporation rate of the Dead Sea water**
2	**Inflow from the streams to the Dead Sea**
3	**Future fuel prices**
4	**Discount rate**
5	**Exchange rates**
6	**Electricity demand forecasts**

The principal economic benefits from electric power generation to be derived from the development of the hydropower project are ***savings in the cost of generation by the Israel Electric Corporation (IEC) system***. These savings, consisting of fuel, capital, operation and maintenance, loss of energy benefits (dynamic benefits), also accrue to the project due to the value of the unique dynamic characteristics of the hydroelectric resource in a thermal system.

Thus the main economic purpose of the conveyance is to produce hydroelectric energy. Hydroelectric power generated from regulating reservoirs has special merits due to its high dependability and flexibility. It can supply a considerable proportion of the variable load in the electrical grid. Therefore each unit of energy produced by the project will be of especially high value because it will replace expensive fuels and inefficient generation of power during peak demands and crises.

Diversification of energy sources will reduce the ***economic and security risk*** that results from dependence on imports. "The Steering Committee of the Mediterranean Dead Sea Project" initially emphasized this economic and security value in 1981. Dependence solely on fossil fuels, such as coal and natural gas, involves economic and security risks. Most of this comes from the necessity of maintaining significant fuel stocks. Inventory policies still leave the country open to economic and security risks, which a conveyance project can reduce. Therefore, diversifying energy sources reduces this risk. As around 95 percent of the cost of a hydroelectric project is expected during construction, the economic and security risks to Israel's energy sector are significantly reduced.

One potential benefit of the Mediterranean Dead Sea project is the geographic distribution of power stations. Currently, most of Israel's power generation is located on the Mediterranean coast, mainly due to logistics (transportation of fossil fuel, such as coal, natural gas and diesel and heavy oil). When the power stations are located in the same geographical area, they are more vulnerable to various threats, such as sabotage and terrorism, in times of conflict and more intensive military operations.

A major hydropower project would also be an alternative to a nuclear power generation option. However, this alternative has not been a very popular choice in Israel, particularly after the Fukushima nuclear disaster in 2010. Many industrialized countries, including Germany, decided to give up on nuclear power generation and invest considerable amounts in renewable energy technology after this tragedy.

Until May 2012, Jordan, considered building nuclear power (World Nuclear Association, 2013) since it has significant uranium resources. According to the World Nuclear Association, Jordan's plans included a 750-1200 MW nuclear power unit, that would be operational for power production by 2020 and a second one for operation by 2025. However, in May 2012 the Parliament of Jordan decided to suspend the country's nuclear program, including uranium exploration, to "endorse cautious proceedings" before implementing any programs for nuclear power. The Jordanian Parliament also accused the Jordan Atomic Energy Commission of misleading them (World Nuclear Association, 2013).

3.6 Benefits for Regional Development

Many recent plans have suggested wide-ranging benefits that could be implemented from any of the conveyances. Although less common in scientific literature, they are found often in business and government proposals as well as media. These benefits include using seawater to create lakes for tourism, clean industrial waste, raise the level of the Dead Sea, create fish ponds, grow algae, and cool power plants (Stern and Gradus 1981). If the additional water supply also reaches Jordan and the Palestinian Authority, it will then boost the regional development in these areas as supplementary water will enable the improvement of the living conditions in these water scarce regions. Further, the water supply will enhance agricultural development in Jordan.

Water supply and recovery system for power plants will also be able to serve desalination and other needs. Several locations can be considered, for example near the Dead Sea or alternatively near Be'er Sheva, in areas where, as a result of urban planning, water consumption will develop in the future (Interview, Russell F. Robinson, 2012).

The conduit water can be used to cool industrial processes and energy related projects. The availability of cooling water for inland power stations is a serious consideration and constraint when considering the location for future power plants.

Other opportunities are related to the construction of possible solar lakes and ponds, mining, mineral extraction, oil shale exploration and desalination of seawater inlands. None of the above mentioned business developments can be realized in their full potential without water supplied by the Mediterranean Dead Sea conduit. Additional uses develop when seawater becomes available in large quantities in the northern Negev and the Dead Sea regions (TAHAL, 1983).

With the refilling of the Dead Sea and its expansion to its original size, the sea's marvelous and singular scenery will re-emerge. As the Dead Sea is refilled, restoring it to its original surface area, the presently unattractive areas of salt and marshes will again be covered by water. The project has the potential for establishing tourism and recreational inland centers. Lakes constructed near the reservoirs would have advantages over the tourist centers already existing at the Dead Sea, since they could be used for recreational purposes.

3.7 Case Study on Negev Development

"By the Negev, the Jewish people will be tested"

David Ben-Gurion, Former Prime Minister of Israel

The Negev covers 60 percent of the State of Israel, yet only 8 percent of Israel's population lives in the Negev, thus giving the area phenomenal development opportunities. A conveyance routed through Be'er Sheva and other parts of the Negev could potentially bring jobs, water, and energy, to the region.

The Government of Israel together with various philanthropists and Zionist organizations, such as Keren Kayemeth LeIsrael – Jewish National Fund (KKL-JNF) and Keren Hayesod, have invested a great amount of resources to settle and develop the Negev, enabling life to flourish on its dry desert lands. Numerous projects have been carried out in the Negev, including building roads, water reservoirs and infrastructure, preparing land for agriculture and communities, establishing research and development stations, working to combat desertification, and developing forests and parks for the benefit of man and environment.

Within this framework, JNF USA has introduced a plan called Blueprint Negev (JNF USA 2012) to develop the Negev region of Israel. The Blueprint Negev project aims to increase the Negev's population by 500,000 new residents, improving transportation infrastructure, adding and developing businesses and employment opportunities, preserving water resources and protecting the environment.

"The framework of the Blueprint Negev is an objective of 500,000 people to the Negev", states Russell F. Robinson. For instance, Be'er Sheva's urban plan is for 450,000-500,000 people. Today Be'er Sheva has over 200,000 residents, and is one of the fastest growing cities in Israel. Similar plans have been prepared for Yeruham, Dimona, Arad, Mitzpe Ramon, Ofaqim and other development towns in the Negev, all of which add up to the 500,000 new residents.

"With these projects you can provide affordable housing and job opportunities. If you don't do this, you don't have a place for people to move into. If you don't plan this well, you will have an overcrowded Tel Aviv."

Russell F. Robinson, CEO, JNF USA

The implementation of a Mediterranean-Dead Sea conveyance will bring significant economic and social changes in the Negev, provide benefits for the national economy, and result in the improvement of the quality of life in the region. New jobs would be created and the quality of life in the Negev would be improved. The availability of large quantities of seawater in arid zones will bring about development which would otherwise be impossible. The conveyance also enables desalination in locations that would not be feasible without the seawater supply (TAHAL, 1983).

3.8 Agricultural Development

The main limitations to agricultural development in Israel are arable land, water and markets for conventional produce.

The Med-Dead project will make this development possible by supplying seawater for use in areas that do not have agricultural land or suitable water.

Mekorot is currently investing in Israel's National Water Carrier, as it is required by the construction of the new desalination facilities on the Mediterranean Sea coast. However, if hundreds of thousands of people move to southern Israel, the National Carrier would have to adapt to supply water for the future development of this region. The development of the water carrier would nonetheless depend on the overall consumption of water.

> *"For example, in order to keep the national land in the Negev, if the government of Israel would decide to cultivate an additional half a million dunam, hundreds of millions cubic meters of water would be required annually. Because agriculture is a political issue, the government is dealing with agriculture not as an economic issue, but as a national interest. …. Thus the implementation of the Mediterranean Dead Sea conveyance would be a very logical decision."*
>
> *Anonymous, Water Expert*

In addition, the Mediterranean Dead Sea conveyance would make possible completely new business opportunities related to the marine agriculture. The Negev and Arava are very suitable for marine agriculture because of the location and climate. Due to the government's desire to develop the southern region, the area is an attractive place for business developments such as fish farming.

Fish farming would provide excellent business opportunities for the Arava and Negev regions, in both Israel and Jordan, and could make the region a considerable producer of fish. These business and development perspectives should be further studied to determine quantified benefits.

4 Technical Aspects and Engineering of the Project

> *"From an engineering point of view, I don't think there are any problems related to the Mediterranean-Dead Sea conveyance project. Much more complicated projects have been implemented around the world."*
>
> *Anonymous, Water Expert*

With such a large undertaking, the only way to guarantee lucrative and productive benefits is with appropriate and meticulous planning. Over the years, various detailed proposals have emerged. This chapter looks at some of the main elements of the proposed plans.

A detailed technical and engineering study was conducted by TAHAL in 1983 and further assessed by BW Engineers in 1984 on Mediterranean Dead Sea Project's Southern Alignment from Qatif of Gaza to Nahal Parsa. The Mediterranean Dead Sea conveyance project would consist of certain major engineering concepts: **Sea Inlet, Main Tunnel, Regulating Reservoir, Power Station, Outfall Canal, and Pumped Storage and Desalination Facilities.**

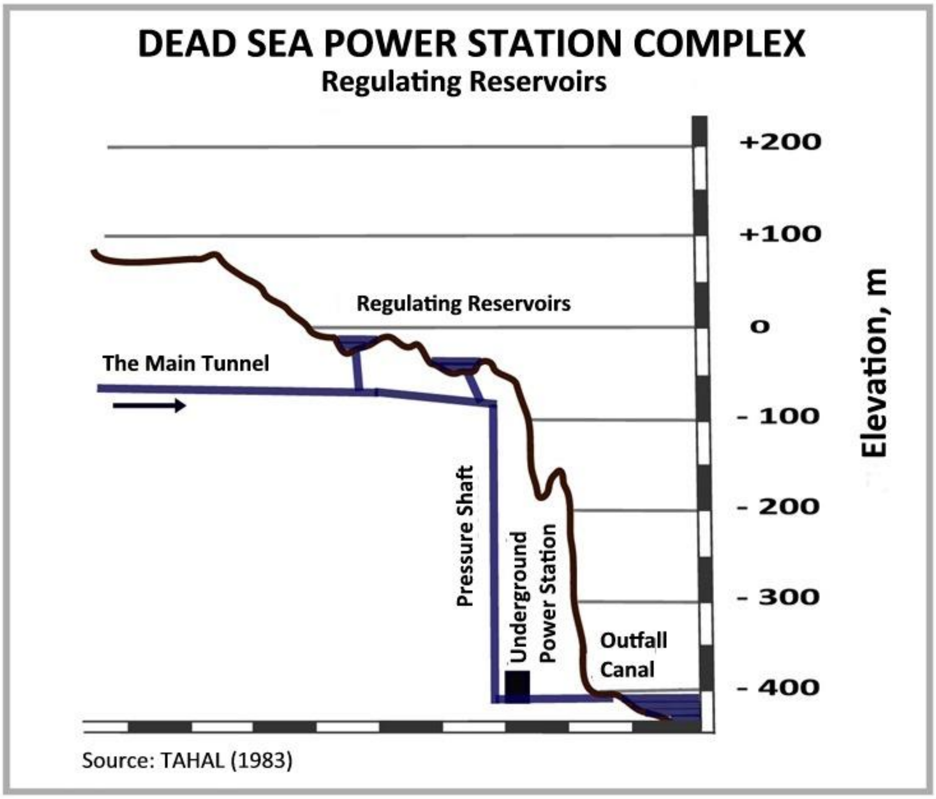
Additionally, depending on the project design the following components were needed in the Southern Alignment that TAHAL (1983) studied: **Pumping Station**, **Pressure Pipeline, Chlorination Facilities** and **Trapezoidal Canal** with the highpoint at an elevation of 100 meters**.** The following subchapters break the engineering project into its main components and describe the basic elements.

4.1 Main Tunnel

The main tunnel conveys Mediterranean Sea water from the sea inlet at the Mediterranean coast to the Dead Sea Power Station complex, across the Judean Mountains at depths of up to some 500-750 meters depending on the alignment. The general direction of the tunnel is from west to east. The proposed location of the tunnel inlet and related facilities varies and is conditional to the tunnel alignment.

The main tunnel terminates in a valve chamber which connects it with the power station's headrace tunnel and the regulating reservoir inlet/outlet tunnel (Figure 9). The tunnel discharges into the regulating reservoir and/or directly into the pressure shaft leading to the turbines. The Conveyance discharges the Mediterranean Sea water either at the Masada or the Ein Gedi site depending on the alignment.

Figure 9: Dead Sea Power Station Complex



The tunnel's longitudinal profile has a mild slope in the direction of flow along its entire length, varying between 0.1 and 1.2 m/km, as dictated by hydraulic and geotechnical considerations. The design of free flow facilitates the emptying of the tunnel in its entirety, which may be required for maintenance purposes.

According to the study conducted by TAHAL (1983), the expected influence of earthquakes on the tunnel is considered to be low or even negligible (supported and lined tunnels). The eastern end of the tunnel is at the margin of the Dead Sea seismic belt, in which recent movements are inferred or suspected, along several faults. However, the seismic risk to underground structures in this area is small.

Lining the main tunnel is required to prevent leakage of Mediterranean Sea water into the surrounding rock because this could cause contamination of groundwater. The purpose of the tunnel lining is to minimize the friction losses, ensure that it is watertight, but also to withstand the internal water pressure, together with the precast concrete supports. Thus, cast-in-situ concrete lining was recommended as it gives the tunnel an acceptable smooth finish. In certain sections of the tunnel, steel lining may be required since it provides a very smooth surface and has excellent sealing properties. The TAHAL study (1983) also considered the possibility of applying epoxy coated lining as it provides a highly smooth surface and excellent water tightness. In order to keep the tunnel walls free of fouling[3], hypochlorite solution may be injected into the water.

[3] **Fouling** is the accumulation of unwanted material on solid surfaces to the detriment of function. The fouling material can consist of either living organisms (biofouling) or a non-living substance (inorganic or organic) (Wikipedia, 19.02.2013)

The TAHAL study (1983) states that a greater type of lining (compared to concrete lining), such as waterproofing membranes, was selected for the conveyance, although the risk of groundwater contamination in case of leakage from the tunnel is low, due to the fact that most of the alignment would go under the groundwater table.

4.2 Hydropower Plant

The power station complex would be located on the western limit of the Dead Sea depression which constitutes the lowest part of the Syrian-African Rift Valley (TAHAL, 1978 and 1983). The western limit of the Rift Valley is built up of normal faulted step blocks in a general north-south direction. The Jericho fault extending to the Ein Gedi area seems to be a potential source for earthquakes with 7 to 7.25 magnitude on the Richter scale. An additional earthquake source could be the Lisan fault in the western part of the Dead Sea and the Arava. The location of the power station nearest to the Dead Sea is preferable. However, according to the TAHAL study (1983) the minimum possible distance from the Dead Sea is approximately one kilometer due to geographical and geological constraints.

The regulating reservoirs, located on the plateau above the power station, are designed to store the water conveyed by the main tunnel for release to the main power plant during hours of peak energy demand. However, the location of the powerhouse directly below the regulating reservoir is undesirable due to the danger of water leaking from the reservoir and seeping along the pressure shaft lining, risking a buckling of the steel lining due to excessive external groundwater pressure.

The geotechnical and tectonic conditions prevailing in the region of the Dead Sea coast strongly favor underground powerhouse construction. The advantages of the underground power station alternative compared to construction at ground level are threefold. Firstly, the pressure shaft is shorter than the surface penstock required in the case of the ground level powerhouse. Secondly, an underground station will be less affected by earthquakes than the ground level station, which would be within the seismologically active faulted belt. Thirdly, the construction of a large diameter penstock on the unstable slopes of the Dead Sea cliff and across geological faults involves relatively difficult engineering problems.

In addition to the above mentioned benefits, when constructing an underground power station more freedom in design is possible, since the layout of a ground level station would have to take into consideration lack of available area and unfavorable topographical conditions near the Dead Sea area. Therefore there would be minimal damage to the unique Dead Sea landscape. In addition to the above mentioned benefits, underground construction has greater protection from sabotage and flooding.

The disadvantages of the underground alternative are higher construction cost of the tailrace tunnel and access tunnel, longer construction time, and more expensive ventilation and air-conditioning facilities.

Overall, adoption of the underground alternative is highly favorable, in particular due to its protection from seismic influences.

4.3 Desalination Plants

"The water consumption by humans is leading to an environmental crisis. This is why we have to substitute the pumping of natural ground water resources and instead start producing desalinated water. When we think about long-term solutions, the effort should not be put into the desalination itself but rather the energy that we use for desalination. In general, there is no other solution than desalination when the population is increasing at such a rate."

Eli Raz, Geologist, Ecologist and Environmental Consultant, Dead Sea and Arava Science Center Researcher

The construction of desalination plants along the Mediterranean-Dead Sea and Red Sea-Dead Sea conveyance routes has been proposed by several studies, and by professionals and experts. Adding desalination capacity enables further development of the Negev and Arava, rural and urban development in Israel, Jordan and the Palestinian Authority. The following chapter discusses briefly the topic of desalination.

In the past, desalination production was limited to the southern resort town of Eilat, and the surrounding agricultural communities, where no freshwater alternative existed. Today, modern membrane technologies, increased energy efficiency, and decreased overall cost from US$2.50 per cubic meter in the 1970s, to slightly more than US$0.50 by 2003, have allowed for widespread implementation of desalination facilities along the Mediterranean coast (Becker et al. 2010).

At the start of 2012, Israel had three major seawater reverse osmosis (SWRO) desalination facilities (see Figure 10) located along the Mediterranean coastline at Ashkelon, Palmachim and Hadera. In May 2011, the financing agreement was signed for the construction and operation of a desalination plant in Sorek, 2.2 km from the Mediterranean coast and 15 km south of Tel Aviv.

Figure 10: Existing industrial scale desalination facilities in Israel

Facility	Inauguration	Production (MCM/year)	Contractor
Ashkelon	Sept 2005	119	VID, a special purpose joint-venture company of IDE Technologies, Veolia and Dankner-Ellern Infrastructure
Palmachim	2007 (April 2010)	30 (45)	Via Maris Desalination Ltd. Consortium
Hadera	2009	127	H2ID, a consortium of IDE Technologies (IDE) and Shikun & Binui Housing and Construction
Sorek	2013	150	SDL, owned by IDE Technologies and Hutchinson Water International Holdings Pte.
Ashdod	2013	100	ADL, subsidiary of Mekorot

In total, the five desalination plants along Israel's Mediterranean Coast will produce 540 MCM annually by 2020, accounting for 85 percent of domestic water consumption. By 2050, expansion of existing plants will increase the total production capacity to 750 MCM annually, accounting for 100 percent of Israel's domestic water consumption (GLOBES 2011).

Beyond the 2020 goal of 540 MCM, a second stage of the plan, recently announced, provides for the establishment of five more desalination plants between 2040 and 2050. These facilities, which account for the needs of both Israel and the West Bank, will each have a production capacity of 150-200 MCM/year for a total of 1.75 billion cubic meters of desalinated water (Table 3). The first of these plants is planned for the Western Galilee in northern Israel, and will likely begin production in 2017.

The National Planning Council of Israel has stated, however, that there is uncertainty regarding the construction of any of these five proposed plants, as it is difficult to predict future water demands. (Global Water Intelligence, 2011).

Table 3: The Planned Desalination in Israel

Number of Additional Plants	Additional Water Capacity per Facility	Additional Water Capacity in Total	Estimated Cost	Financing Method
5	150-200MCM	1.75BCM	US $15 Billion	80% Tariff
				20% State

As a byproduct of the improving membranes for desalination, membrane technology for other uses has improved tremendously. This includes osmotic power. Just as RO plants use energy to force water against the osmotic pressure, osmotic pressure can be used to generate energy. The world's first osmotic power plant opened in Norway on November 24, 2009. In this system, freshwater and seawater are put next to each other with a membrane dividing them. The freshwater rushes past the membrane and joins the seawater creating pressure. This pressure can be used to generate electricity. Experts have already recognized the potential to use desalinated reject brine for energy generation (The New York Times 11/24/2009).

This concept can be applied to any conveyance route from the Red Sea or Mediterranean Sea to the Dead Sea. The reject brine, (less than twice as salty as seawater) paired up with Dead Sea water (9.5 times saltier than seawater), has enormous potential to create osmotic power. Energy-intensive desalination plants have traditionally run on fossil fuels, but renewable energy, particularly solar power, is now beginning to play a part. For instance, thermal desalination uses heat as well as electricity in distillation processes with saline feed water heated to vaporize, resulting in the freshwater evaporating and the brine being left behind (Yapp, 2012). According to Yapp (2012), the use of solar power will bring huge cuts to the facility's contribution to global warming and smog compared to use of Reverse Osmosis method in desalination. Therefore, due to the significant energy requirements of desalination and water pumping, all clean energy options should be fully explored for any conveyance route.

4.4 Sea Intake Structure

The sea intake, located on the Mediterranean Sea shore, is designed to draw Mediterranean Sea water into the system and convey it to the Main Tunnel in a controlled fashion and keep it as free as possible from sand and other foreign particles. The location of the intake should be such that would minimize rock excavation.

Various types of intakes were studied that considered the alignment from Qatif to Nahal Peres by the Dead Sea (TAHAL 1983):

1. An intake basin, created by two breakwaters. The width of the basin and opening between the breakwaters is designed to ensure entry of seawater at velocities lower than the threshold velocity at which sand grains could be transported, and at the same time be wide enough to permit easy entrance of marine equipment
2. A submarine conduit, the inlet of which is designed to endure smooth sand-free water entrance at the required diversion capacity, and placed at sufficient depth as to not pose a hazard to small marine craft

According to the 1984 study by BW Engineers', the intake basin concept was nevertheless found to be far more advantageous than the submarine conduit, and was therefore adopted as the preferred alternative. The maintenance of the submarine conduit requires periodic scouring for the removal of marine fouling, which is considerably more expensive than the maintenance of the sea intake. The total cost of the intake basin is about half that of the submarine conduit. The stilling basin[4] design reduces the quantity of suspended sand in the water.

4.5 Regulating Reservoir

The regulating reservoirs are part of the structures associated with the Power Station complex. The purpose of the regulating reservoir is to store water conveyed by the main tunnel, and thus, to balance the continuous flow through the main tunnel. This would be during the hours when the power plant, designed to generate peak power, is not operating.

The reservoir should be located at the outlet of the main tunnel on the plateau above the selected site for the power station (however, not directly above the station). According to TAHAL (1983), the most advantageous site for a reservoir would be one that allows part of the reservoir sides to be cut into natural ridges, therefore, reducing the length of embankment to be filled, which in turn, reduces construction costs.

The reservoirs should be lined to prevent leaks or seepage into the underlying permeable rocks. Thus, it should be sealed with asphalt-concrete and bitumen or with sealing sheets.

4.6 Outfall Canal

The outfall canal conveys water from the tailrace tunnel of the Dead Sea power station to the Dead Sea. It is one component of the Dead Sea power station complex, which is comprised of the end section of the main tunnel, the regulating reservoirs, the power station, the tailrace tunnel and the outfall canal.

The outfall canal starts from the tailrace tunnel outlet from where the water discharges through a regulating structure and enters an open canal. The canal discharges the water into the Dead Sea over a gabion weir[5] structure. The alignment will go along the shore.

[4] A stilling basin is a pool, which is usually lined with reinforced concrete. Its purpose is to dissipate the energy of rapidly flowing water and to protect the riverbed from erosion.

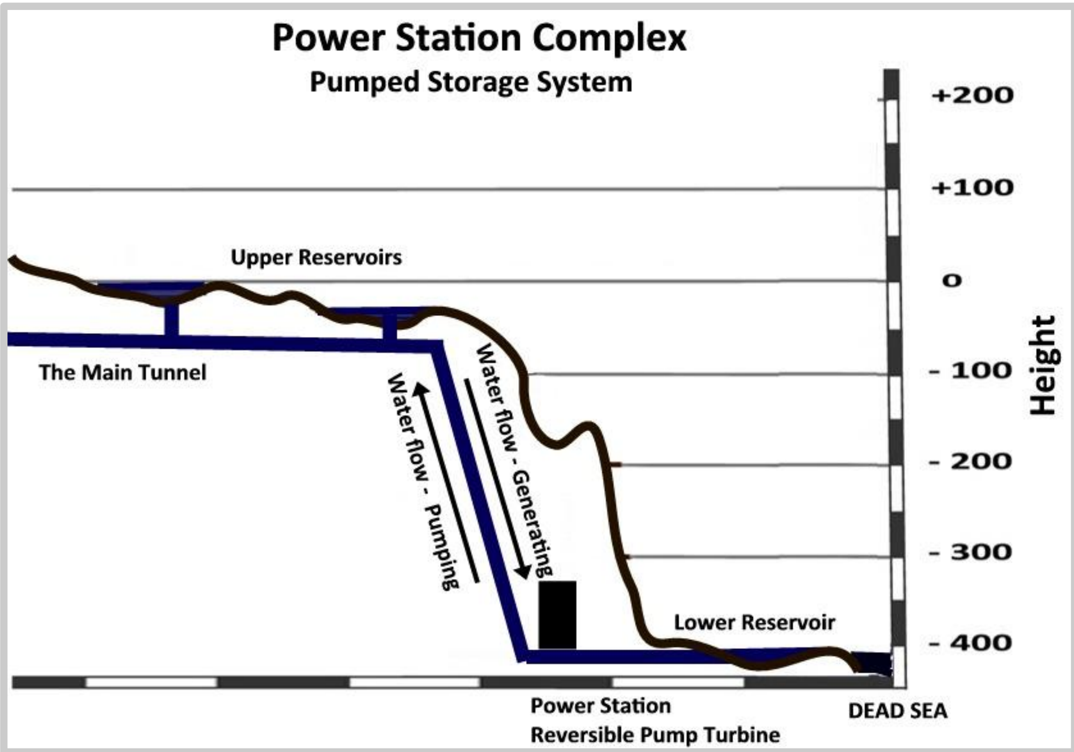
[5] A gabion weir is a structure (dam) that is widely used for formation of reservoirs and for water diversion, and has high capacity to withstand significant velocities and erosive forces

4.7 Pumped storage

The desire to protect the frequency, stability, and reliability of electricity supply has led many industrialized nations to make considerable investments in hydroelectric and pumped-storage projects (BW Engineers, 1984).

The pumped-storage hydroelectricity (see Figure 11) is a type of hydroelectric power generation that stores energy in the form of water and is the most widely used form of bulk energy storage. Pumped storage hydropower facilities typically take advantage of natural topography, and are built around two reservoirs at different heights. The water is pumped from a lower elevation reservoir to a higher elevation reservoir during low-cost off-peak periods by pumps and during periods of high electrical demand, the stored water is released through hydroelectric turbines to produce electricity. Thus during non-peak hours, water is pumped from a low elevation to a higher elevation reservoir by exploiting the surplus capacity of efficient thermal units. This would increase the power generation capacity for peak hours. This would also enable power generation at full capacity to continue with the same weekly pattern even when the steady state condition of the Dead Sea is reached.

Figure 11: Dead Sea Pumped Storage System



Despite the losses of the pumping process, the system increases revenue by selling more electricity during periods of peak demand due to higher electricity prices. With the peak load pumped storage, facilities can generate a relative advantage over thermal stations despite the energy loss in pumping and regenerating. (BW Engineers 1984)

Taking into account evaporation losses from the exposed water surface and conversion losses, approximately 70 to 85 percent of the electrical energy used to pump the water into the elevated reservoir can be regained (The Economist, 2012). This technique is currently the most cost-effective means of storing large amounts of electrical energy on an operating basis, but capital costs and the presence of appropriate geography are critical decision factors. Still, the construction costs of pumped-storage schemes are relatively low.

Hydroelectric power generated from regulating reservoirs and pumped storage systems have special merits due to their high dependability, flexibility and availability. It can supply a considerable proportion of the variable load in the electrical grid. Therefore each unit of energy produced by the Mediterranean Dead Sea Project will hold especially high value because it will replace expensive fuels and inefficient generation of power during peak demands and crises (BW Engineers, 1984).

4.8 Operational Benefits of Hydroelectric Resources

This chapter discusses the benefits of hydropower resources in comparison with the thermal systems that currently dominate the Israeli energy production. The advantage of a hydroelectric power generation is its operational flexibility. The hydroelectric resources that the Mediterranean Dead Sea conveyance project introduces to the region will bring a number of operational benefits over an all-thermal energy system. This particularly applies when the system is not interconnected with any other system.

The primary operational benefits of the project in the various expansion plans are fuel savings, capital savings, operation and maintenance, and loss of energy savings. The energy produced by the Med-Dead project is mainly replacing energy that otherwise would be generated by coal and gas units (Israel Electric Corporation, 2012).

According to BW Engineers (1984), the quantified additional benefits (also known as the dynamic benefits) add value to the project due to the unique dynamic characteristics of a hydroelectric resource in a thermal system. These benefits are startup savings, spinning reserve savings, and loss of generation savings. The non-quantified benefits include diversification of the sources of fuel, a reduction in air pollution, and the value of stabilizing the Dead Sea. Diversification of the fuel sources will help in emergency situations.

However, hydroelectric projects are generally limited in their generating capacity by their source. The project's production capacity is dictated by the discharge capacity of the main tunnel in the short run and by the absorption capacity of the Dead Sea in the long run.

Especially during extreme heat waves, the electricity reserves can dip dangerously low causing power blackouts and power failures. On days when the electricity demand reaches 11,500 megawatts, the Israel Electric Corporation (IEC) is forced to conduct planned blackouts to balance out the system (Jerusalem Post, 13.07.2012).

The Mediterranean Dead Sea conveyance and hydroelectric project can provide back-up power in cases of crisis or electrical grid emergencies. Thus the project will increase the efficiency, flexibility and reliability on the entire system. A hydroelectric plant has much better mechanical availability than does a thermal plant. It is thus much less complex, and requires less routine maintenance and has a lower incidence of breakdown.

The need for **spinning reserve**[6] stems from possible unexpected failure of generating resources or unexpected customer increase in demand. Provision of spinning reserve is costly because more plants are

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[6] The spinning reserve is the extra generating capacity that is available by increasing the power output of generators that are already connected to the power system. (Wikipedia, 19.02.2013)

committed than are strictly necessary to meet the load. This results in running a plant for long periods at less than optimum output. The second difficulty is that the thermal plant cannot readily meet sudden changes in demand, and large changes in load are just not met at all. (BW Engineers 1984)

The hydro-plant that would serve the Mediterranean Dead Sea Project would have very low costs in providing spinning reserve. Thus, only part of a large hydro-plant can carry the entire system's spinning reserve with considerable savings in fuel and money. A hydro-generation plant can increase load quickly and sustain that increased load. (BW Engineers, 1984)

It is costly to **startup a thermal plant** for a period of generation and then to close it down again, because the plant has to be heated through and brought up to temperature gradually. Once synchronized, the plant has to be loaded slowly and, therefore, runs at an inefficient loading for a period of time. Another factor is that because a thermal plant has to be loaded slowly, it generally has to be brought on in advance of requirements and, therefore, forces other plants to be operated less efficiently. Similar arguments also apply during shutdown. Thermal cycling brings about an increase in maintenance requirements. When the Dead Sea power plant is not generating electricity at its full capacity, the main function is to serve as stand-by for the generating system and to react rapidly in the event of failure of a generating unit. Thus it is available for loading at very short notice and at lower cost. This is essential for a country that is striving to base its economic system on sophisticated industry. (BW Engineers 1984)

The greater reliability, rapid load-on capacity, emergency availability, and other intangible benefits, above energy and capacity values, are such that hydroelectric power generation is selected even when its cost may be higher that a fossil fuel alternative. These benefits make the Mediterranean Dead Sea conveyance project an attractive option for Israel's future power generation.

5 The Conveyance Routes

"In terms of the routes, when you consider the points of view of economics and environment, it is for sure more feasible to convey water from the Mediterranean Sea in the west to the Dead Sea than from the Red Sea, if any, but you would have to convince the two governments."

Eli Raz, Geologist, Biologist and Environmental Consultant, Dead Sea and Arava Science Center

The engineering and financial resources required for each project heavily depends on the route chosen, and over the last 150 years, multiple routes have been proposed for the conveyance project. The six most seriously considered of these proposals consist of the Valley Route, which first pumps water into the Jordan River, four mountain routes, which must traverse the Judean Mountains, including two Northern Routes through the West Bank, one Central Route exclusively in Israel, and one Southern Route through Gaza, and, lastly, the Red-Dead route beginning in the Red Sea instead of the Mediterranean. These plans differ considerably in terms of financial cost of construction and operation, engineering feasibility, environmental impact, and political possibility. In this chapter, these routes will be compared and contrasted based on previous reports and data collected.

5.1 The Valley Route

The Valley Route would use Israel's natural landscape to transport the water cheaply. As shown in Map 3, water would be pumped to an elevation of 58 meters and canals in contours like the Jezreel and Jordan Valleys would transport the water 68 kilometers across the country. The water would end in a reservoir above the Jordan River and a 310 meter column would be constructed to produce hydroelectricity. This would generate 506 million KWh (Stern and Gradus 1981). The route uses advantage of the string of valleys: Zevulon, Jezreel, Harod and Bet Shean that cuts across the mountain range.

One of the major advantages of this route is that its power station would not entail major difficulties or unexpected engineering challenges. There are ways to prevent the risk of aquifer contamination by constructing a thick clay layer, asphalt membrane, drainage system and automatic system that will pump seawater that infiltrates the tunnel. According to the study conducted in 1978 (TAHAL), the canal would be built of concrete with a double sealing layer to prevent leakage.

The route consists of two parts: 13 kilometers in Zevulon Valley and 55 kilometers in Jezreel Valley. Between the two parts, near the Amakim Junction, there will be a pumping station that will elevate the water to a 50+ meter level, and thus the trapezium tunnel would not require drilling along the Jezreel Valley.

The level of the water tower that powers the turbine will depend on the water level in the canal and the Jordan River level. The system and the water level will be regulated on a daily basis and will produce up to 405 MW peak power. However, given the burden on the pumping station in the Amakim Valley, the power station will produce at most 375 MW, with a yearly power production that amounts to 952 MkWh during the filling period of the Dead Sea and 565 MkWh at the steady state.

The following figures show schematic, economic, and engineering features of conveyance.

Map 3 : Schematics - Valley Route

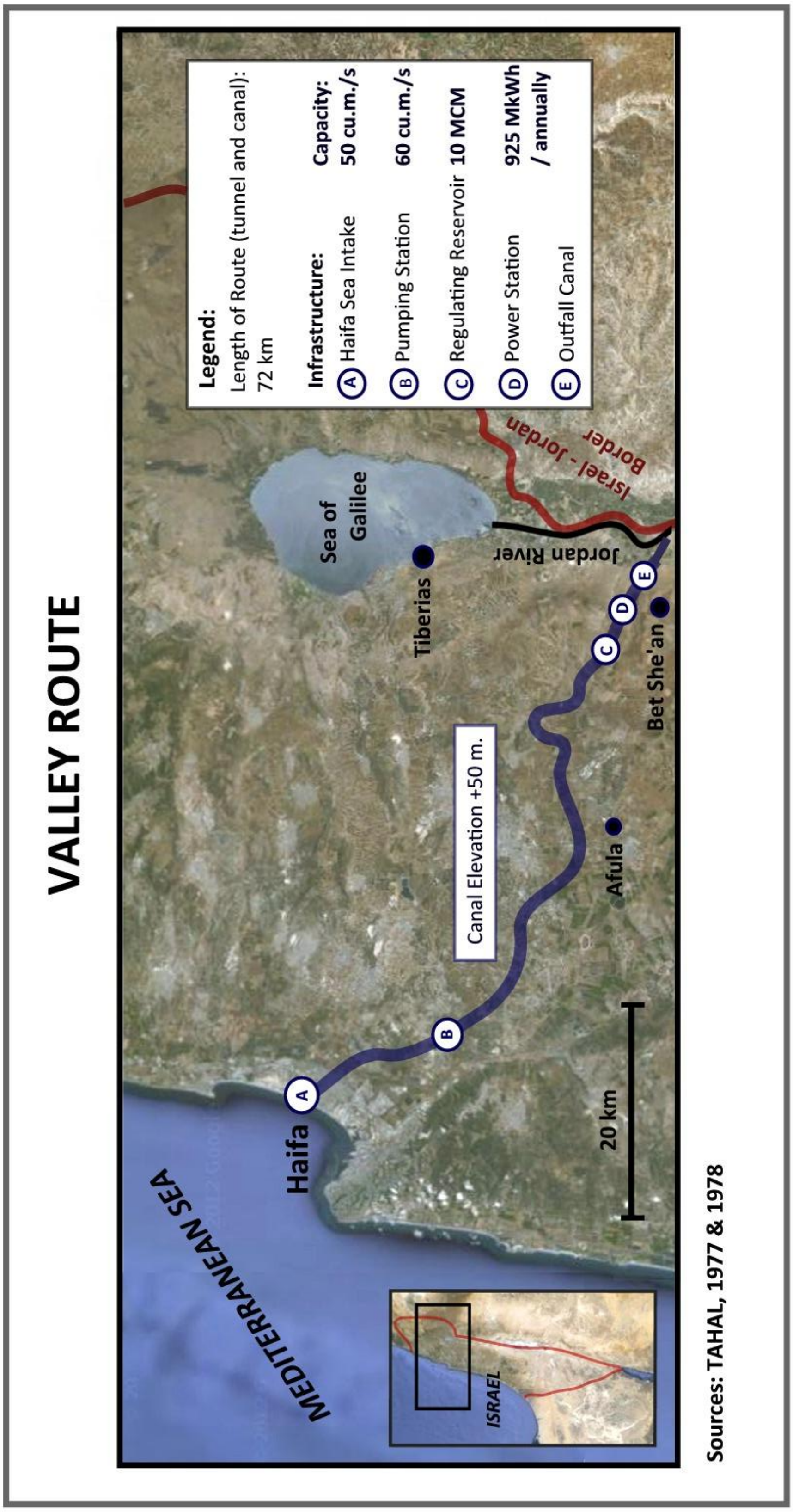


Table 4: VALLEY ROUTE: The Project Economic Summary TAHAL 1977-1978, TAHAL 1983, BW Engineers 1984		
	VALLEY ROUTE	
	HAIFA BAY - JORDAN RIVER 72 km	
ITEM	Field Cost USD 2012	Annual Operation Cost USD, 2012
Sea Intake	17,300,000	180,000
Chlorination Facility	17,300,000	1,200,000
Haifa Pumping Station	-	-
• Civil Works	13,900,000	80,000
• Engineering Mechanical	44,600,000	190,000
Elevation 50m Canal	244,700,000	2,220,000
Conveyance Tunnels	266,600,000	130,000
Regulating Reservoir	120,600,000	120,000
Dead Sea Power Station	-	-
• Civil Works	142,700,000	550,000
• Engineering Mechanical	95,900,000	890,000
Outfall Canal	64,700,000	1,240,000
Pumped Storage System	-	-
Dike Separating the Dead Sea Basins	-	-
Overhead 10%	102,830,000	680,000
TOTAL COST	1,131.130,000	7,480,000

Average Price for Electricity / kWh	0.14	USD
Discount Rate	5 %	

	HAIFA BAY – JORDAN RIVER	
Annual Total Electricity Production	925	MkWh
Net Present Value (NPV)	479,000,000	USD
Internal Rate of Return (IRR)	9 %	

	HAIFA BAY – JORDAN RIVER
Payback Period	13 years

NPV	20 years of operation
IRR	20 years of operation

Table 5: VALLEY ROUTE: The Main Characteristics of the Conveyance Design Source: TAHAL 1977-1978
VALLEY ROUTE
The Design Components:
• **Sea Intake** • **Elevation Zero Canal** • **Pumping Station** • **Elevation 50 Canal** • **Tunnels** • **Regulating Reservoir** • **Power Station** • **Pumped Storage System** • **Outfall Canal** • **Desalination Facilities** • **Chlorination Facilities**
Length the Conveyance: • **50 km of canal** • **22 km of tunnel**
Type: • **Trapezium Canal** • **Circular, concrete-lined tunnel**
Canal Width / Tunnel Diameter: • **30-35 meter** *(canal)* • **4-6 meter** *(tunnel)*
Slope: • **0.1 m – 0.25 m /km (0.001% - 0.025%)**
Lining: • **Combination of precast concrete segments, cast-in-place concrete, pressure grout and plastic foil**
Flow rate (maximum): • **50 cu.m/s**
Power Station Capacity: • **925 MkWh**
Regulating Reservoir Capacity: • **10 MCM**

Environmental and Natural Heritage Assessment

There are several nature reserves near or on this Valley Route from Haifa Bay to the Jordan Valley. Nature reserves include Hai Bar Carmel, Alonei Abba, Mount Tabor, Nahal Tavor, Shimron, Nahal Me'arot, and Moaz Haim. The route from Hadera would potentially impact Hasharon National Park and Alexander Stream National Park.

Haifa Bay has some of Israel's most polluted coastal water due to the concentration of chemical industries in the area (Ministry of the Environment 2007). Metal and organic pollution and nutrient over-enrichment are common in Haifa waters. Heavy metals include varying levels of mercury with the highest in the port as well as concentrations of other metals higher than outside the bay. High levels of TBT pollution in Haifa Port and Akko are higher than Israeli water quality criteria. Nitrogen and phosphorus enrichment are higher in the bay (Shefer et al. 2006).

Despite the high concentration of pollution, Haifa Bay is actually home to the highest biodiversity of marine life on the Israeli Mediterranean coast (Ministry of the Environment 2007). However, some of the microorganisms are potentially toxic (Shefer et al. 2006). Considerations of pollution and damage to species diversity or damage from toxic microorganisms need to be addressed in any conveyance from Haifa Bay.

There are literally hundreds of archeological sites along the Valley Route. Sites begin in the Lower Paleolithic period and cover the entire range of human habitation. Major sites include: The Carmel Caves, Tel Megiddo, Beit She'an, Beit Alpha, Tel Menorah, Belvoir, and Beit She'arim (Archeological Survey of Israel, 2012).

A tunnel will not impact the archeology, and a pipeline can be laid to avoid the sites. There is potential for construction equipment to create extra dust or runoff, or bring in people who might harm the sites whether by accident or intentionally. The digging should be monitored to determine if any archeological sites are discovered. Mitigation of damage to nearby sites should include: restricting movement of vehicles to designated roads, monitoring waste dumping, educating the workforce, and fencing the sites (Environmental Resources Management – ERM, 2011). Beit She'an would have an increased risk due to the outfall being located nearby. Due to the sheer number of sites, this constitutes a moderate risk.

Political Assessment

Israel would like to have control over the conveyance system. The route from Haifa to the Jordan Valley would give Israel total control over every aspect as passes through Israeli territory. Even after a final peace agreement, only construction for reject brine will flow through the Jordan Valley of the West Bank, which currently is classified as "Area C[7]".

Infrastructure would have to be built within the West Bank in order to transport the brine. This can become an issue as the international community generally objects to Israel building in the West Bank. As mentioned in Chapter 2, some UN members voted to condemn Israel because of Hague Convention No. IV of 1907, in which an occupying power could not build permanent infrastructure (A/37/328).

On the other hand, the Hague convention states, "Territory is considered occupied when it is actually placed under the authority of the hostile army" (Hague Convention of 1907 Sec. III, Article 42). The

[7] Area C is complete Israeli civil and security control, and is located in the West Bank

convention does not define what a “hostile” army is, and so Israel may actually have the internationally-recognized legal ability to construct.

Given that water demand currently exceeds the available supply in the Palestinian Authority which has led to lower consumption rates (Waslekar, 2011), and that the key problem in the West Bank face today is the reduction of fresh potable water in the Mountains, the conveyance would be favorable for the Palestinian Authority. However, if the water supply wont raise in the future there will be negative impact on the standard of living in the West Bank and Gaza.

If a peace agreement between Israel and the Palestinian Authority is reached within the next decade, the supply of water to the West Bank will increase.

5.2 The Mountain Routes

The following four routes all differ from the valley route because they would not force seawater into the Galilee or the Jordan River. As a trade-off, they all must be conveyed much further over the mountains to reach the Dead Sea. Each of the four differs in its political implications, as some go through the Palestinian Territories and others do not.

Northern Alignment

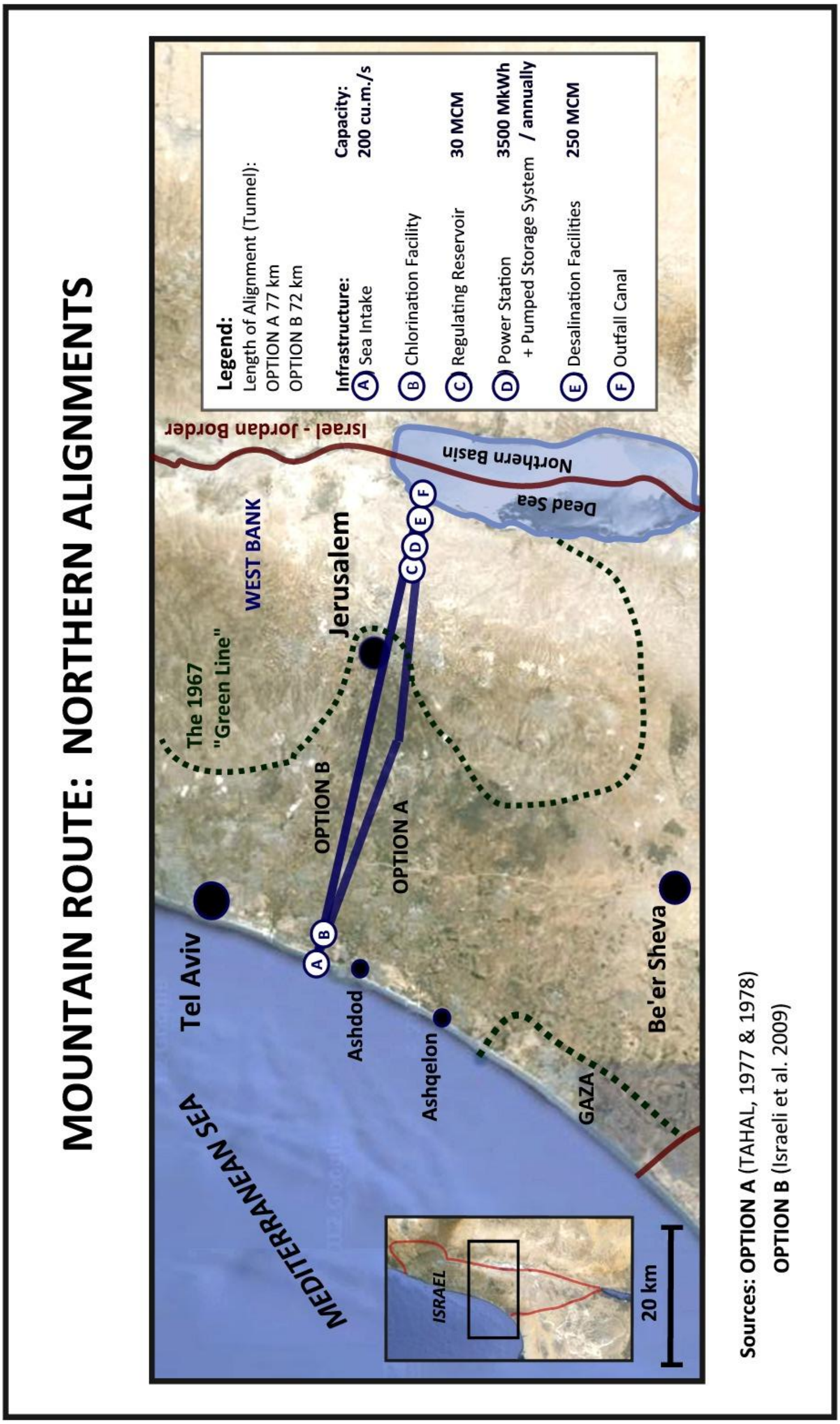
The Northern Alignment (Map 4) through the Judean Mountains would be the most direct shortest route. In this route, the conveyance would cut directly from the Mediterranean Sea near Ashdod for 77 kilometers (***Option A***), ending near Qumran at the northern end of the Dead Sea. This would cut through the West Bank and go almost directly underneath Jerusalem. The reservoir would be located at the edge of the rift and the water column would have a 370 meter hydraulic head (Stern and Gradus 1981).

The Northern Alignment plays an important role in the plans of private individuals seeking to create a Mediterranean Sea route for the conveyance. In 1993, Mr. Randolph Gonce, manager of Dead Sea Vision LLC, developed a plan for a Mediterranean-Dead Sea conveyance. In his plan, a 72 kilometer tunnel (***Option B***) would be created below sea-level from Palmachim to the Dead Sea. This plan would also use mechanical vapor compression (MVC) desalination for maximum utilization of water (Israeli et al. 2009).

The plan put forth by Dead Sea Vision LLC uses the TAHAL Northern Alignment (1978) as its basis. In this plan, a tunnel would be drilled from Palmachim on Israel's Mediterranean coast to a reservoir near the Dead Sea in the West Bank. The tunnels would be lined to be watertight against both aquifer intrusion and contamination.

A reservoir would be created at Palmachim/Ashdod for the intake of seawater. To avoid contaminating the Coastal Aquifer, the reservoir would be created out of carved sandstone below sea level. Water can be filtered as it enters the reservoir. The location for the Dead Sea Regulating Reservoir was chosen because there is no underlying aquifer and the drainage basin is the Dead Sea. The heavy, packed clay soil will also help prevent water from seeping through. Hydroelectricity would be generated from the 370 meter elevation drop, and then the water would flow to the Dead Sea where it will form an upper layer due to its lower density and thus will not mix with the Dead Sea water. A desalination plant can then pump water from this upper layer, desalinate, and put the reject brine back into the Dead Sea below the upper seawater layer (Israeli et al. 2009).

Map 4: Schematics - Mountain Routes - Northern Alignments



Central Alignment

The Central Alignment (Map 5) through the Judean Mountains curving south of the West Bank would be politically the most feasible option as all the installations completely avoid the West Bank and are within the “1967 Green Line”.

In this route, the conveyance would cut 92.5 kilometers from Ziqim of the Mediterranean Sea near Ashqelon, ending in Nahal Qenaim near Masada at the southern end of the northern basin of the Dead Sea. The reservoir would be located at the edge of the rift and the water column would have around 350-370 meter hydraulic head (TAHAL, 1977/78 & 1983).

A sea intake would be constructed at Ziqim to intake seawater. The intake would be designed in the form of a stilling basin to minimize the impacts to the Mediterranean Sea. Water would be filtered as it enters the Main Tunnel. A hypochlorite generation plant would create the chlorination and, using pipelines, insert it at the beginning of the Main Tunnel. This would help prevent biofouling of the system.

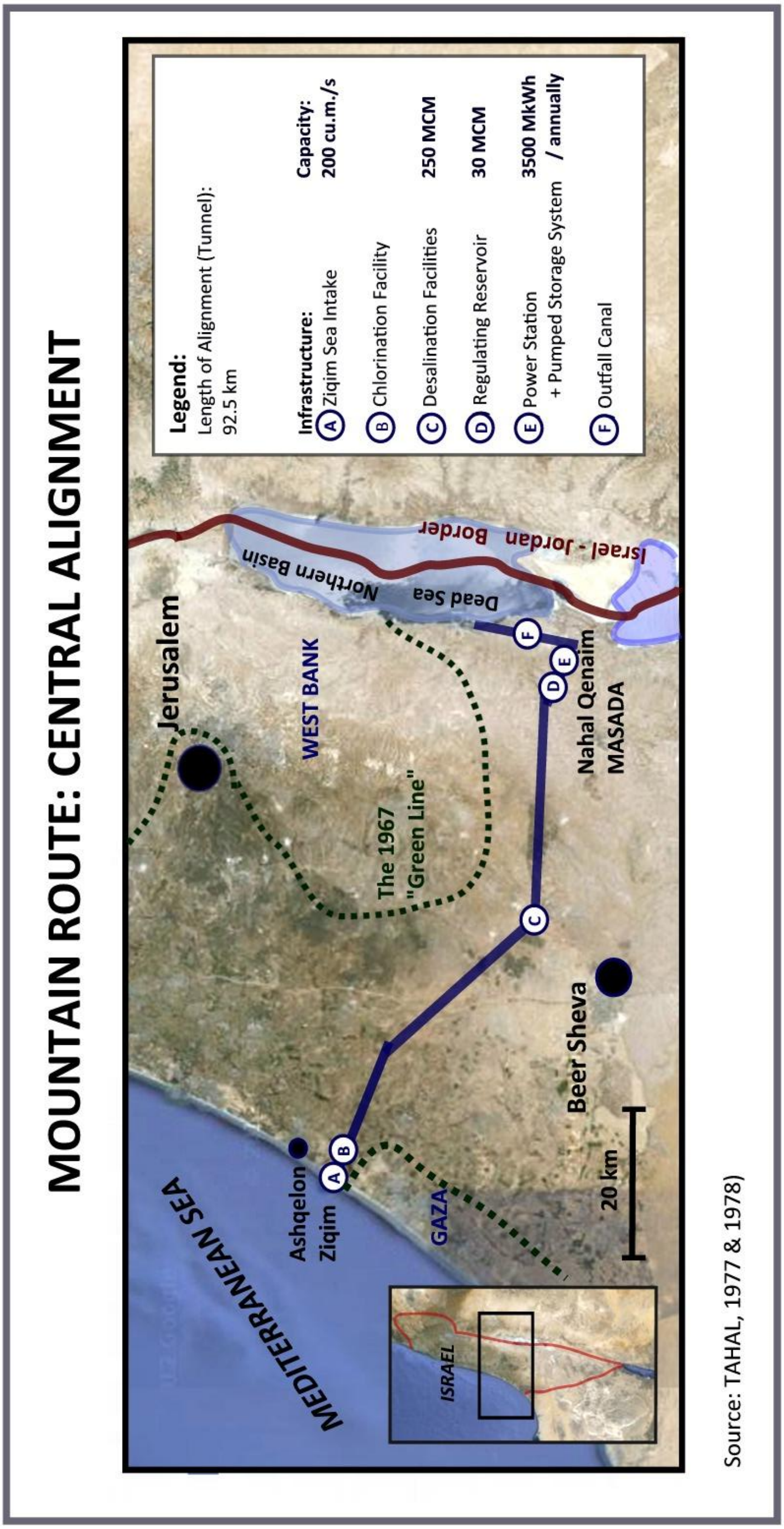
The main criteria in selecting the location for the regulating reservoir of 30 million cubic meters is the elevation and volume required. Also at this site, there is no underlying aquifer and the drainage basin is the Dead Sea. The heavy, packed clay soil will also help prevent water from seeping through.

Hydroelectricity would be generated from the 350-370 meter elevation drop, and the water would then be moved to the Dead Sea where it should become an upper layer due to its lower density. In this plan, the hydroelectric plant and the desalination plant would not work together in the same location, as many past plans have them. According to an Israeli water expert (2012), finding an optimum location for the desalination facilities would have to be further studied due to at least these three major factors: the first, maximizing the benefits of using the pressure from the Dead Sea power plant in desalination; the second, minimizing the cost of pumping water back into the mountains in Israel; and the third, minimizing the cost of building a new major water carrier to convey water from the Dead Sea to Negev, and further, instead, maximizing the use of the existing National Water Carrier.

The desalination facilities in the Central Alignment plan could be located near the city of Be’er Sheva, where the major water consumption will be in the future as the city develops. Thus the desalination plant would pump the water from the Main Tunnel to the surface, namely, from around 50 meters below sea level to around 300-400 meters above sea level, and then release the reject brine back into the conveyance, therefore mixing it with the seawater.

Tunnel boring would be done from three to five points, both ends as well as one to three access points in the middle.

Map 5: Schematics - Mountain Routes - Central Alignment



Southern Alignment

The Southern Alignment (Map 6) has many options, but two main ones will be examined. One goes through central Gaza from the Qatif pumping station and the other goes around Gaza and is slightly more northern (TAHAL 1978).

The Southern Alignment starts in central Gaza at Qatif and totals 112 km (TAHAL 1983). The sea intake would have a stilling basin extending 500 m into the sea. This would calm the water and reduce its speed. The water would then enter a 0 m elevation conduit 1.5 km long. A pumping station would bring the water 7.6 km in a pressure pipeline up to an elevation of 100 m.

At this point a hypochlorite generation plant would create the chlorination and, using pipelines, insert it at the beginning of the 0 meter conduit, the beginning of the pipeline, and the beginning of the main tunnel. This would help prevent biofouling of the system. The next section is a 19.9 km long canal. It would be trapezoidal, lined with two layers of asphalt, and with an intermediate drainage layer and drainage collecting system to prevent leaks. After that would be an 80.4 km long main tunnel. This would be concrete lined to withstand internal pressures and prevent leakage. The last section of the conveyance would be two regulating reservoirs of 7.2 million cubic meters and 4.3 million cubic meters capacity (Mediterranean—Dead Sea Company Ltd. General Report 1983).

The following figures show economic and engineering features of the Mountain Routes.

Map 6: Schematics - Mountain Routes - Southern Alignment

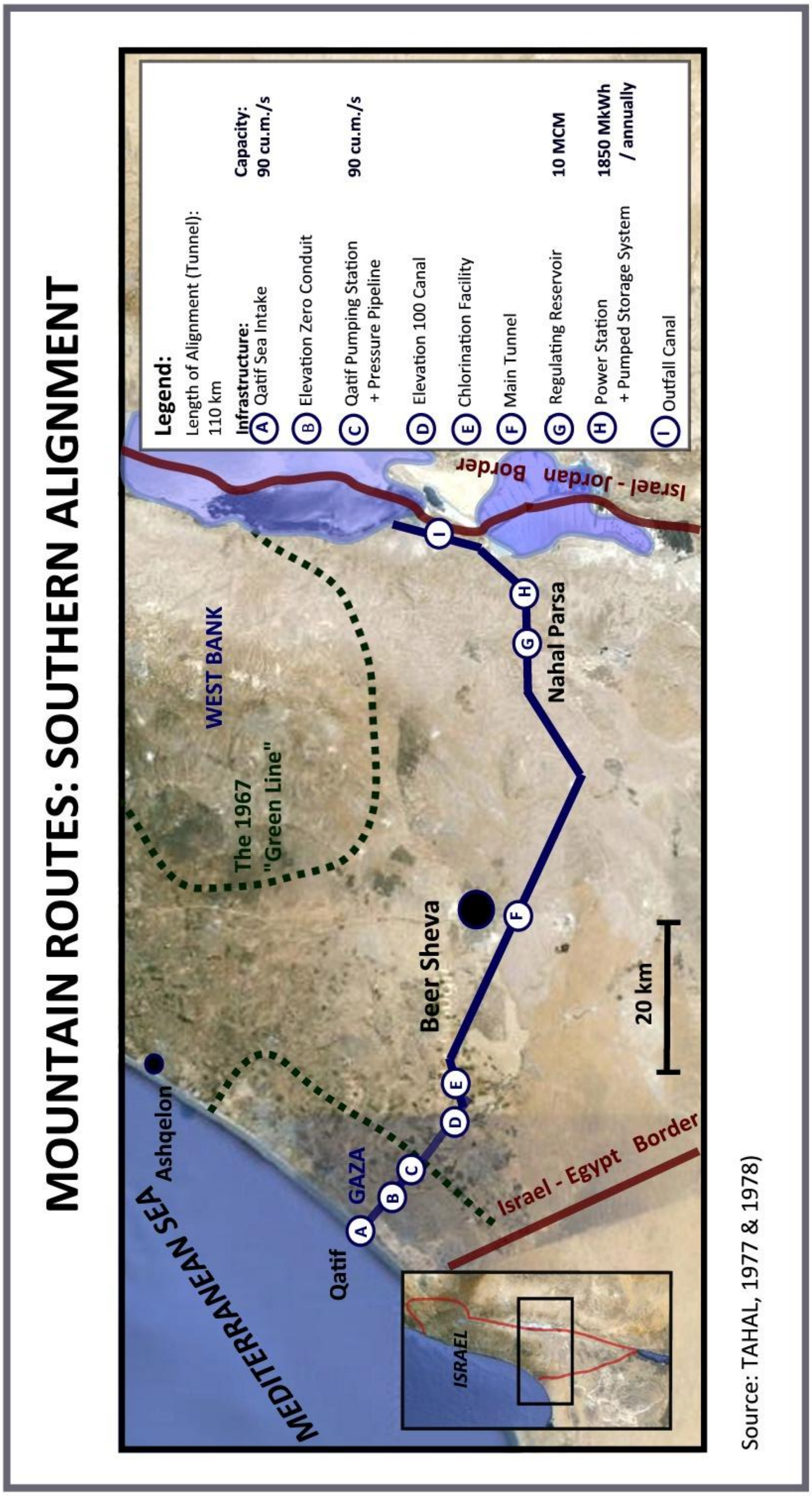


Table 6: MOUNTAIN ROUTES: Northern and Central Alignments: The Project Economic Summary
Sources: TAHAL 1977-1978, TAHAL 1983, BW Engineers 1984, Dead Sea Vision 2011 (Palmachim – Qumran Alignment)

	NORTHERN ALIGNMENTS				CENTRAL ALIGNMENT	
	OPTION A ASHDOD – QUMRAN 77 km		OPTION B PALMACHIM – QUMRAN 72 km		ASHQELON – NAHAL QENAIM 92,5 km	
ITEM	Field Cost USD 2012	Operation Cost USD, 2012	Field Cost USD 2012	Operation Cost USD, 2012	Field Cost USD 2012	Operation Cost USD, 2012
Sea Intake	69,400,000	710,000	69,400,000	710,000	69,400,000	710,000
Chlorination Facility	69,400,000	2,600,000	69,400,000	2,620,000	69,400,000	2,620,000
Main Tunnel	1,888,000,000	1,020,000	1,765,500,000	960,000	2,268,200,000	1,080,000
Regulating Reservoir	381,000,000	370,000	381,000,000	370,000	381,000,000	370,000
Dead Sea Power Station						
• Civil Works	642,200,000	2,480,000	642,200,000	2,480,000	642,200,000	2,480,000
• Engineering Mechanical	431,500,000	4,010,000	431,500,000	4.010,000	431,500,000	4,020,000
Outfall Canal	145,500,000	2,780,000	145,500,000	2,780,000	145,500,000	2,780,000
Pumped Storage System	-	-				
Dike Separating the Dead Sea Basins	300,000,000	-	300,000,000		300,000,000	
Overhead 10%	392,700,000	1,397,000	380,450,000	990,000	430,700,000	1,400,000
TOTAL COST	4,319,700,000	15,367,000	4,184,950.000	10,910,000	4,737,900,000	15,460,000

Average Price for Electricity	0.14	USD
Discount Rate	5 %	

NPV	20 years of operation
IRR	20 years of operation

	ASHDOD – QUMRAN		PALMACHIM – QUMRAN		ASHQELON – NAHAL QENAIM	
Annual Total Electricity Production	3500	MkWh	3500	MkWh	3500	MkWh
Net Present Value (NPV)	1,433,000,000	USD	1,496,000,000	USD	980,000,000	USD
Internal Rate of Return (IRR)	8 %		8 %		7 %	

	OPTION A	OPTION B	ASHQELON – NAHAL QENAIM
Payback Period	14 years	13 years	15 years

Table 7: MOUNTAIN ROUTES – SOUTHERN ALIGNMENT: The Project Economic Summary
Sources: TAHAL 1977-1978, TAHAL 1983, BW Engineers 1984

	SOUTHERN ALIGNMENT			
	QATIF (QAZA) – NAHAL PARSA 110 km		QATIF (QAZA) – NAHAL PARSA 110 km	
ITEM	Field Cost USD 1982	Annual Operation Cost USD, 1982	Field Cost USD 2012	Annual Operation Cost USD, 2012
Sea Intake	14,000,000	143,000	31,200,200	319,000
Elevation Zero Conduit	15,300,000	70,000	34,100,000	160,000
Chlorination Facility	14,000,000	529,000	31,200,000	1,180,000
Qatif Pumping Station				
• Civil Works	11,200,000	59,000	25,000,000	130,000
• Engineering Mechanical	36,000,000	150,000	80,300,000	330,000
Pressure Pipeline	54,000,000	633,000	120,400,000	1,410,000
Elevation 100 Canal	79,000,000	718,000	176,200,000	1,600,000
Main Tunnel	566,500,000	279,000	1,263,300,000	620,000
Regulating Reservoir	54,100,000	53,000	120,600,000	120,000
Dead Sea Power Station				
• Civil Works	128,000,000	494,000	285,400,000	1,100,000
• Engineering Mechanical	86,000,000	800,000	191,800,000	1,780,000
Outfall Canal	29,000,000	554,000	64,700,000	1,240,000
Pumped Storage System				
Dike Separating the Dead Sea Basins				
Overhead 10%			242,400,000	1,000,000
TOTAL COST	1,087,100,000	4,482,000	2,666,600,000	10,989,000

Average Price for Electricity	0.14	USD
Discount Rate	5 %	

	QATIF – NAHAL PARSA 2012	
Annual Total Electricity Production	1850	MkWh
Net Present Value (NPV)	755,000,000	USD
Internal Rate of Return (IRR)	8 %	

	QATIF – NAHAL PARSA 2012
Payback Period	14 years
NPV	20 years of operation
IRR	20 years of operation

Table 8: MOUNTAIN ROUTES: The Main Characteristics of the Conveyance Design Sources: TAHAL 1983, BW Engineers 1984 (some of the figures adjusted 2012)		
NORTHERN ALIGNMENT, OPTIONS A AND B	**CENTRAL ALIGNMENT**	**SOUTHERN ALIGNMENT**
	The Design Components:	
• *Sea Intake* • *Main Tunnel* • *Regulating Reservoirs* • *Power Station* • *Pumped Storage System* • *Outfall Canal* • *Desalination Facilities* • *Chlorination Facilities*	• *Sea Intake* • *Main Tunnel* • *Regulating Reservoirs* • *Power Station* • *Pumped Storage System* • *Outfall Canal* • *Desalination Facilities* • *Chlorination Facilities*	• *Sea Intake* • *Elevation Zero Canal* • *Pumping Station* • *Pressure Pipeline* • *Elevation 100 Canal* • *Main Tunnel* • *Regulating Reservoirs* • *Power Station* • *Pumped Storage System* • *Outfall Canal* • *Chlorination Facilities*
	Length of the Conveyance:	
• 72-77 km tunnel	• 92-95 km tunnel	• 80.4 km of tunnel • 30 km of canals
	Type: Circular, concrete-lined tunnel Tunnel Boring Machine excavated	
	Tunnel Inside Diameter:	
• 8-10 meter	• 8-10 meter	• 5.5 meter
	Tunnel External Diameter: *(Based on the assumption of 50 cm concrete lining)*	
• 9-11 meter	• 9-11 meter	• 6.5 meter
	Slope:	
	0.1 m – 1.2 m /km *(With continuous downward slope averaging 0.6 m/km for Southern Alignment)*	
	Lining:	
	Combination of precast concrete segments, cast-in-place concrete, pressure grout and plastic foil	
	Flow rate (maximum):	
• 200 cu. m/s	• 200 cu. m/s	• 90 cu. m/s
	Power Station Capacity:	
• 3500 MkWh	• 3500 MkWh	• 1850 MkWh
	Regulating Reservoir Capacity:	
• 10-30 MCM	• 10-30 MCM	• 10 MCM

Environmental and Natural Heritage Assessment

> *"I think that there may be serious environmental problems in the route from Ashqelon to Masada, unless proven otherwise. One has to study the environmental impact to the Dead Sea, and to act accordingly. The project should not change the Dead Sea very seriously. If one can prove the environmental and economical feasibility of the project then it can be done."*
>
> *Professor Uri Shani, former Israeli Water Commissioner and the Head of the Israel Water Authority*

Issues of the Mediterranean water near Ashdod include medium levels of DDT (dichlorodiphenyltrichloroethane) pollution in the cooling basin of the Ashdod power plant. There are also high levels of TBT (tributyltin) [8] pollution in the Ashdod marina and port and medium levels of mercury in the Ashdod port and marina. There is also enrichment of microalgae in coastal waters of Ashdod (Shefer et al. 2006). Issues of water quality will need to be addressed for any conveyance project.

The Eastern Mediterranean has less nutrients, leading to fewer microorganisms or nutrient-rich debris. According to the Mediterranean-Dead Sea Company's Environmental Assessment (1983), there were no endangered species inhabiting the coast. There are, however, more than 280 species of fish, several dozen of which swam from the Red Sea through the Suez Canal.

A tunnel will not impact the archaeological sites, and a pipeline can be laid to avoid the sites. There are several aspects of the construction that is potentially damaging to these sites: work camps and associated structures, new roads for access and maintenance, debris from excavations, trenching for laying pipes, damage from individuals (treasure-seeking and defacing), and the raising of the water level of the Dead Sea. The digging should be monitored to determine if any archeological sites are discovered. Mitigation of damage to nearby sites should include: restricting movement of vehicles to designated roads, monitoring waste dumping, educating the workforce, and fencing the sites (Environmental Resources Management, 2011). Most of this route is projected to be a tunnel, so impact will be minimal. The outfall location for the Northern Alignment will be near Qumran, the site where the Dead Sea Scrolls were found, and thus historically significant. Overall, this route constitutes a minor risk. The outfall location for both Central and Southern alignments are located near Masada.

Issues of the Mediterranean water near Ashdod include TBT pollution in the Ashkelon marina and port, and medium levels of mercury in Ashkelon marina. There is also enrichment of microalgae in the coastal waters of Ashkelon (Shefer et al. 2006).

According to TAHAL's assessment in the early 1980s, no endangered plant species would be threatened by the Gaza Southern Alignment (Mediterranean-Dead Sea Company Ltd. Environmental Assessment 1983). The assessment expected no change for the Ashkelon route. However, the conveyance could easily impact animal species such as the Negev Tortoise, jackal, oryx, ibex, gazelle, and many others. The fact that this route would be primarily a tunnel would help prevent any damage to sensitive habitats. Near the intake, however, the Ashdod Nitzanim Sand Dune Park is located. Even with the tunneling, however, there may be disturbances due to construction equipment, increased traffic, and shafts from the tunnel.

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[8] TBT (tributyltin) compounds are considered toxic chemicals which have negative effects on human and environment (Wikipedia, 19.02.2013).

Mitigation of damage to nearby sites should include: restricting movement of vehicles to designated roads, monitoring waste dumping, educating the workforce, and fencing the sites (Environmental Resources Management, 2011). Most of this route is projected to be a tunnel, so impact will be minimal. However, the Ashkelon National Park is near the intake, and is a significant site of archeology and historical significance. Near the outfall is Ein Gedi Antiquities National Park, a site of ancient human habitation and Masada, a UNESCO World Heritage Site. As well, shafts from the tunnel will have to avoid sensitive sites such as Tel Arad and Tel Be'er Sheva.

Israel has a series of nature reserves in the Negev as well as sites with important ecological functions. Potential impact of construction and maintenance of a conveyance include: Ein Besor, Nahal Besor Nature Reserve, Ein Sharuhen, Mazad Aluf, Be'erot Asnat Nature Reserve, Nahal Be'er Sheva, Nahal Hed Sands Area, Mishor Rotem, Har Amasa, Judean Desert Nature Reserve (North), Judean Desert Nature Reserve (South), Ein Gedi, Einot Kana, Einot Zukim (Mediterranean-Dead Sea Company Ltd. Environmental Assessment 1983).

A tunnel conveyance can easily avoid nature reserves, and a tunnel or a canal can be adjusted to avoid sensitive habitats. There would, however, be damage due to construction. A canal also would have problems due to flashflood risk and blocking migration of land animals. Overall, this route constitutes a minor risk.

The route, which passes south of Be'er Sheva, avoids freshwater aquifers and other water bearing strata. This is the main factor why the alignment from Gaza to the Dead Sea was preferred in the 1983 TAHAL report.

There are many archeological sites within five km of the Southern Route. These sites include: Tel Gamma, Tel Sharuhen, H. Ma'on, Tel Be'er Sheva, Tel Masof, H. Zafad, H. Aro'er, H. Kasif, Tel Arad, H. Uza, H. Radium, Mizpe Zohar, Mazad Matrurim, Mazad Boqeq, Mazad Zohar, Masada (Mediterranean-Dead Sea Company Ltd. Environmental Assessment 1983).

Political Assessment

The Northern Alignment would flow through much of the West Bank. The political situation is exacerbated further, as the hydro plant and desalination plant would be located in the West Bank. Israel will not want to give up control over them in a final peace agreement, and thus a "peace conduit" may actually make peace further out of reach.

> *"If you think about the world fundraising, it will never support an Israeli project that ends in the northern end of the northern basin. If it should be an Israeli project, it should end at the southern end of the northern Basin. If it is an international project and there is an agreement between Israel and the Palestinian Authority, then the route through the Palestinian territories may be possible."*
>
> *Professor Uri Shani, former Water Commissioner and the Head of the Israel Water Authority*

The Central Alignment

The Central Alignment is fully within Israel from the intake on the Mediterranean to the brine flow into the Dead Sea. Thus, it provides Israel with the most control and security and would be seen as the best option politically. This route avoids Palestinian territory, so there are no issues of building and international law.

However, the Palestinian Authority would insist on sharing jurisdiction as water demand currently exceeds the available supply in the Palestinian Authority which has led to low consumption rates. Also one needs to point out, that water security is one of the most important strategy issues in the Middle East. According to Waslekar (2011), the key problem that the Palestinian Authority in the West Bank face today is the lack of fresh potable water in the Judean Mountains and Samaria.

Jordan would prefer to have control over its water supply for desalination since the Mediterranean Dead Sea route crosses Israel, and not Jordan. If in the future Jordan would purchase water from Israel, it would be more dependent on the large quantities of water produced in Israel.

On the other hand, according to an Israeli environmental expert (2012), "from an idea of big dream of peace in the region, the peace could be achieved better if the two nations (Israel and Jordan) would be more dependent on one another. This conveyance project is a real cross border project".

The Southern Alignment is unfeasible due to the political instability and terrorism in Gaza. Israel would not place any part of a major asset such as the conveyance system under the control of Hamas. Should stable peace be created, this option would be feasible, though Israel would probably not desire it.

Hamas, which controls Gaza, would see no benefit from the conveyance as Palestinian water is allocated to the West Bank region and not Gaza. Therefore they have no incentive to allow such a construction. However, Gaza would benefit from the Israel National Water Carrier, as additional capacity can easily be constructed to ease the water situation in Gaza.

5.3 Red- Dead Route

The Red Sea-Dead Sea conveyance is a much different project than the Med Dead. It would take water from a different body of water and go through Jordan instead of Israel. There has been a fair amount of research on the feasibility of such a project in the last decade or so and recently with a comprehensive report from the World Bank (2012), but the following summarizes this research in a comparable way to the descriptions of the Med Dead routes above.

Schematic

The Red Sea-Dead Sea Conveyance has been proposed as a means of restoring the declining water level of the Dead Sea. Due to the economic, cultural, and touristic importance of this trans-boundary body of water, Israel, Jordan, and Palestine must come together to identify solutions for its restoration, while simultaneously increasing water security in the region.

To this end, the World Bank and Coyne & Bellier of France, in coordination with the governments of Israel, Jordan and the Palestinian Authority have conducted a feasibility study on the construction of a 200 km conveyance to transport annually 2,000 million cubic meters from the Red Sea to the Dead Sea. Called the Red-Dead Sea Conveyance (RDSC) or "Peace Canal," this project would pump seawater from the Gulf of Aqaba to an elevation of 220 meters above sea level in the Arava Valley, and then flow by gravity to the Dead Sea (World Bank, 2012).

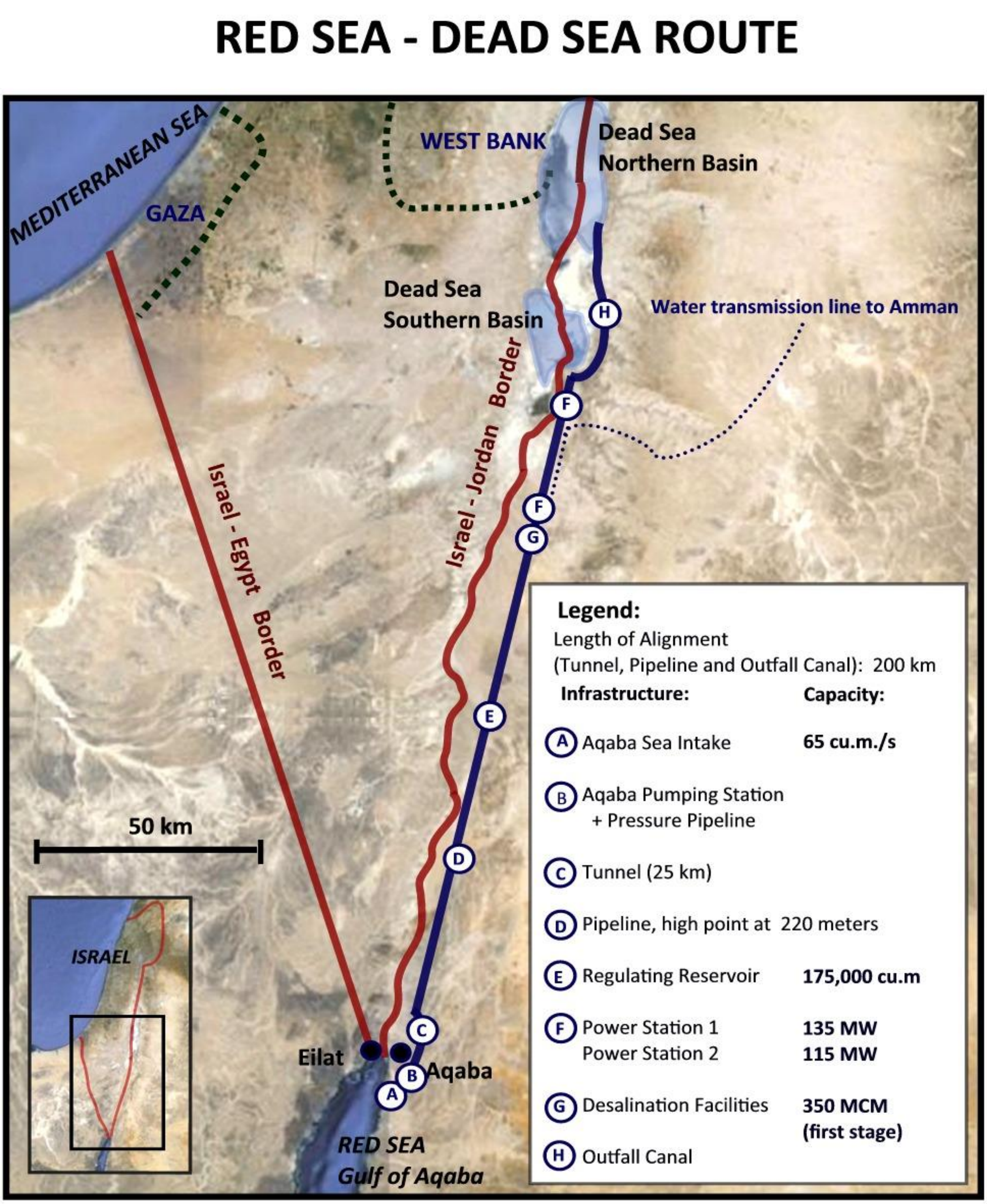
The World Bank studied a total of fifteen possible conveyance configurations. Based on the conclusions and recommendations of the screening and evaluation process, three main options for Red Sea Dead Sea alignments were further assessed. The first one is a low level gravity flow tunnel conveyance (nominal elevation of 00 meters), the second a high level tunnel/canal conveyance (nominal elevation of +220 meters), and the third, a pipeline conveyance (high point at an elevation of about +220 meters). This third option, the pipeline conveyance, was eventually considered as the recommended optimum configuration based on a multi-criteria assessment process.

The pipeline conveyance (see Map 7) incorporates a pumping station immediately adjacent to the Aqaba sea intake located in the south of the city. The water needs to be pumped to a higher elevation through a short section of pressurized tunnel around the eastern and northern fringes of Aqaba. After the pressurized tunnel, the water needs to be pumped to a series of parallel pipelines from the downstream end of the tunnel to a regulating reservoir (tank) at a high point in the Arava Valley about 80 kilometers north of Aqaba. From the regulating reservoir (tank), gravity drives flow through a series of parallel pipelines to the hydropower plant at the southern end of the Dead Sea. The alignment is approximately parallel to the border between Israel and Jordan typically 5 km to 10 km east of the border. The pipeline crosses the Jordan Dead Sea road a number of times. The desalination plant for the high level desalination variant of this configuration will be located on the pipeline alignment about 50 km north of the regulating reservoir. The project would divert an estimate 65 cu. m/s

Two power plants have been proposed, Plant One would be upstream of the high level desalination plant, and Plant Two would be close to the Fifa village south of the chemical industry evaporation plants, and would generate hydropower for the Jordan national grid. The hydropower head for the Plant One would be 211 meters generating 135 MW and the head of Plant Two would be 215 meters generating 115 MW.

The following figure (Map 7) shows a schematic of Red Sea Dead Sea conveyance route.

Map 7: Schematics - Red Sea - Dead Sea Route



Based on Israel-Jordan Peace Agreement 1994
Sources: TAHAL 2010, World Bank 2012

Economic Assessment

This is the longest route and therefore the most expensive. The expense is even larger due to the fact that it has to be built in order to withstand seismic risk. However, according to TAHAL's Techno-Economic Report in 2000, while the Red Sea route requires more investment, it would get better financing (TAHAL Techno-Economic Report 2000). Further, the World Bank study (2012) suggests that as a multinational project – and a symbol for peace – it could "more likely attract the international donations and great aid necessary to make the project financially feasible". However, following the global financial crisis, which started in 2008, financing multi-billion projects can be more difficult, especially if the project is not economically attractive, and would rather require donor money.

The World Bank (2012) study concludes, that out of the ten billion US dollar constructions costs, about four billion would have to be funded in donations and grant aid to fund "the environmental component of the project", the actual pipeline conveyance.

According to the World Bank study (2012) the project from the Red Sea to the Dead Sea is estimated to cost US$ 9,969 million (December 2009 prices). At the beginning of operation in 2020, the annual costs are estimated to be US$ 282 million not including the operating costs of the water transmission lines. This is based on the estimates of the World Bank (2012) on the basis of experience for operation and on existing tariff information for energy, the major component of the annual cost.

It is estimated that the project will require about six years to construct excluding the time for feasibility evaluation, design, and financing arrangements (World Bank 2012).

Table 9 below summarizes the costs highlighted by the World Bank (2012). The cost-benefit analysis was not included in the table due to the lack of relevant financial figures.

Table 9: RED SEA ROUTE: THE PIPELINE OPTION The Project Economic Summary
World Bank 2012

	RED SEA-DEAD SEA ROUTE
	AQABA BAY - DEAD SEA
ITEM	**Field Cost USD 2009**
Aqaba Sea Intake	**23,000,000**
Pumping Station	**294,000,000**
Main Water Conveyance • **Tunnel** • **Steel Pipes**	 **1,887,000,000** **2,803,000,000**
Desalination Facilities	**2,437,000,000**
Hydropower Plants	**241,000,000**
Outflow Canal	**267,000,000**
SUB TOTAL	**7,952,000,000**
Water Transmission Line to Amman	**2,016,000,000**
TOTAL COST	**9,968,000,000**

Table 10: RED SEA-DEAD SEA ROUTE: The Main Characteristics of the Conveyance Design Sources: WORLD BANK 2012
RED SEA ROUTE
The Design Components:
• Sea Intake • Pumping Station • Conveyance Tunnel • Gravity Pipeline • Regulating Reservoir • Power Stations • Outfall Canal • Desalination Facilities
Length of the Conveyance: 200 km
Type: Tunnel (25.5 km) Pipeline, modular 3-6 parallel pipelines depending on the section
Lining: Combination of precast concrete segments, cast-in-place concrete, pressure grout, welded steel lining and epoxy lining (internal), three layer polyethylene coating (external)
Flow rate (maximum): 65 cu.m/s
Power Station Capacity: Power Station 1: 135 MW Power Station 2: 115 MW
Regulating Reservoir Capacity (Tank): 270,000 cubic meters

Environmental and Natural Heritage Assessment

The feasibility assessment conducted by the World Bank (2012) studied and addressed the environmental and social baseline and potential impacts of the Red-Dead project. The recommended configuration emerging from the Feasibility Study is a pipeline conveyance from the Red Sea coupled with desalination on the edge of the Dead Sea basin and freshwater pipelines to population centers in Jordan. The Red Sea Dead Sea conveyance represents a fairly conventional linear construction, avoiding the usual drawbacks of this type of project that include displacement, resettlement, disruption of social and commercial activities, and severance of communities and ecosystems.

Several issues were identified and evaluated in the "Environmental and Social Management Plan". The potentially most significant concerns are (World Bank, 2012): Dead Sea appearance and water quality; Effects on the Red Sea water quality and turbidity; Hydrology and flood risk; Archeology and cultural property; Social and socioeconomics; Landscape and visual appearance of the desalination and power plants; Ecology; Hydrogeology; Public health; Nuisances and disturbances; and last, the energy demand and climate change. Further, the key issues were rated, and potential risks mitigated. "Environmental and Social Management Plan" (ESMP) was developed for the scheme to minimize the negative impacts of the Red-Dead project. The plan noted that, "with appropriate attention to the implementation, supervision and monitoring of the Environmental and Social Management Plan … the Scheme could be implemented without unacceptable environmental or social impacts." (World Bank, 2012)

According to the World Bank (2012) feasibility study report, all the studied Red-Dead configurations for conveyance routes potentially have some moderate (or higher) impacts on flora, birds, protected areas and connectivity during construction phase. The main impacts are highly site-specific, with the wadi (dry riverbeds) mouths and proposed protected areas along the conveyance line being the most sensitive receptors. The only 'major' impacts on ecology relate to the disturbance to birds at a number of locations during construction, but this kind of impact will be temporary.

The potential socio-economic impacts, which were investigated and which may occur during construction and operation phases, relate to livelihoods and employment; community health; safety and wellbeing; infrastructure; local and regional economy; community cohesion and relations; and cultural heritage. The potential socio-economic impacts of moderate and major significance in Jordan are listed below (World Bank, 2012):

- Land acquisition may affect a small number of individual communities and buildings directly, or could affect the access of communities to certain areas
- Cumulative nuisance impacts from pipeline or tunnel or freshwater line construction could negatively impact communities at certain locations, such as tunnel entrances. These include traffic safety impacts to communities, potential for inappropriate disposal of general and hazardous waste, potential overloading of existing social services
- Threat to Dead Sea tourism if the project negatively impacts the perception of the Dead Sea as a tourist destination. This could result in impacts of moderate to major significance given the importance of tourism in the Dead Sea region
- Threat to the chemical industry if the project has negative impacts on the physics and chemistry of the Dead Sea
- Health and safety risks associated with the canals: there is recognition that open canals can be dangerous to local communities, shepherds, children and animals

The potential socio-economic impacts of moderate and major significance in Israel and the Palestinian Authority are listed below (World Bank, 2012):

- There will be some visual impacts at Masada during the freshwater pipeline construction, depending on the exact routing
- Lack of community support could be used by various opponents of the project to create significant opposition at the decision making or planning approval stages. Proper care should be given to explain both the national and local benefits of the project. Lack of community support could result in an impact of moderate significance
- Threat to the chemical and tourist industries if the project has negative impacts on the physics and chemistry of the Dead Sea
- The impact of installation of the freshwater conveyance on agricultural activity

The fact that the Red-Dead conveyance would go along the active fault line is a major concern. Specifically regarding the pipeline conveyance option, given its situation within a potentially active fault area, leakage of saltwater from the conveyance into groundwater supplies could cause deterioration in well water quality, and this is an issue of concern for communities. According to the World Bank study (2012), numerous measures and construction arrangements have been incorporated into the design of the pipeline in order to reduce the leakage risk and minimize the significance of impacts.

The World Bank study's (2012) environmental impacts section concludes that a "number of significant environmental and socio-economic impacts have been identified but it is considered that all of these can be mitigated to a level where they would be acceptable", and therefore, from an environmental point of view, would not provide grounds for overall negation of the proposed project.

Political Assessment

Jordanian and Israeli delegates to the 2002 Johannesburg Summit for Sustainable Development declared their preference for the construction of a major infrastructural project linking the Red Sea to the Dead Sea (Abitbol, 2009). The planned Red-Dead conveyance would be entirely in Jordanian territory, and thus construction itself would not require political consensus either from Israel or Palestinians. The fact that the Dead Sea is a shared watershed means the riparian states would need an agreement, especially regarding the Dead Sea water levels.

Abitbol (2009) notes, that the Red Sea Dead Sea conveyance has several intangible benefits that overlap with the political assessment. Firstly the environmental benefits associated with the reversal of the degradation of the Dead Sea. Secondly, the cultural heritage benefits of preserving a site with global religious and cultural significance. Thirdly, the "Peace Dividend" benefits associated with utilizing regional cooperation to solve the practical problems linked to a major infrastructure project.

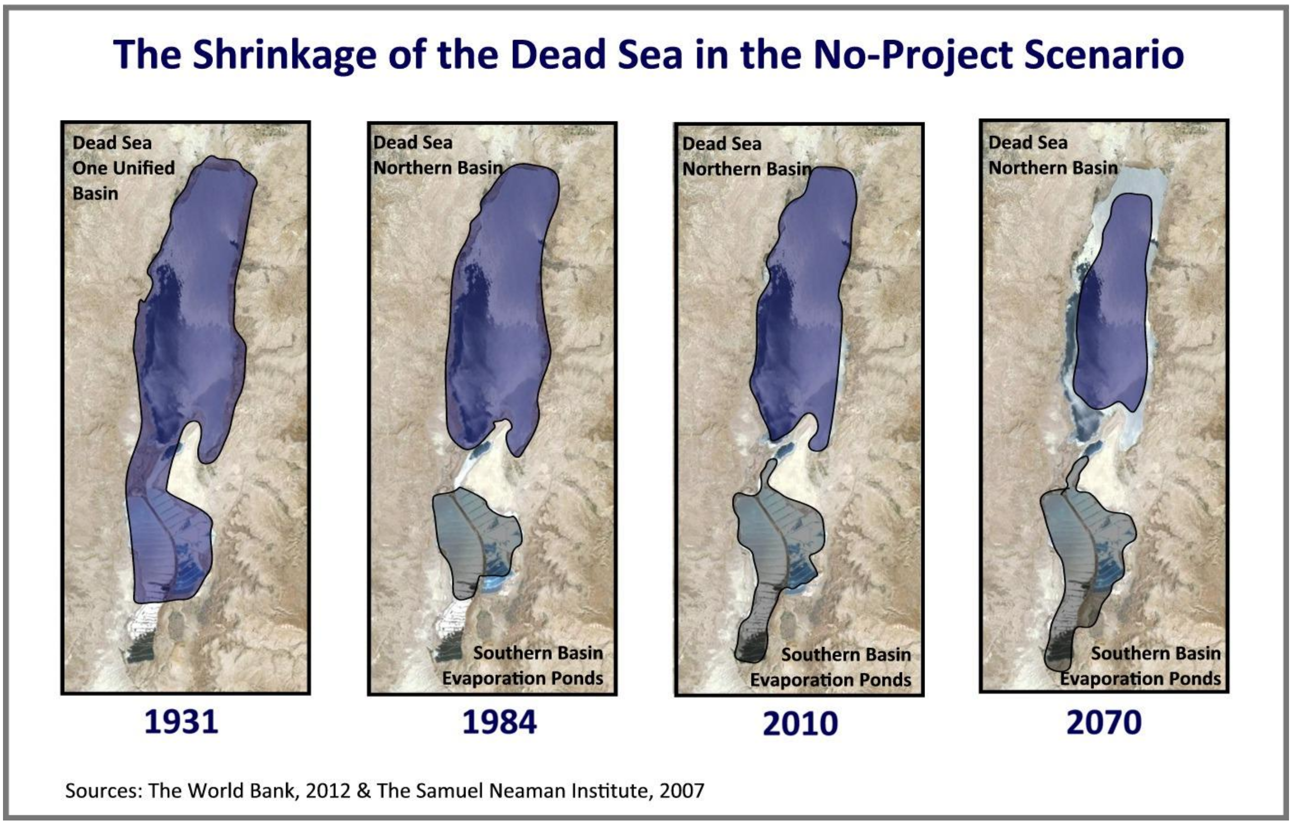
According to the Red Sea Dead Sea conveyance project Terms of Reference (2012), the project's main objective is to "create a symbol of peaceful co-operation in the region", and therefore one of the intangible benefits arising from the project would be a so called "peace dividend".

Further, the World Bank (2012) study continues "that there are strong reasons to believe that there is a potential "peace dividend" from the project and it is clear that if it materialized, it would bring with it a very significant economic value in addition to contributing to a reduction of human misery and suffering associated with the conflict". There is a belief that the development of the Red Sea – Dead Sea pipeline project could play, at least a small part, in moving the region towards co-operation and ultimately to partnership but only if the project were to be structured in the right way with the specific objective of achieving this.

6 Dead Sea Impact

The Dead Sea is a severely disturbed ecosystem, greatly damaged by anthropogenic intervention in its water balance. Since the beginning of the twentieth century, the Dead Sea level has dropped by more than 30 meters, and in June 2012 it was about 426 meters below sea level (Arab Potash Company 2012). The rate of water level drop over the last 10 years is about 1.0 m/yr, representing an annual water deficit of about 650 million cubic meters (Gavrieli & Bein 2006). The Figure 12 shows the shrinkage of the Dead Sea in a case when there is no project to raise the Dead Sea water level.

Figure 12: The Shrinkage of the Dead Sea



The sharp level drop reflects the annual interception by riparian countries of over 1,000 million cubic meters of freshwater which in the past drained to the Dead Sea. The intercepted water is diverted from the Sea of Galilee to the Israeli National Water Carrier and from the Yarmuk River by Jordan and Syria (Waslekar, 2011). Additional water is diverted upstream of the Sea of Galilee by Lebanon and smaller tributaries either draining to the Lower Jordan River or directly to the Dead Sea. Besides the water interception upstream, the Israeli and Jordanian mineral industries contribute to this deficit by artificially maintaining extensive evaporation ponds in the otherwise now dried southern Dead Sea basin. The Industries (mainly Dead Sea Works and Arab Potash Company) pump together 450-500 million cubic meters from the Dead Sea into these evaporation ponds where halite (NaCl), and carnallite ($KMgCl_3 * 6H_2O$) precipitate. At the end of the evaporation process, less than 200 million cubic meters of concentrated brines are returned to the Dead Sea. (Gavrieli & Bein, 2006)

6.1 Layering

Until 1979 the Dead Sea had a stratified structure. The stratification of water occurs when water masses with different properties - salinity (halocline), oxygenation (chemocline), density (pycnocline), temperature (thermocline) - form layers that act as barriers to water mixing. These layers are normally arranged according to density, with the least dense water masses sitting above the more dense layers.

The stratification of the Dead Sea lasted so long as large quantities of water continued flowing from the Jordan River. However, in the summer of 1979 the two main layers became about equal in their densities and the phenomenon known as “inversion” occurred, resulting in homogenization of the entire lake ending a period of about 300 years of stratification (Gavrieli & Bein 2006). It is reasonable assume that any stratification resulting from the natural large inflows of waterthat might occur in the future would be a temporary phenomenon only.

According to Gavrieli and Bein (2006), the stratification of the Dead Sea water column is not a new phenomenon in the Dead Sea and therefore in itself will not have a negative environmental impact, provided that the composition and density of the upper water body would not alter to the degree that the Dead Sea would lose its uniqueness.

The introduction of seawater into the lake is expected to restore the salinity stratification. When the lighter Mediterranean water is brought into the Dead Sea, it will be mixed only in the epilimnion[9] and new density stratification will be established. As the water level rises, during the filling period, the less saline upper layer will expand, pushing down the pycnocline[10] to a depth of several tens of meters. The rate at which the density will decrease will be determined by the rate of inflow and depth of stratification. Once the desired lake level has been attained, inflow will be controlled so that it will only compensate for evaporation (Gavrieli & Bein 2006).

6.2 Mixing

Precipitation of gypsum could be a problem when the Mediterranean Sea water mixes with the Dead Sea water depending on the amount of water added to the Dead Sea. Mixing between the calcium (Ca_2) – rich Dead Sea brine and the sulfate (SO_4) – rich seawater will result in precipitation of gypsum ($CaSO_4 \cdot 2H_2O$).

When certain conditions in the Dead Sea occur, the salts reach saturation point and crystallize. According the TAHAL study (1983), it would seem that in the past, crystallization of aragonite in the Dead Sea has occurred as a result of inflow of relatively large quantities of carbonic acid, which was dissolved in the natural runoff.

At the end of the 1950s, aragonite and gypsum crystals were observed in a suspended state. Suspended gypsum particles could form only under exceptional conditions of high temperature and concentration that may only prevail under conditions of an undisturbed lake at some specific locations, and over very short durations. This phenomenon, causing a very light turbidity[11] in the water, has been referred to as “whitening”. (TAHAL 1983)

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[9] The top-most layer in a thermally stratified lake (Wikipedia, 17/07/2012)

[10] Layer where the density gradient (∂ρ/∂z) is greatest within a body of water (Wikipedia 17/07/2012)

[11] Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the bare eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. (Wikipedia, 21/01/2013)

The rate at which the gypsum crystals or agglomerates settle from the upper water column will determine if, how, and to what extent the turbidity of the water column will increase. An increase in surface water turbidity is not a desired outcome of the project because it may be accompanied by local climatic changes due to changes in the reflectivity of the water's surface and may also impact negatively on the visual attractiveness of the Dead Sea. Gavrieli and Bein (2006) conclude that it still needs to be determined at what point, if at all, the turbidity becomes unbearable to the extent that it will hinder the conveyance project.

Nevertheless in any event, after about two months from the time of bringing in the Mediterranean water, the salts are expected to precipitate to the lake bottom. Thus, with the future inflow of Mediterranean seawater to the Dead Sea, no accelerated precipitation of aragonite is expected because Mediterranean Sea water does not contain carbonic acid in amounts larger than those in the runoff waters in the past. (TAHAL, 1983)

Findings indicate that the crystals precipitated are relatively large (tens of microns and above), the rate of growth is rapid, their density (2.3) is far higher than that of the lake water and they do not stay in suspension for any significant length of time. Therefore any gypsum produced would occur mainly at the bottom of the mixed layer and sink to the lake bottom. Under special conditions, small crystals can stay in suspension for short intervals (TAHAL 1983).

Algal and bacterial blooming has been observed in the Dead Sea in the past, following particularly rainy winters, when the upper water column was diluted (Gavrieli et al., 2005).

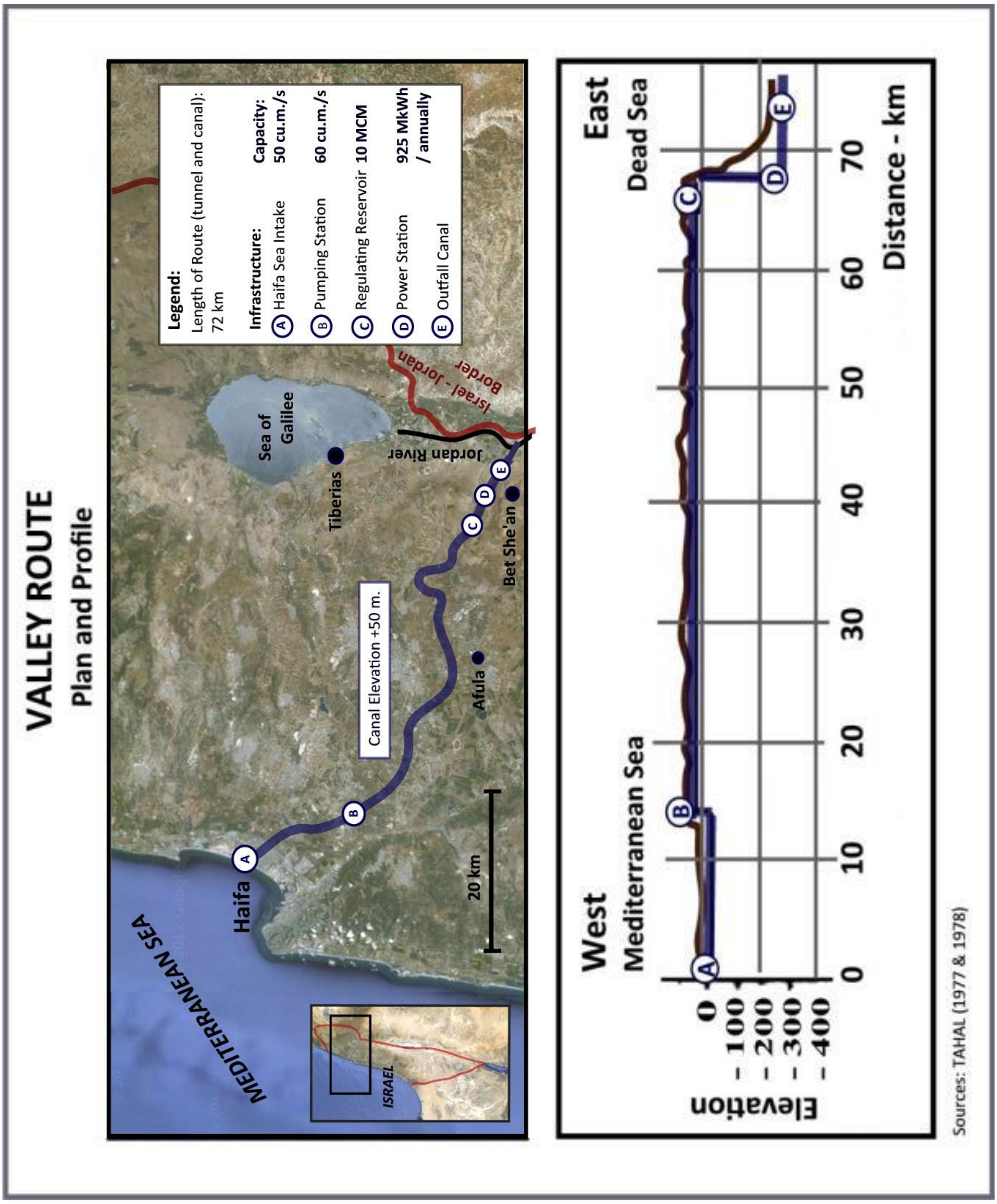
Seawater, though salty, would still have the same effect (Gavrieli et al. 2005). The organisms growing would be microscopic and would not constitute enormous changes, but would result in a shift in the Dead Sea's ecology, possibly limiting the current halophilic dwellers to saltier depths. Those that require sunlight would have a difficult time, as the less salty water would be on top, partly blocking out the sun.

The algae blooms may give the Dead Sea a variety of colors depending on the exact salinity and chemical makeup of the water. Red, green, and even purple algae blooms are possible (Oren 1999). The addition of the low-phosphate Mediterranean water would basically limit the growth of algae. The generally deep pycnocline (deeper that 10-15 meters), expected to form during most of the project operation, cannot give rise to a massive algal bloom because of insufficient penetration of light. Without mass development of algae, the growth of halobacteria will also be inhibited, thus, the unfavorable ecological conditions will probably prevent any significant reddish bloom (TAHAL, 1983).

Gavrieli and Bein (2006) conclude, that a conveyance, the 'Peace Conduit' as they refer to it, "will have both positive and negative impacts on the future evolution of the Dead Sea". Further, based on current knowledge, the various aspects of Dead Sea – seawater mixing does not provide grounds for overall negation of such a conveyance project.

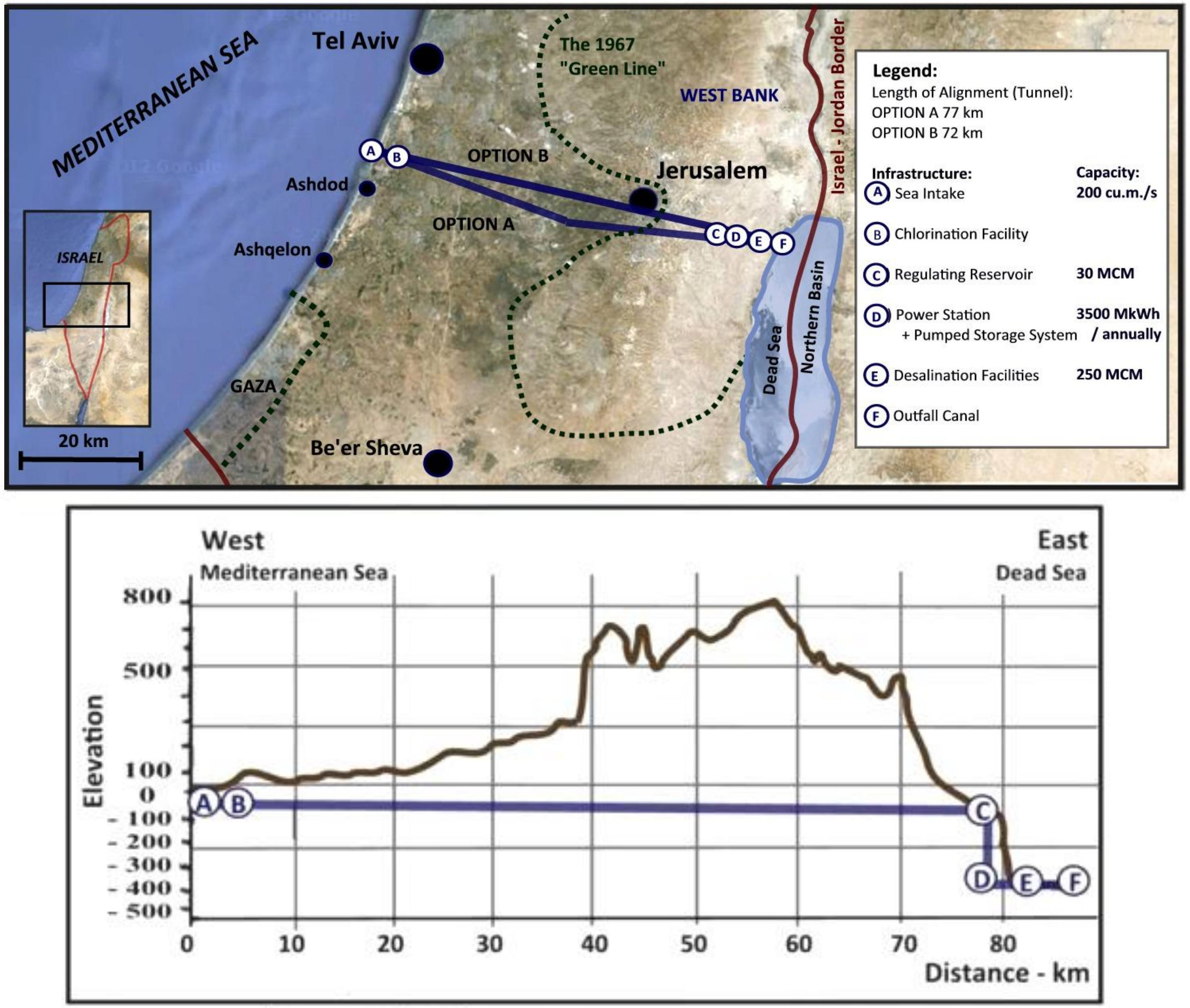
The Mediterranean Dead Sea project can potentially reverse processes of environmental degradation that have resulted from the diversion of freshwater from the Jordan River and other tributaries. Gavrieli and Bein (2006) say that based on current knowledge, it is not possible at this stage to quantify expected changes in the Dead Sea and therefore their environmental, industrial and economical outcome cannot be assessed. They continue, "…such examination requires quantification of the processes described above and their interdependencies in the long run", and therefore, "a long-term complex forecast and integration of these processes is possible only through a dynamic limnological model".

Appendix: Vertical Profiles of the Conveyances



MOUNTAIN ROUTES: NORTHERN ALIGNMENT

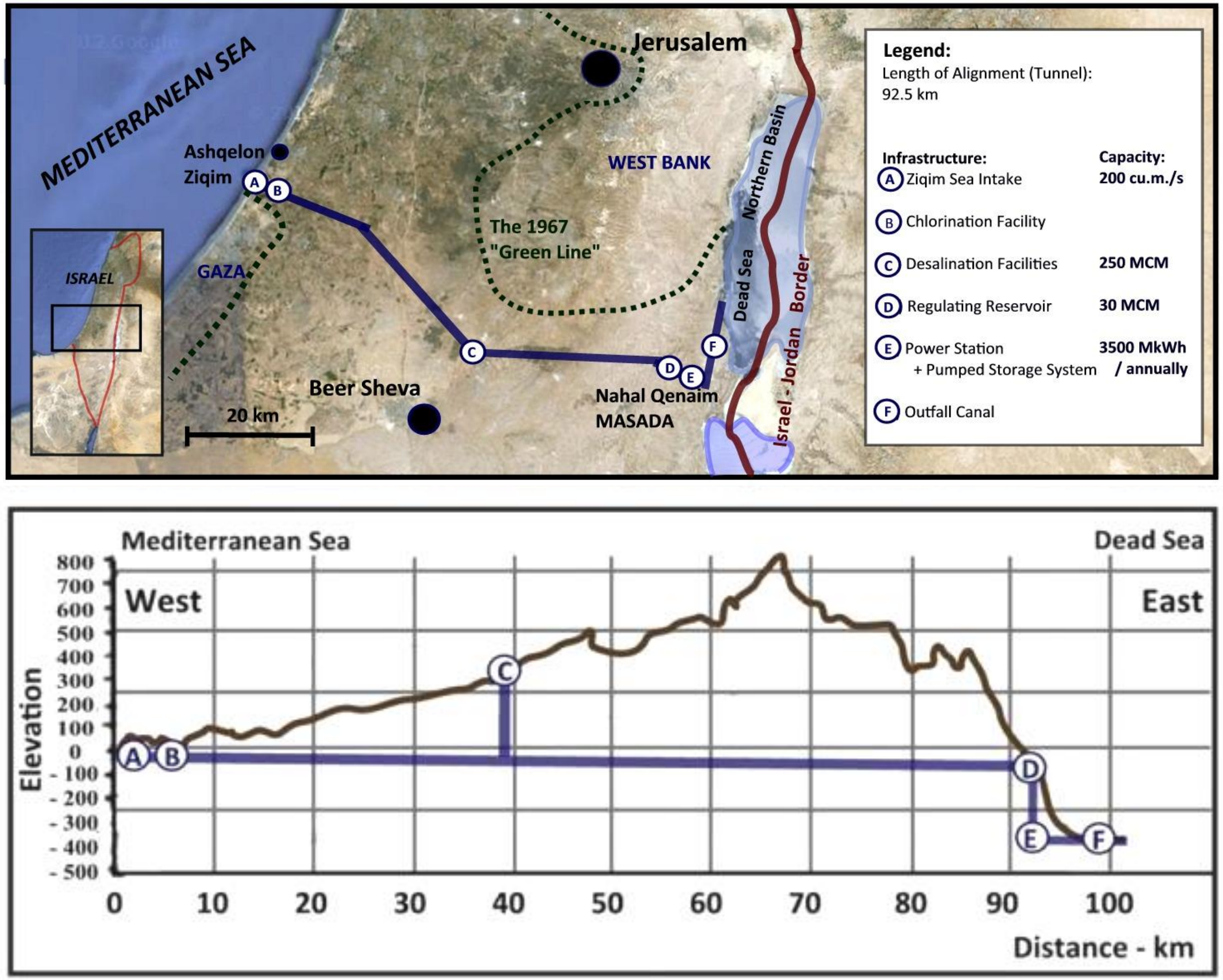
Plan and Profile



Sources: OPTION A (TAHAL, 1977 & 1978)
OPTION B (Israeli et al. 2009)

MOUNTAIN ROUTE: CENTRAL ALIGNMENT

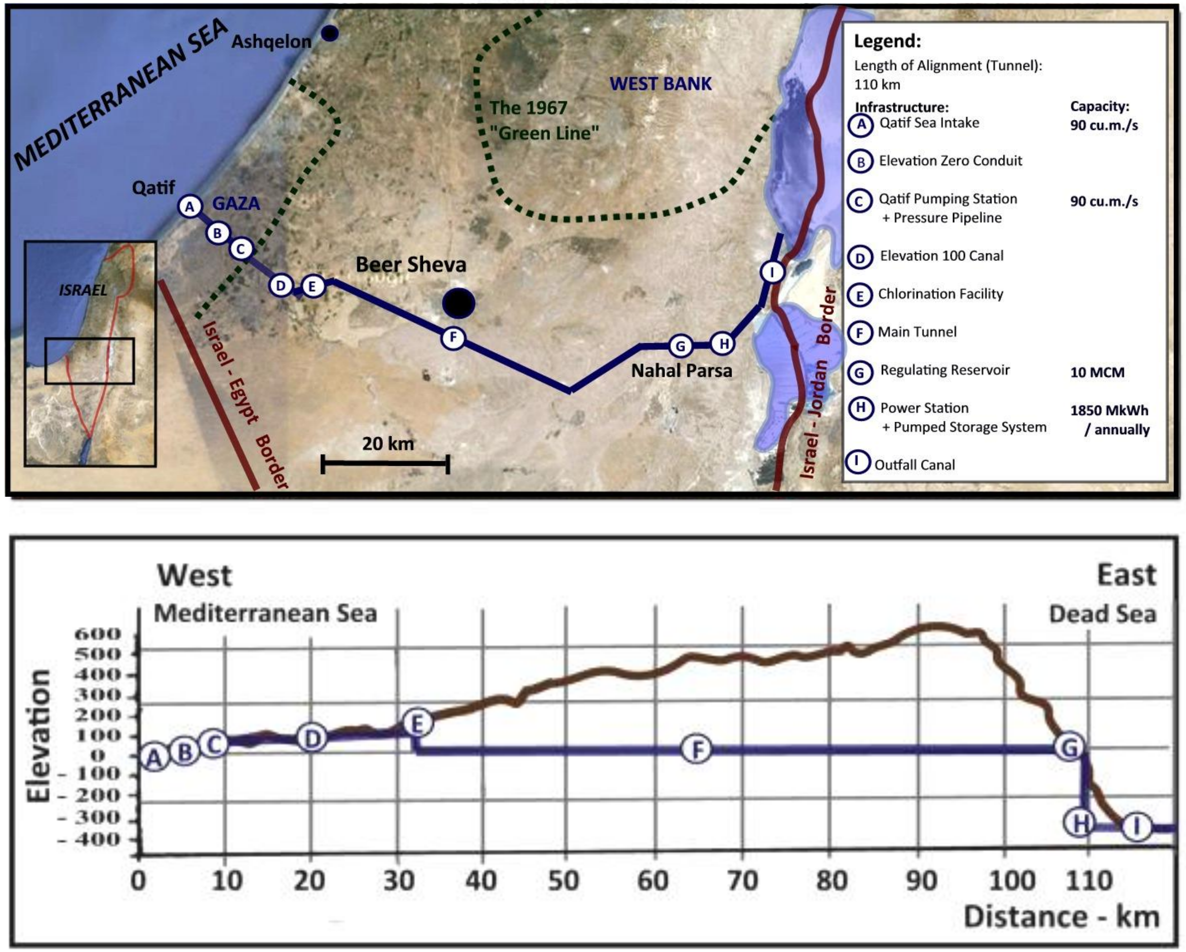
Plan and Profile



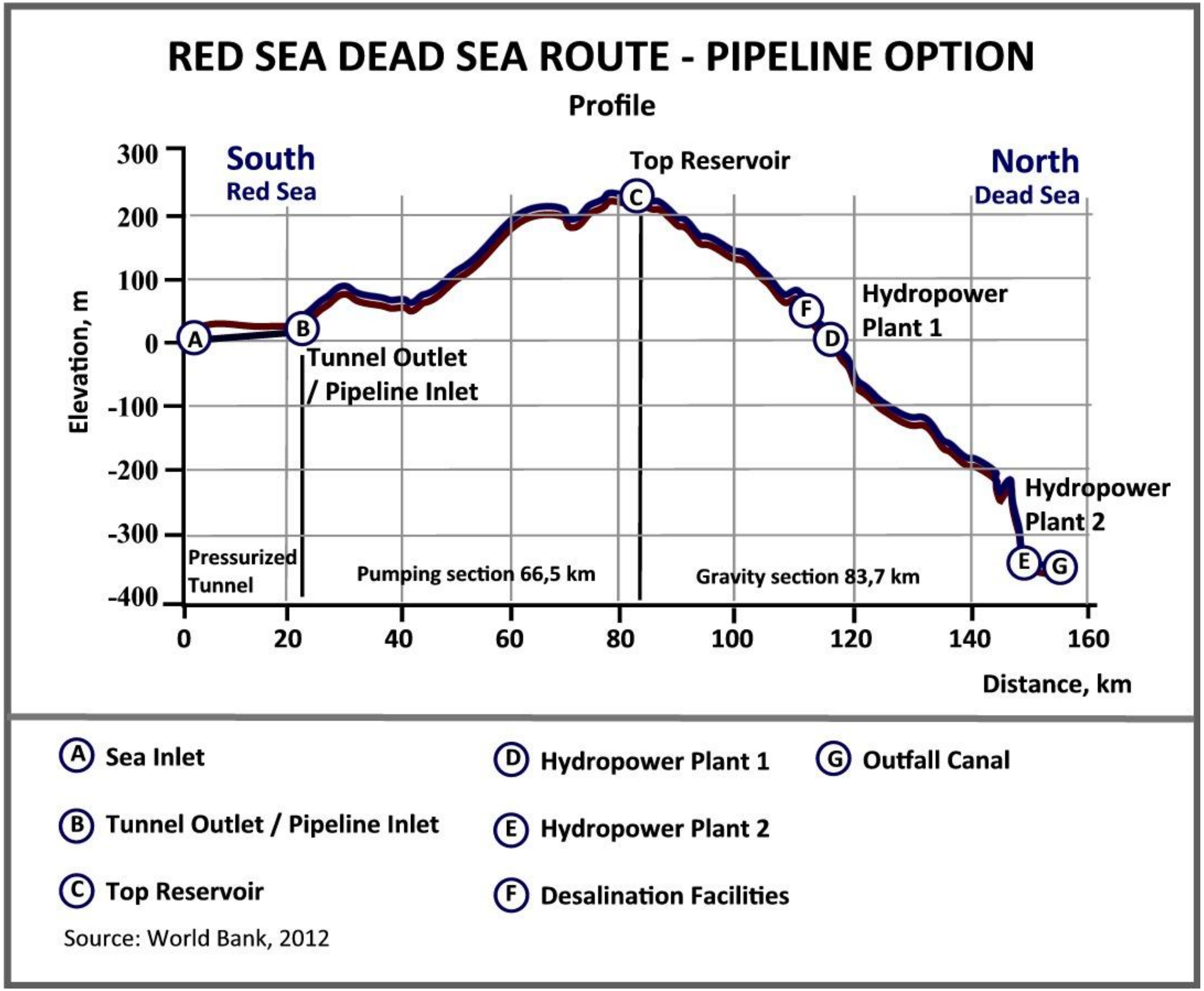
Source: TAHAL, 1977 & 1978

MOUNTAIN ROUTE: SOUTHERN ALIGNMENT

Plan and Profile



Sources: TAHAL, 1977, 1978 & 1983)



RED SEA DEAD SEA ROUTE - PIPELINE OPTION
Profile
South
Red Sea
North
Dead Sea
Top Reservoir
Tunnel Outlet
/ Pipeline Inlet
Hydropower
Plant 1
Hydropower
Plant 2
Pressurized
Tunnel
Pumping section 66,5 km
Gravity section 83,7 km
Elevation, m
300
200
100
0
-100
-200
-300
-400
0
20
40
60
80
100
120
140
160
Distance, km
A
B
C
D
E
F
G
A Sea Inlet
B Tunnel Outlet / Pipeline Inlet
C Top Reservoir
D Hydropower Plant 1
E Hydropower Plant 2
F Desalination Facilities
G Outfall Canal
Source: World Bank, 2012

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