COYNE ET BELLIER
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In association with:-
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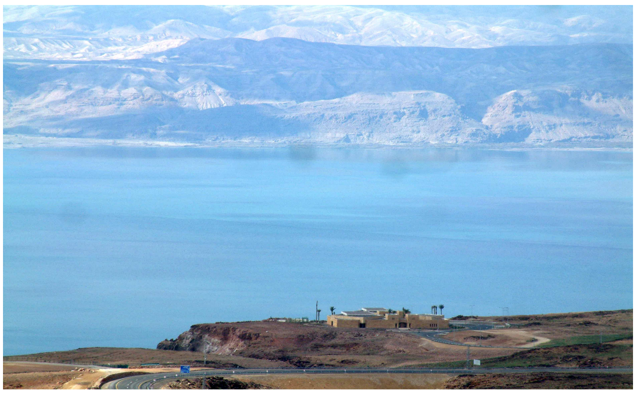
RED SEA - DEAD SEA WATER CONVEYANCE STUDY PROGRAM

FEASIBILITY STUDY

Draft Final Feasibility Study Report

Summary



Report No. 12 147 RP 04 **July 2012**

Draft Final Sub-Studies Report

Summary

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Draft Final Sub-Studies Report

Summary

1. INTRODUCTION

1.1. This Draft Final Feasibility Study Report builds on the previous Draft Final Sub-Studies Report in December 2010. It addresses the Terms of Reference in full with the following provisos:-

- The report is based on the “Best Available Data” and “Mid Term” Reports provided by the teams carrying out the Red Sea Modelling Study and the Dead Sea Modelling Study supplemented by information provided by these teams during meetings held up until January 2011.
- Preparation of the Indicative Financing Plan remains work in progress and will not be finalised until ongoing consultations with a representative cross section of potential funding institutions have been completed.
- Some minor evaluations need to be completed to firm up on the projected unit cost of potable water and to finalise the economic evaluation. This is in part dependent on the outcome of the indicative financing plan and the resultant cost of finance.

1.2. The report does not incorporate any responses to the comments received from the SMU and the Panel of Experts on the Draft Final Sub-Studies Report due to the late receipt of the comments which will now be addressed in the Final Report.

1.3. The main objectives of the Red Sea – Dead Sea Water conveyance Project have been previously expressed as follows:-

- To save the Dead sea from environmental degradation
- To desalinate water and/or generate hydro electricity at affordable prices in Jordan, Israel and the Palestinian Authority.
- To build a symbol of peace in the Middle East

These objectives are reiterated in the Terms of Reference and remain the principle objectives of the Study Program.

1.4. The surface level of the Dead Sea is currently (2010) declining at a rate of over 1,000 mm per year and the surface area has shrunk from 960 km² to 620 km² during the last 50 years. This rate of decline is now increasing and has given rise to extensive environmental degradation and damage to industry and infrastructure and also entails substantial intangible impacts and costs. The direct economic cost to Governments of the region and the affected industries (tourism and chemical abstraction) attributable to the decline in the Dead is estimated in this report to be some $ 2.9 billion over the next 60 years.

1.5. The Terms of Reference require the consultant to examine three scenarios as follows;-

- A “No Project” scenario
- The Base Case Scenario – to stabilise the level of the Dead Sea only
- The Base Case Plus Scenario – to stabilise the level of the Dead Sea, to desalinate water and to generate hydro electricity.

1.6. The chapter headings and numbers in this summary correspond to the section numbering and titles in the main report.

1.7. The Feasibility Study is part of a wider Study Program which includes:-

- An Environmental and Social Assessment Study.
- Physical, chemical and environmental oceanographic studies and modelling of the Red Sea.
- Physical, chemical and environmental oceanographic studies and modelling of the Dead Sea.
- A study of Strategic Alternatives

Details can be found on the World Bank project web site at www.worldbank.org/rds

2. Basic Data and Natural Conditions

2.1. The study area is shown on Figure 2.1 and encompasses the Gulf of Aqaba / Eilat, The Wadi Araba / Arava Valley including the escarpments and wadis on either side, the Dead Sea basin and the corridors for the desalinated water conveyance pipelines to Jordan, Israel and the Palestinian Authority (West Bank).

2.2. The area is sub-tropical, arid and for the most part sparsely populated. Population density is typically less than 50 persons per km2 and over much of the conveyance alignment it is less than 10 persons per km2. The main population centres within the Study Area are:-

- Aqaba / Eilat at the northern end of the Gulf of Aqaba / Eilat.
- Within the Dead Sea basin.
- Along the northern end of the potable water pipeline corridor to Amman.

2.3. The side wadis feeding into the Wadi Araba / Arava Valley tend to be deep and steeply incised and are prone to occasional large flash floods which have a significant influence on the selection of project infrastructure location and design. A dominant feature of the morphology is the extensive alluvial outwash fans from these side wadis.

2.4. Geological, seismic and hydro-geological data are presented in detail in Appendix F of the Main Report for this study. Geologically the Study Area is dominated by the Dead Sea Rift Valley and the associated faulting. The floor of the rift valley is overlain by deep alluvial deposits and the escarpments on either side are made up of metamorphic intrusive rocks, mainly granite, granodiorite, monzonite diorite and gabbro cross cut with abundant and thick dykes, in the south east and sedimentary rocks, mainly sandstone, dolomite, limestone and marl in the north east and western sides of the Study Area. The rift valley faulting within the study area is characterised by two main faults trending approximately north-south and numerous associated en-echelon faults mostly trending approximately east-west. The main faults are described as follows:-

- The Arava Main Transform fault is an active strike slip fault with an average slip rate estimated to be in the order of 4 (+/-2) mm/year which runs through the northern intake site and very close to the possible conveyance alignments associated with the northern intake for some 16 km inland from the Gulf of Aqaba / Eilat.
- The Aqaba-Gharandal fault is a major and active normal fault with a lateral slip component and an estimated lateral slip rate of 1 mm/year. It has a major influence on the selection of the conveyance alignment in the vicinity of the Dead Sea.

Figure 2.1: Map Showing Study Area and Dead Sea Catchment Area

It should be noted that here has been an apparent deficit of seismic activity within the study area over the last 500 years or so. The faulting and resultant seismic risk have a significant impact in determining the potential project configurations considered and also significantly influence the structural designs and resultant costs and the overall risk profile of the project.

2.5. The Study area is of major historical, cultural and religious significance and includes some important archaeological sites. It represents a major national and international tourist destination including therapeutic spas based on the Dead Sea and its waters. The study area also encompasses a number of environmentally sensitive and protected locations.

3. CLIMATE CHANGE

3.1. There is clear evidence that climate change is taking place in the region. An assessment, based on a desk study of analysis and modelling carried out by others, suggests that a plausible scenario for the study area would be that temperatures will increase by between 3^0C and 6^0C and that rainfall will decrease by 30% or more by the end of the 21^{st} century. There will also be associated changes in relative humidity and it is likely that a greater proportion of total rainfall will come in extreme rainfall events. It is estimated that run-off and aquifer recharge within the study area could reduce by between 30% and 50% by the end of the 21^{st} century. These changes will combine to adversely impact on water supply and demand budgets, the Dead Sea water mass balance and the long term environmental baseline of the region.

3.2. The following climate change parameters have been adopted for the projections of future Dead Sea level presented in this report.

Table 3.2: Climate Change Scenario Adopted in Dead Sea Level Projections

	2010	2020	2030	2040	2050	2060	2070	2080
Temperature change	Base	+0.5^{0}C	+1^{0}C	+2^{0}C	+2.5^{0}C	+3^{0}C	+3.5^{0}C	+4^{0}C
Precipitation (mm)	Base	-5%	-10%	-15%	-20%	-25%	-30%	-35%
Surface Run-Off	Base	-5%	-10%	-15%	-20%	-25%	-30%	-35%

4. THE RED SEA

4.1. The northern end of the Red Sea divides into the Gulf of Suez trending northwards and the Gulf Aqaba/Eilat trending north eastwards. It is the Gulf of Aqaba/Eilat arm of the Red Sea that is of particular interest in this study. The Gulf of Aqaba/Eilat is shown in Figure 4.1 below.

4.2. The Gulf of Aqaba/Eilat is a semi-enclosed terminal basin some 180 km in length, 5-25 km wide (with an average width of about 16 km), and up to 1800 m in depth (average depth is around 800 m). The depth to width ratio is thus unusually high for a relatively small enclosed or semi-enclosed sea. The Gulf of Aqaba/Eilat is connected to the Red Sea by the Straits of Tiran, which are some 5 km wide between the Sinai on the West and the island of Jazirat Tiran on the East, 5 km long, and consist of two channels with depths of up to 252 m (the Enterprise Passage) and less than 100 m (the Grafton Passage). The Gulf of Aqaba/Eilat is bordered by Jordan (~27 km of coastline) at its north east extremity and Israel (~11 km of coastline) at its north west extremity. Saudi Arabia lies to the east of the Gulf of Aqaba/Eilat and the Egyptian Sinai Peninsula lies to the west.

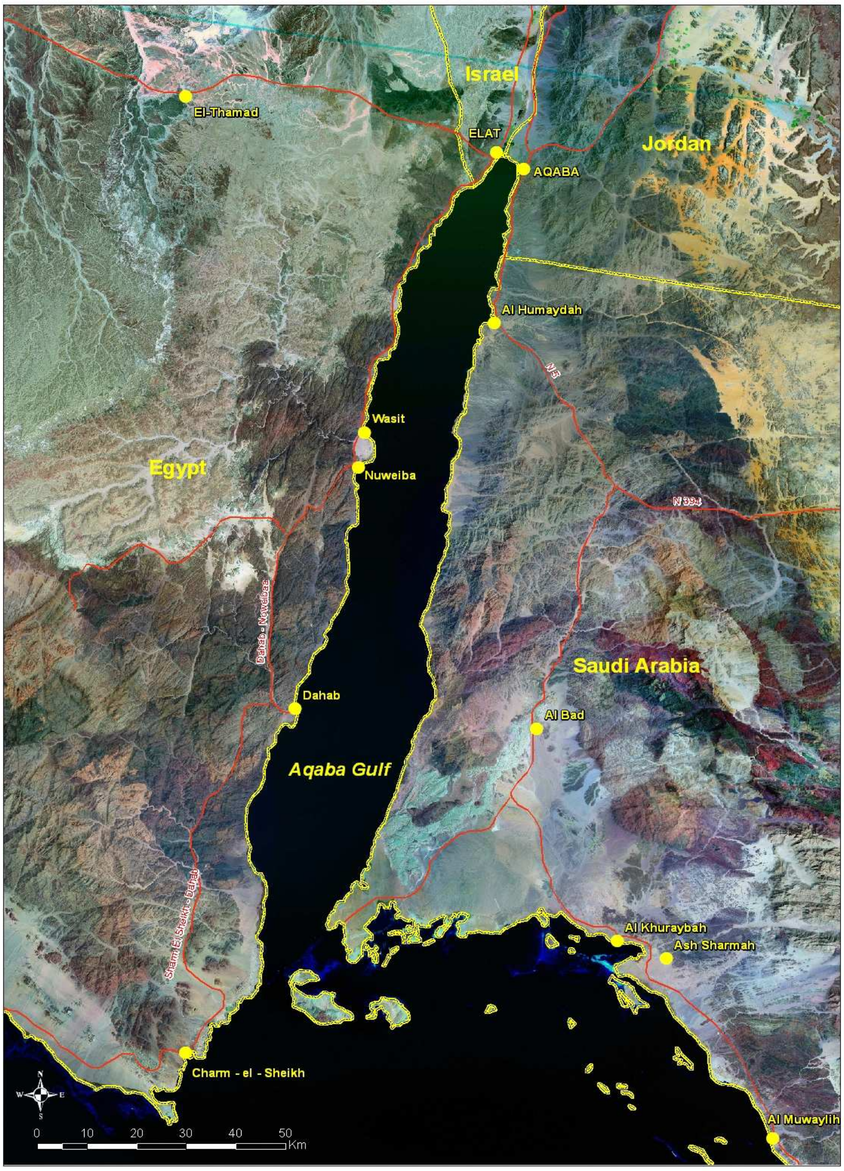


Figure 4.1: The Gulf of Aqaba / Eilat

4.3. The shoreline of the Gulf of Aqaba/Eilat is arid and generally mountainous and is largely undeveloped. Except for the townships of Aqaba and Eilat at the head of the Gulf there are very few substantive settlements on the shorelines. However, due to the clarity of the water, the presence of coral reefs, the aquatic biodiversity of the coral reefs and a number of interesting wrecks the Gulf of Aqaba/Eilat represents a world renowned diving destination. The main resorts are located at the head of the Gulf and along the western shoreline.

4.4. Both Aqaba and Eilat are significant holiday resorts and further substantial residential, commercial and tourism developments are planned, especially on the Jordanian coastline. This will inevitably put pressure on the water quality and marine ecology at the head of the Gulf.

4.5. Based on the best available data at the present time the Red Sea baseline conditions can be characterised as follows:-

- Temperature of the surface water ranges between 21^0C in winter and 28^0C in summer and deep water below about 300 m remains at a near constant temperature of about 21^0C throughout the year.

- Salinity is about 15% higher than typical ocean water, mainly due to the high rate of evaporation.

- The tidal range is typically around 0.5 m at neap tides and 0.6 m at spring tides and the resultant tidal streams are weak.

- Circulation is driven by warm surface water entering through the relatively shallow straits of Tiran, which as it flows northwards becomes more saline due to evaporation and then cools in winter at the head of the Gulf. This cool saline water sinks and returns southwards at depth to the Straits of Tiran.

- Wind direction is consistently from the north and wind speed rarely rises above 10m/second. Wind driven currents are generally weak and appear to flow anti-clockwise at the surface and clockwise at depth. However local variations have been observed at the head of the Gulf and both cyclonic and anti-cyclonic eddies have been observed with diameters of between 5 km and 8 km.

- The offshore waters are well stratified during summer. Deep mixing takes place from late October to April. Upwelling occurs on the eastern shoreline and down welling on the western side. Because of the high light levels, even in winter, algae blooms occur as soon as upwelling brings nutrients into the photic zone.

- Water is generally of good quality with very little pollution. However, very heavy suspended solid loads can occasionally be observed at the northern tip of the Gulf as a result of re-suspension of bottom sediment following strong southerly winds and/or due to run-off as a result of exceptional heavy rainfall in the mountains behind Aqaba and Eilat.

- Primary productivity is low, being limited by the general low level of nutrients.

- Three benthic ecosystems are recognised; coral reefs, seagrass and sandy substrate without seagrass. At the head of the Gulf sea grass and sandy substrate are particularly prevalent along the northern shoreline whilst corals predominate along the eastern and western shores.

- Approximately 400 species of fish have been identified in the Gulf of Aqaba/Eilat, of which about 85% live and breed in benthic habitats and 155 in pelagic conditions. Fish assemblages appear to be stable.

- Some 190 species of coral have been identified throughout the Red Sea. There is very little data available regarding the spawning habits, larvae circulation or genetic inter-connectivity between the coral reefs within the Gulf. However, sampling and evaluation to clarify these issues was undertaken as part of the Red Sea Modelling Study.

- Reports on the health and status of the coral reefs at the head of the Gulf vary but it is generally accepted that the condition is stable, albeit there is considerable stress due to growing urbanisation and increasing commercial and tourist activities.

4.6. The potential impacts of the project on the Red Sea were evaluated through the modelling study of the Red Sea. The main concerns regarding potential impacts of the project on the Gulf of Aqaba/Eilat and the current assessments of these concerns are as follows:-

- Potential damage, destruction and loss of benthic habitats: This will be limited to the immediate footprint of the submerged elements of the intake works and surveys of the alternative locations indicate that impacts can be minimised through appropriate selection of the location, depth and configuration of the intake.
- Potential impacts on the formation of deep water at the head of the Gulf: Preliminary results from the Red Sea Modelling Study indicate that any impacts will be minimal.
- Potential impacts on the circulation, and upwelling and down welling patterns: Again the Red Sea Modelling Study preliminary results indicate that any impacts will be minimal.
- Potential disruption to the coral larvae fluxes and the genetic inter-connectivity of the coral reefs: The Red Sea Modelling Study has shown that there is biological interconnectivity between some species of organisms which live in the coral reefs of the Gulf. However, the results available to date do not give any indication of the spawning patterns or temporal and spatial distribution of the larvae fluxes and so it is not yet possible to evaluate the impact of a project intake on these fluxes. However the indications are that, in broad terms, the deeper the intake the less likely will be the impact in this respect and that if the intake is placed below the photic zone at a depth of 90 m or more there will be minimal impact on these larvae fluxes.

These issues are evaluated further with respect to specific alternative intake locations in Section 12 below.

5. THE DEAD SEA

5.1. The catchment area of the Dead Sea is approximately 42,000 km^2 stretching from Lebanon in the north to the Egyptian Sinai peninsula in the south and straddling the Israel / Palestinian Authority / Jordan borders from east to west. The catchment area is delineated in Figure 2.1 above. The bathymetry and topography of the Dead Sea and its immediate surroundings are shown in Figure 5.1 below.

5.2. The Dead Sea is part of the Jordan River basin. It is a hypersaline terminal desert lake located in the Dead Sea rift valley. Geologically the lake is situated within the large Dead Sea basin which is one of the pull apart basins that formed along the Dead Sea rift (Quennell, 1959; Garfunkel and Benavraham, 1996). The deepest point in the lake is 730m below mean sea level and the lake's shoreline is located about 426 m below mean sea level in 2012. The main body of the Dead Sea takes the form of a deep northern basin some 50 km long with a maximum width of 15 km. The maximum depth in 2010 was 307 m. The northern basin is separated from the much shallower southern basin by an east west ridge with a minimum elevation of about -401 m.

Figure 5.1: Topographic and Bathymetric Map of the Dead Sea Basin
(J. K Hall / Geological Survey of Israel, 2000)

5.3. The level of the Dead Sea fell below the elevation of the ridge between the northern and southern basins around 1976. Since that time the level of the Dead Sea has continued to decline and the southern basin would have dried out, had it not been replaced by artificial lagoons constructed and used by the chemical abstraction industry as solar evaporation ponds. The water level in these lagoons is maintained at an elevation of about -406m by pumping Dead Sea water from the northern basin.

5.4. The decline of the Dead Sea level from 1930 to 2009 is shown in Figure 5.4 below. The level of the Dead Sea has declined because the historical annual Jordan River flow of about 1,300 MCM/year has been progressively reduced by upstream diversion – mainly by Israel, Jordan and Syria . This upstream diversion came in response to mounting demand for water driven by the rapid increases in population and economic activity since the 1950s. The main drivers were the allocation of potentially potable water, first to irrigation and secondly to provide the water services of the growing populations. The decline is also caused by significant consumption of Dead Sea water as a raw material for the large chemical industries in Israel and Jordan at the southern end of the Sea. Combined with surface and ground water abstractions from the western side of the basin, the total inflow to the Dead Sea has reduced from around 1,250 million m^3/year in 1950 to around 260 million m^3/year in 2010.

Figure 5.4: Water Level of the Dead Sea 1976 - 2010

(Data from the Israeli Hydrological Service)

5.5. The Dead Sea basin is arid with less than 100 mm rainfall per year and with peak daily temperature in summer sometimes exceeding 45^{0}C. The topography on the eastern and western shorelines of the Dead Sea is typically rugged and mountainous with steep deeply incised valleys and very little natural vegetation. The northern and southern shorelines are formed by the Jordan Valley and the Wadi Araba/Arava Valley respectively and are generally flat supporting some irrigated agriculture. The area is sparsely populated with the main settlements and tourist centres being located at the northeast and southwest corners of the Dead Sea.

5.6. The baseline conditions in the Dead Sea are described in the Dead Sea modelling study. The currently available information can be summarised as follows:-

- The ongoing decline in water level has been discussed above.
- The Dead Sea water mass balance is discussed in Section 6 below.
- Preliminary results from the additional study of the Dead Sea indicate that the wind driven surface water circulation is anticlockwise in direction. Waves with significant heights of up to 1-2 m have been observed over a period of a few hours when the winds are strong.
- Prior to 1979 the Dead Sea was largely meromictic (layered) but this condition weakened due to increasing salinity in the upper layer and a complete overturn occurred in 1979 and the sea became homogenous in composition. From 1982 to 1991 and again from 1995 to the present the sea has been in a monomictic state i.e. seasonal stratification has developed resulting in an annual water turnover. Historically the stratification has been typified by two layers but recent indications have suggested that the chemical industry return brine is sinking to the bottom of the sea without mixing and creating a third denser lower layer.
- Homogenous Dead Sea water contains 343 g/l of dissolved salts and has a density 1.24 g/l. Compared to typical ocean water, the Dead Sea is rich in chlorides, sodium, potassium, magnesium, calcium, and bromide and deficient in sulphates. It appears that the activities of the chemical abstraction industry are perceptibly changing the chemical composition of the Dead Sea by increasing the concentrations of Mg, Ca, Cl and Br whilst the concentrations of Na, K and SO4 are decreasing.

- Historically aragonite and gypsum have been precipitated in the Dead Sea and “whitening” events attributed to this precipitation have been observed. Today the Dead Sea is saturated to over saturated with respect to aragonite, anhydrite, gypsum, halite and possibly also apatite. Since about 1982 most of the precipitation has been halite. It has been estimated (Resnik et al, 2009) that some 38 x 10^8 tons of halite and about 1% of this quantity of gypsum have been precipitated between 1960 and 2008 forming a layer with an average thickness of some 2.5 m over the sea bed. The Final Report of the Dead Sea Modelling Study estimated the current sedimentation of Halite to 10 cm per year, out of which 1 mm (1%) is due to gypsum precipitation.

- The Dead Sea contains relatively high levels of ammonium, around 8.9 mg/litre in 1991, which is the preferred form of N for plant growth. Ongoing tests being carried out under the modelling study of the Dead Sea indicate that P is the limiting nutrient for plant productivity. The Final Report of the Dead Sea Modelling Study evaluated that phosphorus will be co-precipitated on the surface of gypsum crystals which will be formed, hence will limit the potential algal blooms.

- Dense microbial blooms have been observed in the Dead Sea in the past following periods of particularly heavy rainfall followed by enhanced flow of the Jordan River to the Dead Sea. The primary producer is Dunaliella, an unicellular green algae, followed by red halophilic Archaea. It appears that under “normal” conditions the surface water of the Dead Sea is too saline to support microbiological activity but when diluted with unusually high inflows of less saline or fresh water algae blooms occur. The ongoing experiments under the modelling studies of the Dead Sea indicate that the surface layer must be diluted by 10% - 15% for microbial blooms to occur and that additional P may be necessary to support such blooms.

5.7. The main concerns regarding potential impacts of the project on the Dead Sea relate to the effects on the chemical and tourist industries and both the real and perceived effects on the aesthetic and therapeutic properties of the Dead Sea. At the present stage in the modelling of the Dead Sea it is possible to make predictions regarding these concerns and the main issues and the best assessments at the present time are as follows:-

- <u>Changes to the layering, stability and circulation of the water body</u>. The project is unlikely to have any material impact on the circulation patterns of the Dead Sea. Due to the coriolis effect any discharge from the project is likely to turn to the right on entering the Dead Sea and circulate in an anti-clockwise direction. The project is likely to create a more stratified lake with a surface layer of less saline water with an underlying transition zone. Below a depth of about 50 m the main water body would likely be largely unchanged by the project. A third very saline and very dense deep layer formed by the chemical industry return brines will continue to progressively develop. As a result of this layering structure the Dead Sea is likely to revert back to its previous condition when it was more stable with less frequent turnovers.
- <u>Changes in the chemical composition</u>. The surface layer will progressively become less saline than at present and in the long term the chemical composition will progressively take on the characteristics of ocean water concentrated by evaporation. So long as the chemical abstraction industry continues to operate, the chemical composition of the main body of water will likely continue to change, following similar trends to those shown over the last 50 years.
- <u>Potential increase in the frequency and duration of red algae blooms</u>. The impact in this respect was assessed by the Dead Sea Modelling Study. It is clear that the project would reduce the salinity of surface layer of water to some degree. It was evaluated that this dilution itself might cause an algae bloom associated with the discharge of Red Sea water and brine. The Final Report of the Dead Sea Modelling Study evaluated that for a discharge of 400 MCM/year of Red Sea water or rejected brine, the salinity of the upper layer of the Dead Sea will not decrease below the threshold needed to enable any algal or bacterial bloom and that for a discharge of 1000 MCM/year the salinity of the upper water layers will reach the critical value below which biological phenomena may start to occur in the Dead Sea after a few years of operation. The Dead Sea Modelling Study also pointed out that the algal and bacterial blooms will be restricted by gypsum precipitation due to the co-precipitation of nutrients such as phosphorus and iron.
- <u>Potential increase in the frequency and duration of whitening events</u>. It is inevitable that when Red Sea water is mixed with Dead Sea water gypsum will be precipitated. If the precipitation takes the form of small crystals the gypsum will float to the surface causing a whitening effect. It is not yet clear whether in this case the gypsum will remain in suspension within the surface layer of water, potentially turning the water a dilute milky colour, or whether some of the gypsum crystals will float on the surface as a white powder seriously affecting the aesthetics of the Dead Sea. Alternatively, the precipitation may take the form of larger crystals which sink and settle on the sea bed. In this case “whitening” would not occur but the chemical company intake water may contain significant quantities of precipitated gypsum. Further tests and evaluations building on results of the Dead Sea Modelling Study are necessary before any predictions can be made on this issue. The Final Report of the Dead Sea Modelling Study suggested that adding of Gypsum crystals to the discharge of the sea water or rejected brine to the Dead Sea will most probably cause a faster sedimentation of the precipitated Gypsum, hence will mitigate the potential whitening events problem

- Potential changes in the salinity and buoyancy of the surface layer of water. The density of the surface layer of the Dead Sea is currently around 1.24 g/l and is slowly increasing. In the No Project scenario it is estimated it will continue to rise to 1.36 g/l before stabilising. Under the project the density of the surface layer will decline to about 1.17 g/l which is slightly higher than that recorded 50 years ago.

5.8. The main potential benefits of the project with regards to the Dead Sea relate to the rectification of the environmental degradation of the Dead Sea and the limitation of the impacts of this degradation. These include:-

- Decline in the level of the Dead Sea: The level of the Dead Sea is currently declining at around 1.1 m per year. The project would stop, and to some extent reverse, the declining level of the Dead Sea.
- Creation of exposed mud flats and resultant windblown dust: Over 300 km^2 of sea bed has been exposed in the last 50 years with some 5 km^2/year currently being exposed. Most of this "new land" takes the form of unsightly saline mudflats. The project would eliminate the creation of new mudflats and would re-submerge some of the existing established mudflats.
- Creation of sinkholes: Subterranean conditions caused by the decline in the Dead Sea have led to the formation of large numbers of sink holes (over 3,000) around the periphery of the Dead Sea. Sinkholes appear to be initiated by preferable dissolution along existing cracks or fault lines in a fossil evaporate bed at an elevation of about -520 m. Sinkholes appear suddenly without warning and have destroyed buildings, roads and agricultural lands and also pose a significant hazard limiting recreational commercial and recreational activities where they occur. Sinkholes would continue to appear for some time after stabilisation of the Dead Sea but their occurrence would likely gradually diminish and eventually cease over a period of about 10 years if the water level is stabilised.
- Decline in the Groundwater table: The groundwater table around the periphery of the Dead Sea has fallen as the Dead Sea level has declined. The project would eliminate further decline, and partially restore the water table.
- Damage to infrastructure: The surface water channels draining to the Dead Sea have suffered severe headward erosion as a result of the declining level of the Dead Sea. This erosion has caused extensive damage to both private and public infrastructure, especially undermining of roads, bridges and culverts. The erosion would gradually diminish and a new equilibrium would be established over a period of about 10 years if the Dead Sea water level is stabilised.
- Decline in tourism: Statistics show that there has been a decline in international tourist visits to the Dead Sea in recent years and economic studies show that, after isolating other effects and issues, this decline can be correlated with the declining level of the Dead Sea and the development of the environmental degradation discussed above. The project would have the potential to reverse this trend.

6. Dead Sea Water Mass Balance

6.1. The limnology and water mass balance of the Dead Sea is complex and previous attempts at modelling this have proven inaccurate in predicting future levels. This inaccuracy is largely attributable to a paucity of accurate raw data as well as to the complexity of the relationship between varying inflows, surface water salinity and evaporation rates. For the purposes of this study a new, one dimensional physical thermo-dynamic model has been developed to predict the Dead Sea surface water level versus time relationship for any given inflow. The model includes a thermo-energy mass balance sub-module which simulates meteorological and hyper-saline thermo physical conditions to determine evaporation on the basis of an energy mass balance. Outputs from the model for the "No Project" scenario and also for various project inflows to the Dead Sea are presented in Figures 6.3 and 6.5 below.

6.2. Current (year 2010) inflows to the Dead Sea and outflows from the Dead Sea and the net water loss from the Dead sea are assessed to be as follows:-

Table 6.2: Dead Sea Water Mass balance in 2010

Inflows – million m³/year	
Direct Precipitation	39
Surface Run-Off (including flash floods)	210
Irrigation Return Flows	50
Chemical Industry Return Flows	248
Ground Water Depletion	149
Total Inflow	696

Outflows – million m³/year	
Evaporation	754
Chemical Industry Abstractions	650
Total Outflow	1,404

Note : Subsequent to the completion of the study and of the main report the chemical industry reported that they have now reduced their net consumption of Dead Sea water to 320 million m3/year which is 82 million m3/year less than that indicated in table 6.2 above. If this reduced net consumption were to be sustained in the long term, the impact would be to reduce the inflow to the Dead Sea from a RSDS project required to stabilise the level of the Dead Sea as reported herein by an amount of approximately 80 million m3/year. The impact on all other findings and recommendations in this report would be negligible

6.3. From the foregoing Table it can be seen that the net water loss from the Dead Sea is estimated to be about 708 million m^3/year. This equates to a surface level decline of 1,100 mm per year and a reduction in the surface area of over 3 km² or 0.5% per year at the present time. As noted earlier this rate of decline is increasing. The climate change scenario adopted for projecting the future Dead Sea water mass balance is presented previously in Table 3.3. Predictions of the long term decline in the Dead Sea level if there is no intervention to stabilise the situation are presented in Table 6.3 and Figure 6.3 below. These predictions remain to be verified by more sophisticated modelling being undertaken under the modelling study of the Dead Sea which is still in progress.

Table 6.3: Projected Dead Sea Level, Surface Area and Volume in the "No Project Scenario"

Year	Surface Level		Surface Area		Volume - km³	
	Current Conditions	With Climate Change	Current Conditions	With Climate Change	Current Conditions	With Climate Change
2010	-424m	-424m	605 km²	605 km²	114 km³	114 km³
2020	-435m	-435m	576 km²	576 km²	108 km³	108 km³
2030	-444m	-445m	555 km²	555 km²	102 km³	102 km³
2040	-451m	-451m	543 km²	542 km²	99 km³	99 km³
2050	-457m	-457m	531 km²	531 km²	96 km³	95 km³
2060	-462m	-463m	520 km²	519 km²	93 km³	92 km³
2070	-468m	-469m	510 km²	509 km²	90 km³	89 km³

***Note – Assumes the chemical abstraction companies operations continue as planned

As can be seen from Table 6.3 and Figure 6.3 the projected future decline in the level of the Dead Sea in the No Project Case appears to be almost linear, which at first appears to be counter intuitive. However, as the level declines the water becomes more saline which in turn reduces the rate of evaporation; whilst at the same time the surface area is also declining thus reducing the area to which the rate of evaporation is applied. These two effects will combine to progressively reduce the rate of decline in level. However as the surface area of the Dead Sea declines the constant annual net water usage by the chemical abstraction industry equates to an increasing fall in level. These effects tend to cancel each other out and the overall result is a near linear fall in water level.

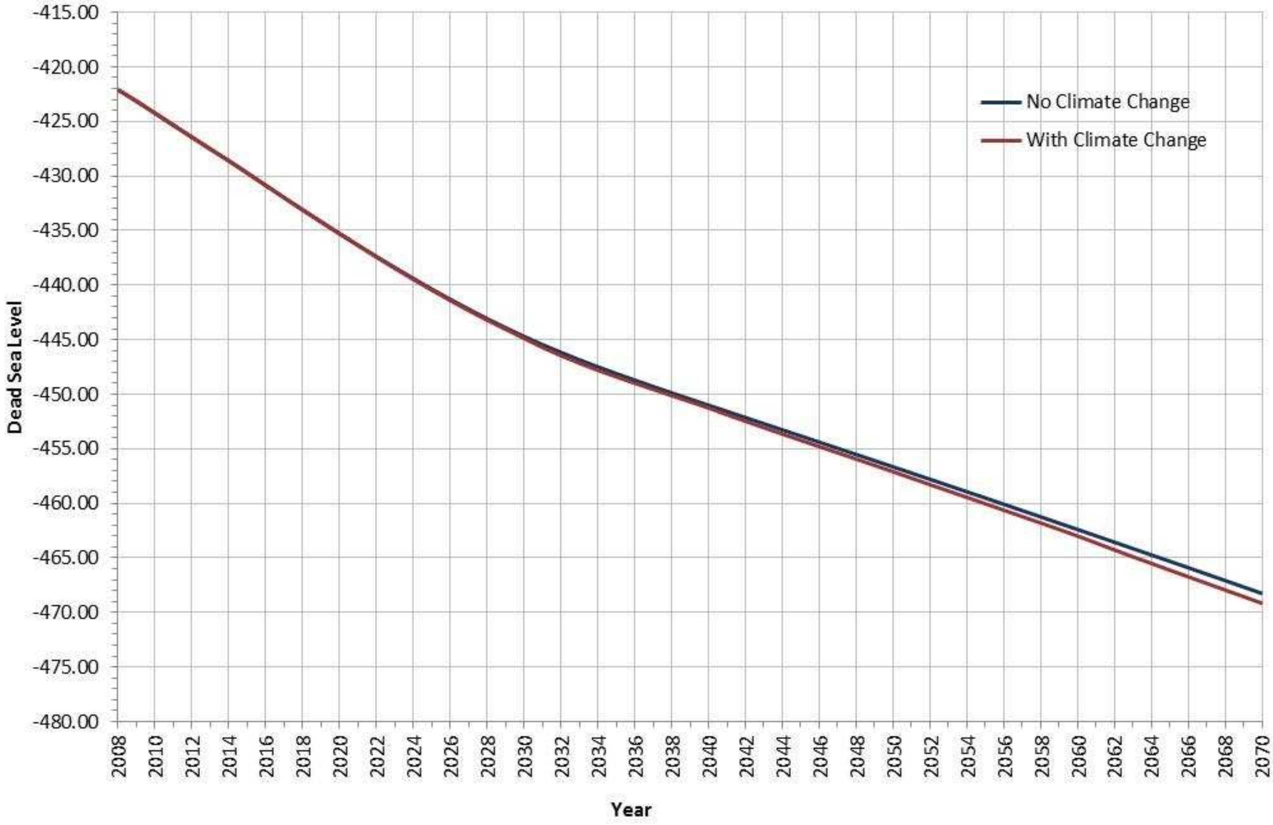


Figure 6.3: Projected Dead Sea Levels Versus Time for the “No Project” Scenario

6.4. The impact of climate change on future Dead Sea levels in the No Project Case is somewhat less than might at first be expected. This can be explained as follows:-

- The main impact of climate change is to reduce precipitation and surface run off. Since these are already relatively small components on the net water mass balance any changes do not have a big overall effect.
- Climate change reduces the amount of fresh water entering the Dead Sea which in turn reduces the dilution of the surface layer and decreases evaporation rates which, to some extent, counteracts the effects of reduced precipitation and surface water inflows.

6.5. Predicted Dead Sea levels with time for a range of potential inflows of Red Sea water are presented in Figure 6.5 below.

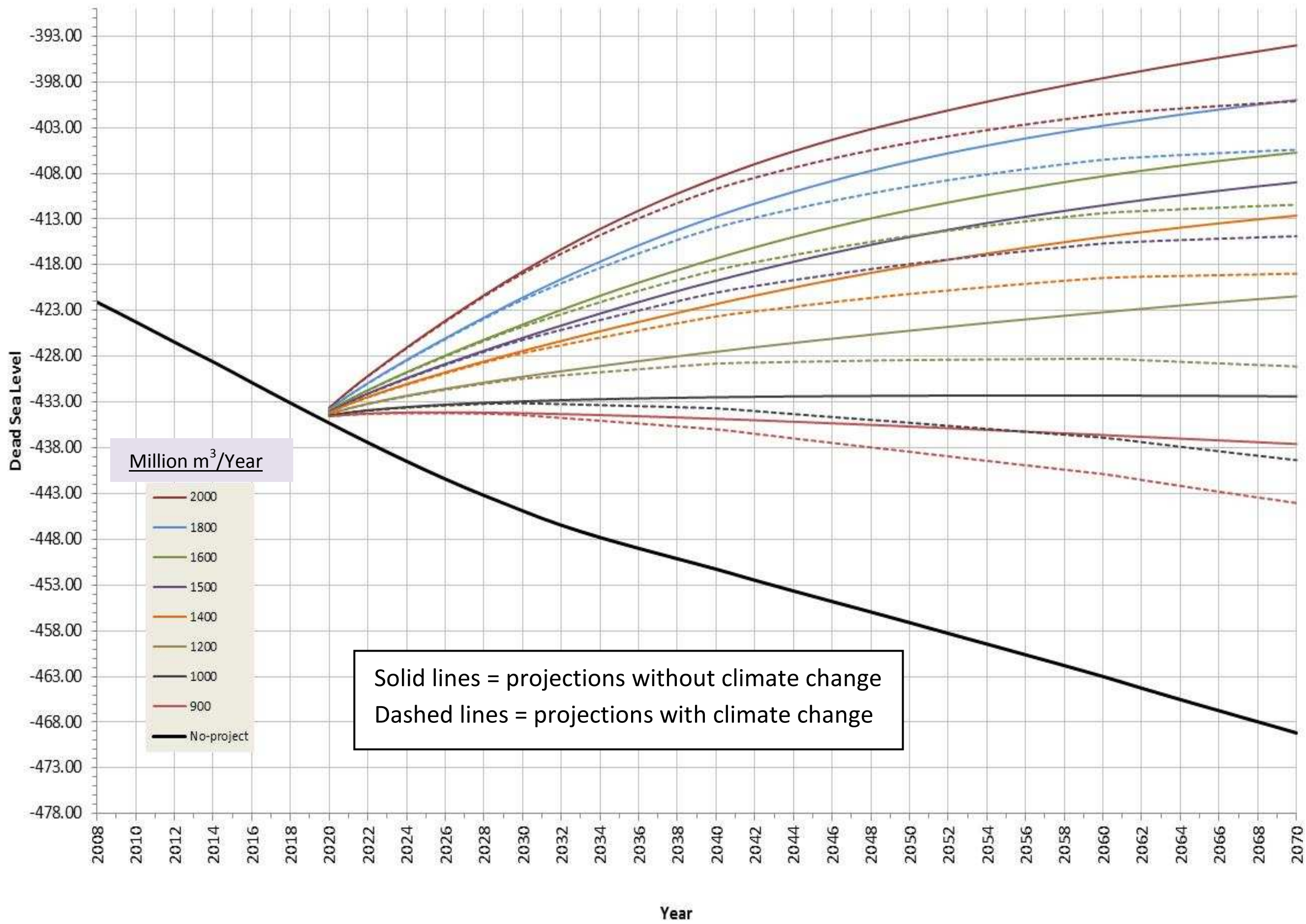


Figure 6.5: Projected Dead Sea Level Versus Time for a Range of Red Sea Water Discharge Flows

7. THE NO PROJECT CASE

7.1. In the event that the chemical abstraction companies remain in operation and no positive action is taken to stabilise the level of the Dead Sea the decline in surface level and surface area will continue for the next 50 years as shown in Table 6.3 and Figure 6.3 above.

7.2. In the longer term this decline will continue for so long as the chemical companies remain in operation. However, if the chemical companies cease to operate under the No Project Scenario the Dead Sea will continue to decline at a decreasing rate as the water body becomes more saline and will reach a new equilibrium at somewhere around -550 m somewhere around year 2150.

7.3. Environmental degradation associated with the declining level of the Dead Sea is discussed in paragraph 5.8 above. All of the forms of environmental degradation identified will continue for so long as the Dead Sea continues to decline except that the development of sink holes may possibly diminish after the level of the Dead Sea water and the surrounding water table falls a further 100 m and is below the level of the fossil evaporite layer, the dissolution of which is causing of sink holes.

7.4. The chemical composition of the Dead Sea will continue to change under the No Project scenario as discussed in paragraph 5.6 above.

7.5. The No Project Case has a number of economic consequences which can be summarised as follows:-

- Impacts on the chemical industry: The declining level of the Dead Sea means that the chemical abstraction companies have to relocate their pumping stations periodically to chase the receding Dead Sea water and experience an ever increasing pumping head to raise the water from the main body of the Dead Sea to the evaporation ponds. This is partially offset by the increasing salinity of the Dead Sea water which increases the efficiency of the solar evaporation process. The overall net present cost to the chemical industry for the next 50 years of these three issues combined has been assessed using capital costs provided by the chemical companies, a discount rate of 10% and an energy cost of $ 60 per kWh to be $ 164 million.
- Impacts on the tourist industry: Statistics show that the international tourist visits to the Dead Sea have reduced in recent years. After isolating other economic factors and effects the decline in visitors has been correlated to the declining level and increasing environmental degradation of the Dead Sea and this has been evaluated using a consumer surplus methodology. The value of consumer surplus has been taken from results published by Bekker and Katz (2006) inflated to current values. This produces a comparable figure to that derived from a project specific contingent valuation survey carried out at the end of 2010. On this basis the net present cost of the ongoing decline in international tourist visitors to the Dead Sea area over the next 50 years has been evaluated using a discount rate of 10% to be $ 2.7 billion.
- Damage to public infrastructure: A net present cost of the damage to public infrastructure, mainly roads, bridges and culverts over the next 50 years using published cost estimates and a discount rate of 10% has been assessed to be $ 85 million.

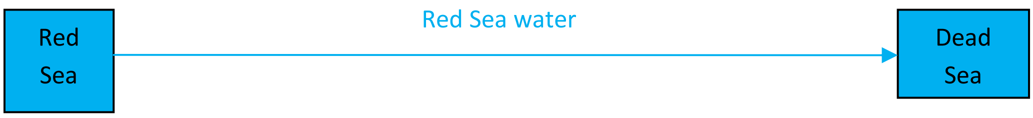
7.6. It has not been possible to obtain enough data to evaluate a number of other impacts under a No Project Case, none the less these are real impacts and should be considered:-

- A number of private buildings and agricultural plantations have had to be abandoned as a result of declining water table levels and the occurrence of sink holes.
- Large tracts of land have been frozen from future development and recreational use due to the risk of sinkholes.
- Significant damage has occurred to solar evaporation pond embankments at Arab Potash Company apparently due to the development of underlying sink holes. One independent observer (Closson, 2005) has put a value of $ 70 million on this damage.
- As the Dead Sea level declines the role of the chemical industry and the scale of that role in the decline becomes ever more significant and ever more prominent and will ultimately lead to pressure to either cease operations altogether or to radically alter the process to reduce water consumption.
- Whilst there are on-going negotiations for a redistribution of *existing* water resources there is apparently no Plan “B” for the provision of a badly needed *new* source of fresh water for either Jordan or the Palestinian Authority. It therefore seems inevitable that if the proposed project proves to be not feasible there will be a significant delay in addressing the serious water budget deficit in the region.

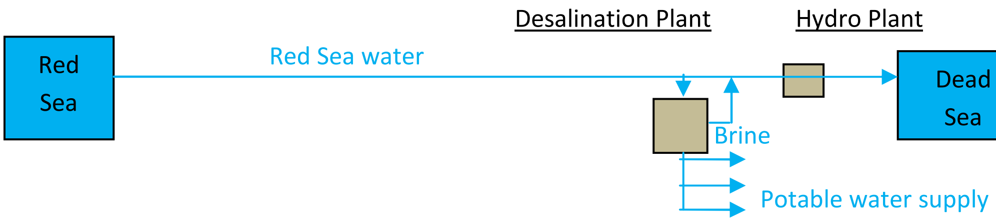
8. Project Flow Rates, Flow Configurations and Potable Water Demands

8.1. Red Sea abstraction and transfer flow rates from 1,000 to 2,000 million m^3/year have been considered together with four potential project flow configurations as follows;-

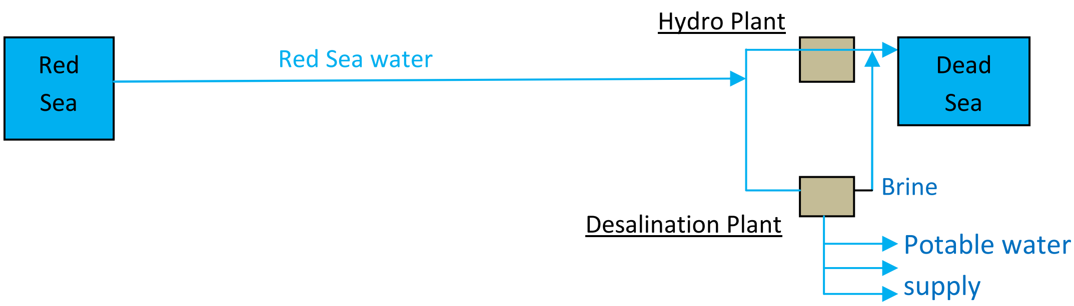
(i) Base Case



(ii) Base Case Plus and High Level Desalination Plant



(iii) Base Case Plus and Low Level Desalination Plant in Parallel with Hydro Plant



(iv) Base Case Plus and Low Level Desalination Plant in Series with Hydro Plant

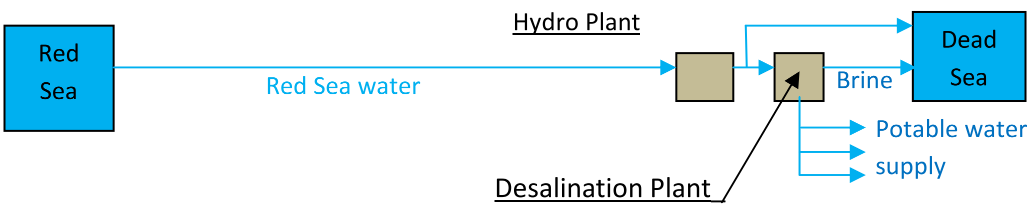


Figure 8.1: Various Possible Flow Configurations

8.2. It can be seen that in all cases the discharge flow to the Dead Sea is equivalent to the total flow of water extracted from the Red Sea less the quantity of desalinated water produced.

8.3. A detailed evaluation of the potable water supply, demands and projections through to year 2060 has been carried out for Jordan and it is proposed that the desalinated potable water supply to Jordan from the project should be as shown in Table 8.3.

Table 8.3: Potable Water Supply to Jordan

Potable Water supply to Jordan	Million m^3/year				
	2020	2030	2040	2050	2060
Total Greater Amman Water Deficit	176	247	294	370	446
Additional Domestic Supply to Neighbouring Governorates	50	61	75	92	113
Total Potable Water Supply to Jordan	226	308	369	462	559

8.4. Insufficient data has been made available to carry out a similar evaluation of potable water supply and demand in Israel and the Palestinian Authority. However, it can be demonstrated that, due to the relative distances and elevations, water supplied to the main demand centres in Israel from desalination on the Mediterranean coast will be cheaper than supplying these same demand centres with desalinated water supplied from a Red Sea - Dead Sea Water Conveyance Project. A simplistic evaluation has been made of the water demands for Israel through to 2060 for the low elevation demand centres in the Dead Sea Basin and the Arava Valley. This simplistic evaluation suggests that a supply of 60 million m^3/year to Israel would suffice to meet demand in these low elevation demand centres through to 2060. It has subsequently been agreed at several Technical Steering Committee meetings that the supply of 60 million m^3/year of desalinated water to Israel will be adopted for purpose of the Feasibility Study.

8.5. It has not been possible to carry out water supply and demand projections for the Palestinian Authority. However, during the course of the Study Program the Consultant has been instructed by letter from the Study Management Unit Leader to adopt a supply of 60 million m^3/year to the Palestinian Authority

8.6. It should be made clear that this allocation of desalinated water from the project is purely for the purposes of determining the feasibility of the project and that the final allocation will be subject to further negotiation and agreement between the Beneficiary Parties if a decision is taken to proceed with the project.

9. OPTIONS SCREENING AND EVALUATION PROCESS

9.1. The Terms of Reference for the Feasibility Study allow for a very wide range of possible project configurations and outcomes. An options Screening and Evaluation Process was therefore conducted early in the study program to identify the full range of realistic options, carry out a preliminary screening and evaluation process and determine a smaller range of the most promising options for a more detailed evaluation and assessment.

9.2. An Options Screening and evaluation report was issued in January 2009 and a detailed presentation was made to a Technical Steering Committee meeting on 4th March 2009. Following this presentation the Technical steering committee confirmed the selected options for further evaluation would be as follows:-

- The Base Case will not be studied or evaluated further in the remainder of the Study Program.
- The Jordanian delegation will consult internally and advise of their preference between the northern and eastern intake. The “preferred” location of the intake will

be confirmed once the modelling study of the Red Sea has been completed provided that other technical considerations do not contradict this choice.

- Three conveyance configurations are to be further studied and evaluated in the remainder of the Study program:-
  - A gravity flow conveyance in tunnel at a nominal elevation of 00 m.
  - A pumped conveyance in a combination of tunnel and canal at a nominal elevation of +220 m.
  - A pumped pipeline configuration with a high point at an elevation of circa +220 m
- A range of target levels for the Dead Sea from -410 m to -420 m to be studied further.
- The upper limit of the water conveyance flow to be 2,000 million m^3/year. The lower limit is to be determined during the study but will not be less than 1,000 million m^3/year.
- The desalination plant will have an ultimate capacity of 850 million m^3/year which is the optimum desalination capacity for a Red Sea water transfer of 2,000 million m^3/year as discussed in detail in Section 11.2.2 of the main report.
- The optimal discharge location on the Dead Sea cannot be determined at this stage and will be studied further based on the conclusions of the modelling study of the Dead Sea.
- The potable water allocations initially approved following completion of the Options Screening and Evaluation process have subsequently been amended as noted above and are now as set out in Table 9.2. *It should again be noted that these figures have been agreed purely for the purposes of evaluating the feasibility of the Red Sea – Dead Sea Water Conveyance. The final allocation of potable water will be the subject of further negotiation and agreement between the Beneficiary Parties in the event that a decision is taken to implement the project.*

Table 9.2: Potable Water Demands Approved by the Technical Steering Committee

Beneficiary Party	Potable Water Supplied from the Project - Million m^3/year				
	2020	2030	2040	2050	2060
Jordan	230	310	370	460	560
Israel	60	60	60	60	60
Palestine Authority	60	60	60	60	60
Available for Further Allocation	0	0	50	90	170
Total	**350**	**430**	**540**	**670**	**850**

10. BASE CASE SCENARIO

10.1. The flow configuration for the Base Case scenario is very simple and is shown in Figure 10.1 below.

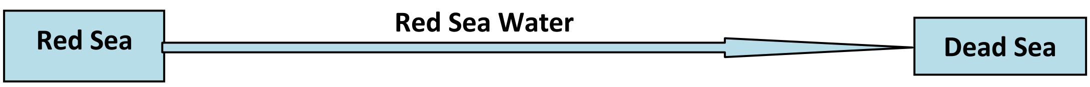


Figure 10.1: Base Case Flow Configuration

10.2. The Dead Sea water mass balance model has been run for a range of Red Sea water discharge flows to the Dead Sea from 900 to 2,000 million m^3/year with inflow to the Dead Sea unconstrained by ultimate target level. The model runs assume that the project will be commissioned in year 2020. The results of these model runs are presented previously in Figure 6.7 and the salient points for the model runs incorporating climate change are:-

- The Dead Sea level will have fallen to -434 m when the project is commissioned.
- For any Red Sea transfer flows of 1,200 million m^3/year or less the level of the Dead Sea will continue to fall for the foreseeable future after the project is commissioned.
- For any Red Sea transfer flow rate in excess of 1,200 million m^3/year the Dead Sea level will continue to rise for the foreseeable future unless the Red Sea transfer flow rate is reduced at the point in time when the chosen target level is achieved.

The minimum amount of Red Sea water necessary to stabilise the level of the Dead Sea shown above (1,200 million m^3/year) is significantly higher than the Dead Sea water budget net deficit of 708 million m^3/year indicate earlier in Table 6.2 and paragraph 6.3. This is primarily because the addition of Red Sea water significantly reduces the salinity of the surface layer and substantially increases the evaporation losses from the Dead Sea. A secondary and lesser cause is the progressive deterioration in the Dead Sea water mass balance due to the effects of climate change.

10.3. In order to assess the amount of reduction in flow required to stabilise the level of the Dead Sea at a chosen target level the Dead Sea water mass balance model has been run with the Red Sea Transfer flow rate constrained by the target level for a range of three combinations of target level and initial flow rate as shown in Figure 10.3 and Table 10.3 below from which it can be seen that for any flows significantly larger than 1,200 million m^3/year the necessary throttling of the system when the target level is attained is in excess of 20%. It should however be noted that in the long term, due to a continuous process of diluting the Dead Sea surface layer with Red Sea water, there will be a continuous but small increase in evaporation rates. This results in a small but continuous decline in the Dead Sea level of a few centimetres per year. Thus a surplus in the capacity of the conveyance system when the target level is achieved would be required to allow a corresponding small increase in discharge to the Dead Sea to maintain a stable water level.

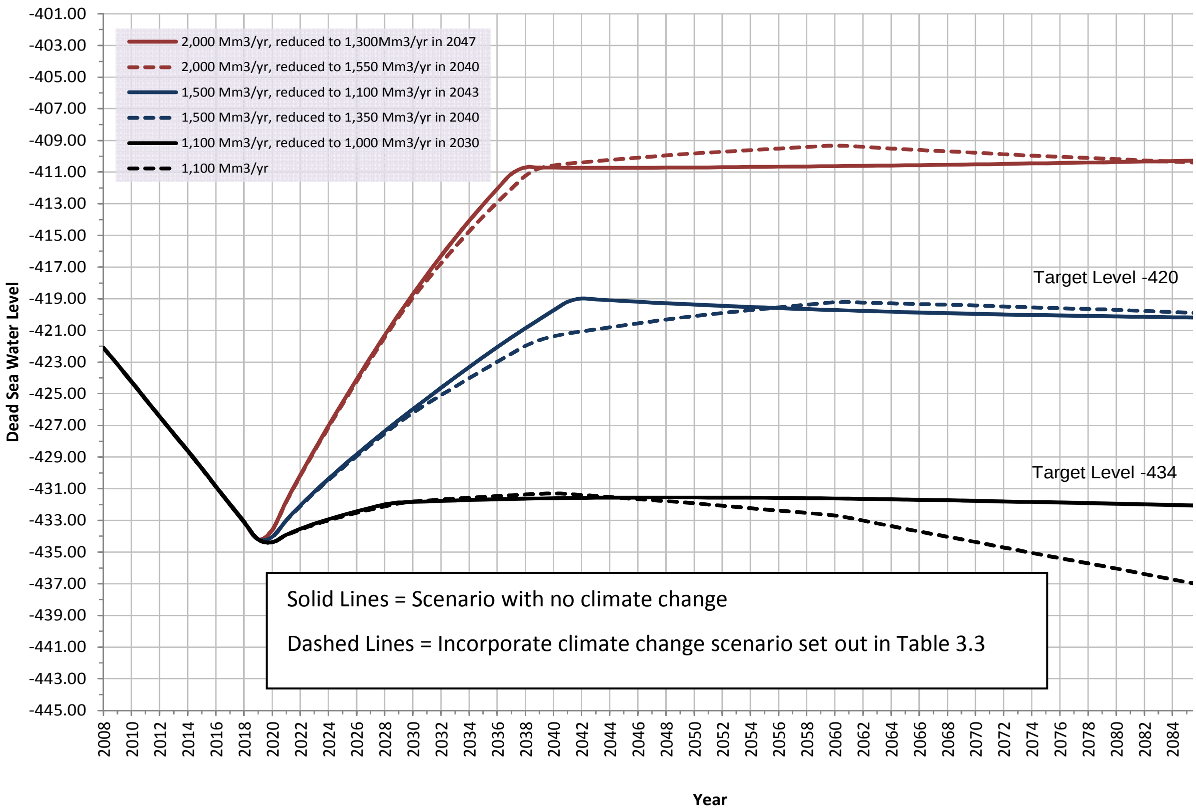


Figure 10.3: Base Case Dead Sea Levels with Red Sea water Discharge Constrained by Dead Sea Target Level

Table 10.3: Summary of Base Case Model Runs with Discharge Rate Constrained by dead Sea Level

Case	Target Level	Initial Flow Rate Mm^3/yr	Target Year	Reduced Flow After Target Level is Reached	
				Flow Mm^3/yr	Redundant Capacity
With Climate Change:-					
B/1100/434	-434m	1,100	2020	The Dead Sea does not stabilise at this flow	
B/1500/420	-420m	1,500	2052	1,350	10%
B/2000/410	-410m	2,000	2050	1,520	23%
Without Climate Change:-					
B/1100/434	-434m	1,100	2020	1,000	9%
B/1500/420	-420m	1,500	2040	1,100	27%
B/2000/410	-410m	2,000	2036	1,300	35%

10.4. Given the scarcity of fresh water in the region it seems highly probable that any significant surplus capacity in the system after the Dead Sea level is stabilised will be utilised to feed a desalination plant to provide potable water, thus reverting to a Base Case Plus scenario. It follows that the only viable Base Case scenario would then be a Red Sea water transfer rate of circa 1,200 million m^3/year which would stabilise the level of the Dead Sea somewhere between -434 m and -428 m.

10.5. However, it should also be noted that the Base Case scenario that would correspond to a similar level of restitution of the Dead Sea as the recommended Base Case Plus scenario would be a Red Sea water transfer flow rate of about 1,500 million m^3/year.

10.6. A preliminary evaluation suggests that for the Base Case a pipeline conveyance would have the lowest capital cost but that a low level gravity flow tunnel would have a substantial advantage in terms of whole lifecycle net present costs. A cost estimate for Base Case low level gravity flow tunnel conveyance with a capacity of 1,500 million m^3/year suggests a capital cost in the order of $4.3 billion and a whole lifecycle net present cost of about $ 6.2 billion.

10.7. As noted previously, following conclusion and agreement of the options screening and evaluation process, the Technical Steering Committee determined that no further work on the Base Case is required beyond that required to complete the options screening and evaluation process.

11. BASE CASE PLUS: DESCRIPTION OF ALTERNATIVE PROJECT CONFIGURATIONS

11.1. As discussed in Section 16 below the recommended desalination process is sea water reverse osmosis and this process provides a fresh water conversion rate of approximately 45%. Thus to provide for an ultimate supply of 850 million m^3/year of desalinated water a minimum Red Sea water intake and transfer capacity of 1,889 million m^3/year is theoretically required. Making an allowance of 5% for inherent uncertainties in the modelling process and the system performance it can be seen that a prudent minimum flow rate is 2,000 million m^3/year.

11.2. The Dead Sea water mass balance model has been run for three Red Sea water abstraction and transfer flow rates of 1,800, 1,900 and 2,000 million m^3/year together with the potable water demands set out in Table 9.2 above and with the discharge to the Dead Sea unconstrained by any target level. The results of these model runs are shown in Figure 11.2 which supports the conclusion in paragraph 11.1 above that a flow rate of 2,000 million m^3/year is necessary to provide an ultimate production of 850 million m^3/year of desalinated water and to stabilise the Dead Sea level within the range of target levels required.

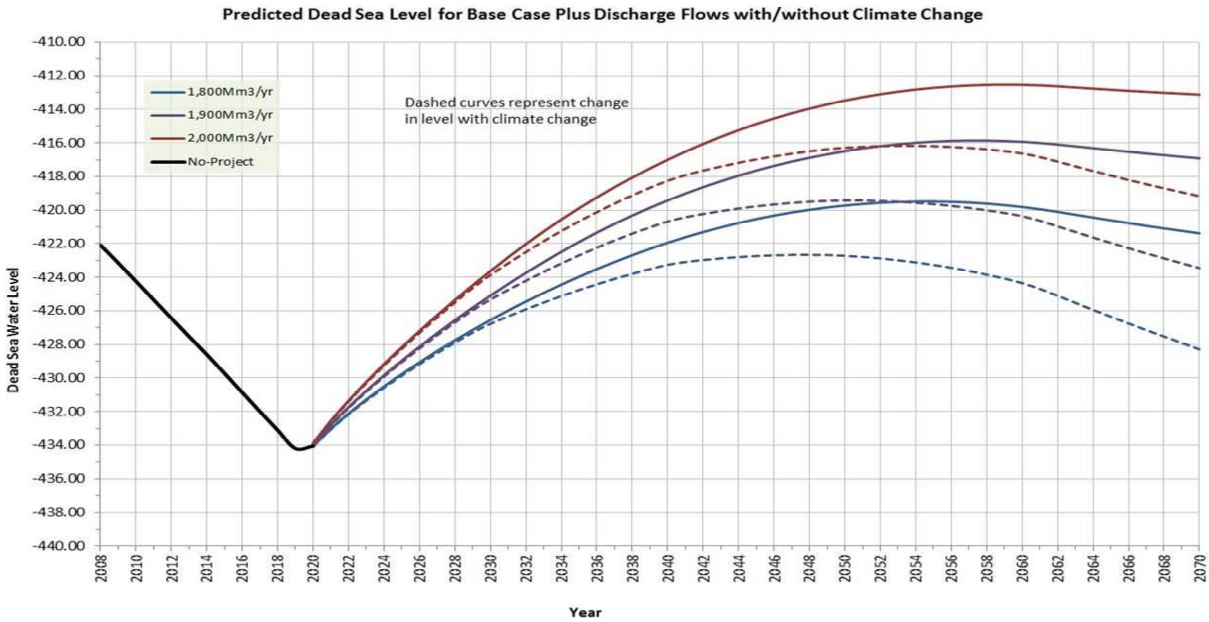


Figure 11.2: Projected Dead Sea Level Versus Time for Various Base Case Plus Flow Rates

11.3. For a Red Sea water transfer flow rate of 2,000 million m^3/year, and with the climate change scenario modelled, the level of the Dead Sea will peak at around -416 m in about 2054 which is about the time that the desalination plant reaches its ultimate design capacity of 850 million m^3/year. Beyond 2054, with a Red Sea water transfer flow rate of 2,000 million m^3/year, the level of the Dead Sea is projected to decline at an approximately constant rate of about 150 mm/year to a level of -431 m in 2150. This decline is due to the fact that with a continuous inflow of Red Sea water into the Dead Sea there is a small but continuous decline in the salinity of the surface water of the Dead Sea with a consequent small but continuous increase in the rate of evaporation from the Dead Sea.

11.4. In order to counteract this long term continued decline in the level of the Dead Sea it is necessary to progressively increase the discharge to the Dead Sea with an additional 225 million m^3/year between 2058 and 2150. In order to achieve this it is necessary to increase the capacity of the conveyance system by approximately 10% over this period. There are several options to achieve this:-

(1) Build the 10% additional capacity into the conveyance from the outset. This option has the disadvantage of requiring major additional up front capital investment for additional capacity that will not be needed until after 2060. However, this is the only feasible solution in the event that a tunnel conveyance is selected.

(2) Expand the capacity of the conveyance when needed in the future. This solution has the advantage of deferring capital cost until the additional capacity is needed but is only feasible in the event that a pipeline conveyance is selected.

(3) Expand the capacity of the conveyance pump station and increase the velocity of the flow in the conveyance when needed in the future. Again this solution has the advantage of deferring capital cost until the additional capacity is needed, but in this case is only feasible in the event that a pumped conveyance system is selected.

Given the inherent uncertainties in the impacts of climate change and very long term projections based on a simple model together with the economic benefits of deferring capital expenditure until needed alternatives (2) or (3) are considered to be more appropriate solutions.

11.5. Following the presentation of the Options Screening and Evaluation Report, the Technical Steering committee left the selection of the preferred intake to the Jordanian delegation subject to this preference not being contradicted by other technical considerations. The Jordanian delegation subsequently indicated a preference for the northern intake location. However, further detailed evaluation of the geology, seismic risks, geotechnical site conditions flood risks and site configurations and constraints conclusively confirm the earlier conclusions given in the Options Screening and Evaluation Report that the northern intake is inherently unsuitable. In particular these evaluations show that the seismic and flood risks associated with the northern intake site exceed internationally accepted norms and that the eastern intake site is much preferred. Based on these conclusions the eastern location has been adopted for all conveyance configurations considered further.

11.6. A total of fifteen possible conveyance configurations were initially evaluated in the options screening and evaluation process. These encompassed:-

- 4 alignments commencing from the eastern intake
- 11 alignments commencing from the northern intake
- 2 all tunnel systems
- 3 all pipeline systems
- 6 combinations of tunnel and canal
- 4 combinations of tunnel, canal and pipeline

11.7. Based on the conclusion and recommendations of the options screening and evaluation process the Technical Steering Committee directed that the following three conveyance configurations should be evaluated in more detail for the Base Case Plus scenario.

- A gravity flow conveyance in tunnel at a nominal elevation of 00 m.
- A pumped conveyance in a combination of tunnels and canals at a nominal elevation of +220 m.
- A pumped pipeline configuration with a high point at an elevation of circa +220 m.

11.8. The alignments of the three selected conveyance configurations are shown in Figure 11.8 below. The main criteria determining the alignment for these configurations are as follows:-

- Topographical conditions.
- Avoidance of major faults and the minimisation of seismic risk in so far as reasonably possible.
- Avoidance of existing infrastructure and development.
- Avoidance of established and designated environmental protection areas wherever reasonably possible.
- Avoidance of existing agricultural activities, both formal and informal in so far as reasonably possible.
- Dictates of morphology and terrain, especially alluvial outwash fans.
- Dictates of hydrology and flood paths.
- Geology and geotechnical conditions.

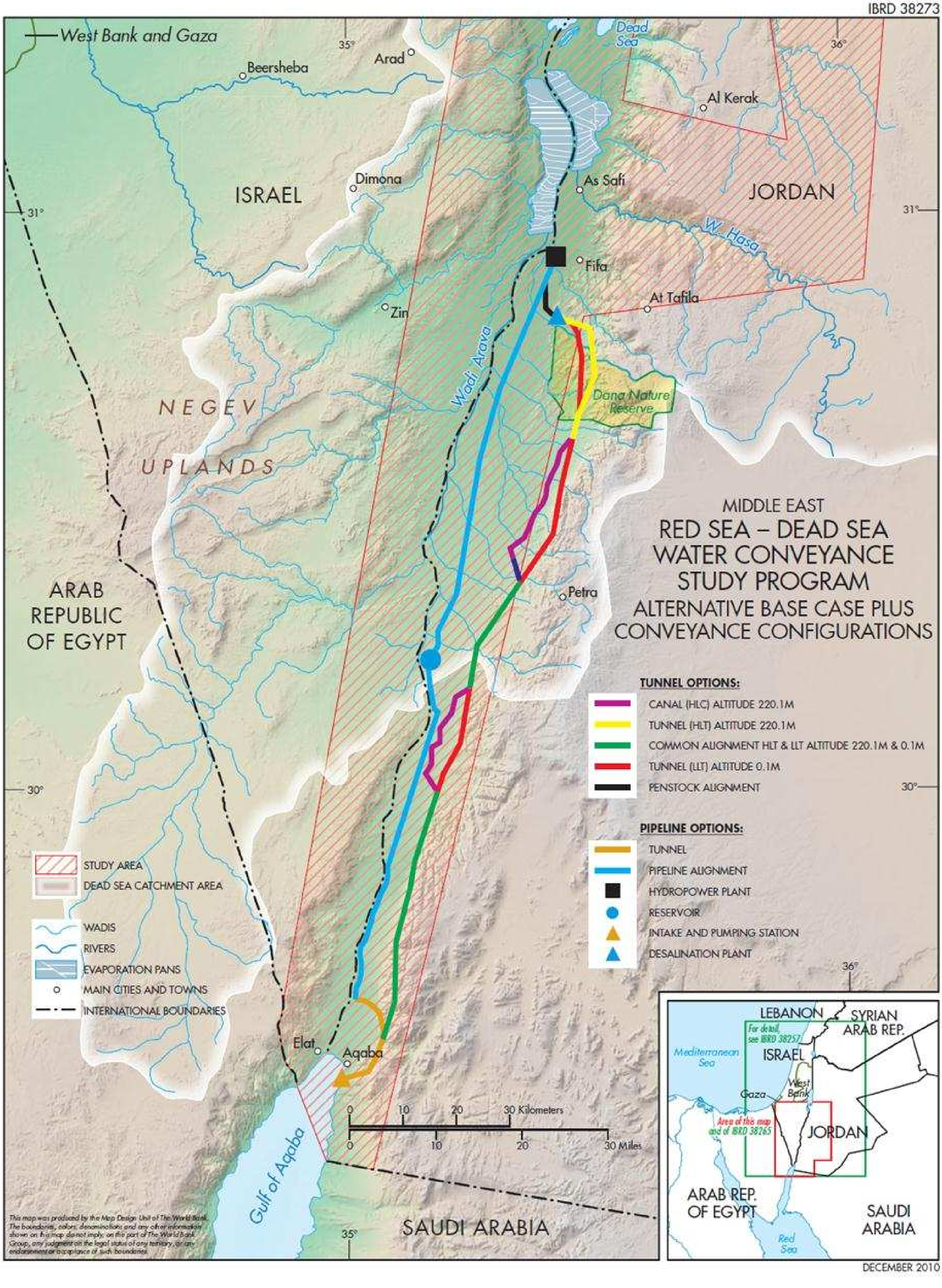


Figure 11.8: Map of Alternative Base Case Plus Conveyance Configurations

11.9. The optimum location for the hydropower plant for all configurations will be at the northern end of the conveyance close to the Dead Sea where the hydrostatic head available for generation of hydro power will be maximised.

11.10. Three alternative flow configurations were initially considered for the desalination process and one of these was eliminated during the Options Screening and Evaluation process for cost and economic reasons. The two remaining configurations to be evaluated for each of the three conveyance configurations are as follows.

(i) A high level desalination plant operating in series with the hydro power facility.

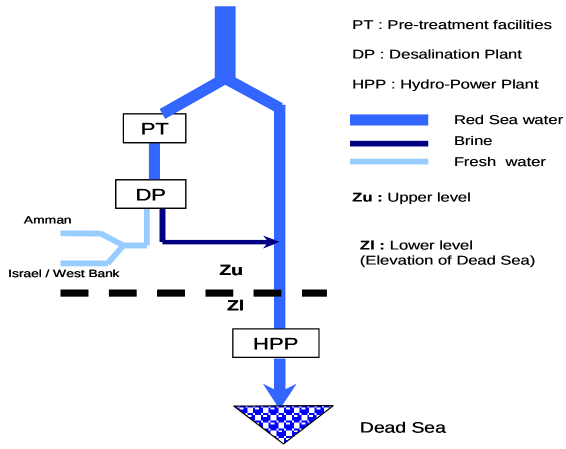


Figure 11.10a: Schematic Flow Configuration for High Level Desalination Plant Operating in Series with Hydropower Plant

This configuration minimises the pumping head required for delivery of potable water to the main demand centres. However the downside is that it also greatly reduces the available hydrostatic head available to drive the reverse osmosis desalination process. In this configuration the flow available to generate hydro power is the total Red Sea diversion flow less the volume of potable water produced. Since the volume of potable water produced increases with time in line with demand growth, the flow available to generate hydro electricity reduces with time by a corresponding amount. Ultimately the flow through the hydro plant is exclusively reject brine from the desalination process.

(ii) A low level desalination plant operating in parallel with the hydro facility.

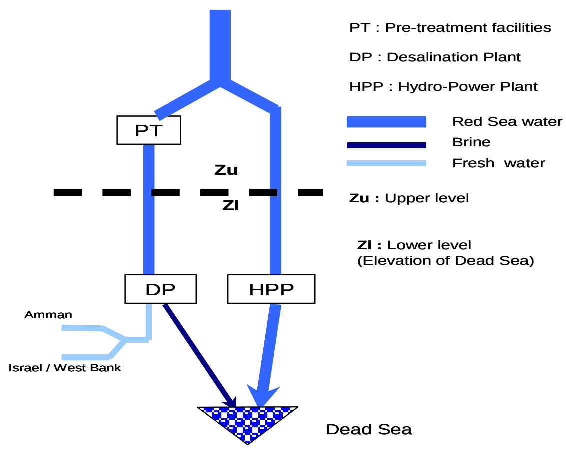


Figure 11.10b: Schematic Flow Configuration for Low Level Desalination Plant Operating in Parallel with Hydropower Plant

This configuration allows the maximum hydrostatic head to be utilised to drive the reverse osmosis process and thus minimises the energy requirements for the desalination process. However, it entails a substantial additional pumping head (from 220 to 400 m depending on conveyance option) to deliver desalinated water to the higher elevation demand centres of the three Beneficiary Parties as compared to the high level desalination plant configuration. In this case the reject brine stream cannot be used to generate hydro electricity and the water flow available to generate power is the total Red Sea diversion flow less the input flow to the desalination plant. When potable water demands reach the maximum capacity of the desalination plant 95% of the total Red Sea transfer flow is required to feed the desalination plant, and thus from this point in time (circa 2060) there will be very little flow available to generate hydro power.

11.11. The low level gravity flow tunnel conveyance alignment is located within the eastern escarpment of the Dead Sea rift valley. The tunnel will have an internal diameter of 8.3 m and will fall gently from the eastern intake at Aqaba to an outlet portal some 160 km north of Aqaba. Tunnel excavation will pass through igneous rocks with abundant cross cut dykes in the southern half of the alignment and through mainly sedimentary rocks in the northern half of the alignment. The alignment is below the ground water table over most of its length. From the tunnel outlet the conveyance will fall more steeply in buried steel penstocks 11 km long to a hydro plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variant of this configuration will be located at the tunnel outlet portal. The desalination plant for the low level desalination plant variant will be located at the downstream end of the penstocks adjacent to the hydro plant.

11.12. The high level tunnel/canal conveyance configuration incorporates a pumping station immediately adjacent to the eastern intake. The conveyance alignment rises sharply from the eastern intake pump station to a high point at an elevation of +220 m some 4.4 km from the eastern intake from where it falls gently in a sequence of tunnel and open canal sections to a tunnel outlet portal some 160 km north of Aqaba. The tunnel sections are located in the eastern escarpment of the Dead Sea rift valley and will pass through similar geology to the low level tunnel as described above in paragraph 11.11, except that in this case the tunnel will generally be located above the ground water table. The open canal sections of this configuration lie within the Wadi Araba at the toe of the eastern escarpment. From the tunnel outlet the conveyance will fall more steeply in buried steel penstocks 14 km long to a hydro plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variant of this configuration will be located at the tunnel outlet portal. The desalination plant for the low level desalination plant variant will be located adjacent to the hydro plant.

11.13. The pipeline conveyance incorporates a pumping station immediately adjacent to the eastern intake. The pumped riser main comprises a short section of pressurised tunnel around the eastern and northern fringes of Aqaba and a series of parallel pipelines from the downstream end of the tunnel to a regulating tank at a high point on the Gharandal saddle which marks the watershed between the Red Sea and Dead Sea water catchments. From the regulating tank, flow is by gravity, again in a series of parallel pipelines, to the hydropower plant at the southern end of the Dead Sea. The pipelines alignment is approximately parallel to the Israeli/Jordan border typically 5 km to 10 km east of the border and crosses the 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 Gharandal saddle (it must be noted that this project configuration provides for 2 hydropower plants, cf. paragraph 17.4). The desalination plant for the low level desalination plant variant will be located adjacent to the hydro plant.

12. RED SEA INTAKE

12.1. Three possible intake locations were initially identified as shown in Figure 12.1 below. One of these, on the west coast of the Gulf of Aqaba / Eilat, was eliminated early on in the Options Screening and Evaluation process. The remaining two on the northern and eastern shorelines have subsequently been evaluated in more detail.

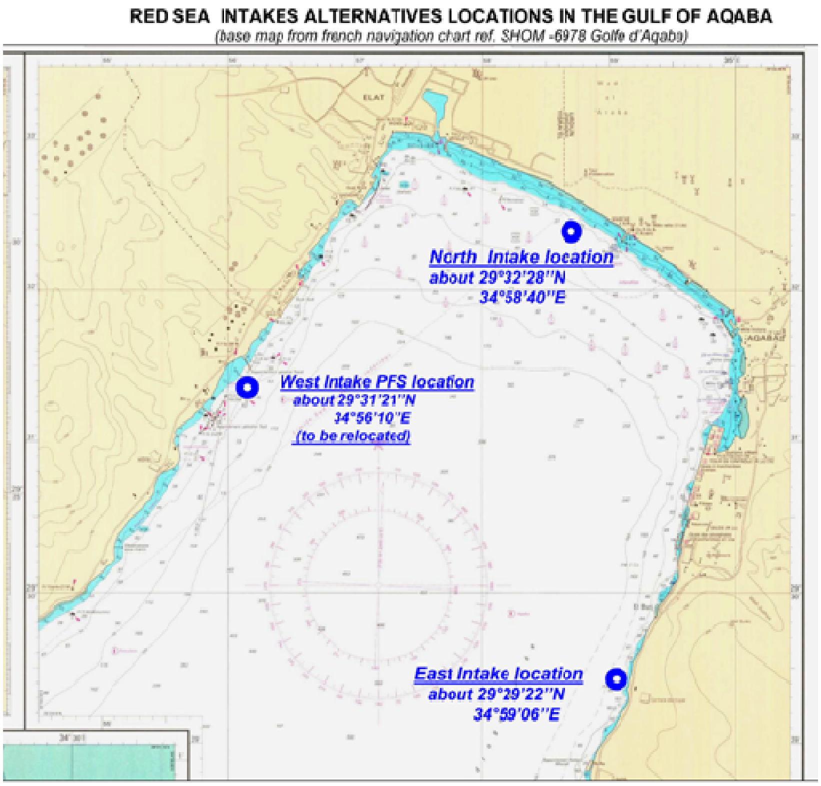


Figure 12.1: Map of Possible Red Sea Intakes Locations

12.2. The northern intake site would result in the shortest conveyance alignment and is the location preferred by the Pre Feasibility Study. However, major challenges associated with this site have been identified as follows;-

- The site is very narrow, bounded to the west by the Jordan / Israel border, to the east by the Ayla Development and to the north by Aqaba Airport. These constraints result in a very restricted site and these restrictions, combined with the site topography and adverse soil conditions, will necessitate complex, difficult and costly construction techniques.
- The northern intake site sits directly on the discharge route of major flash flood discharges from Wadi Yutum which are estimated to be in the order of 777m^3/second for a 1:100 year flood event and 1,300 m^3/second for a 1:1,000 year event. Given the site constraints referred to above it will be almost impossible to re-route these flood flows away from the works or to design adequate flood protection defences for any permanent surface facilities. The site is also subject to flood risk of similar magnitude from the Israeli side.
- Perhaps most significantly the northern intake site is extremely close to a branch of the Arava Main Transform fault which is an active seismic feature with an estimated annual average slip rate of 4 mm/year. Ground conditions are such that the site would be prone to soil liquefaction in a seismic event and there is clear evidence from excavations on an adjacent site that this has occurred in the past. Ground conditions also suggest that the effects of a seismic event would be amplified at the

northern intake site due to a classic basin effect and surveys by others have shown that the spectral response in the vicinity of the northern intake site is double that measured near the eastern intake site location.

12.3. The eastern intake location is on the site of an existing small thermal power station which has been decommissioned. The selection of this site would result in an increase of 5 km in the length of the conveyance compared to the northern intake location but has the following benefits in comparison to the northern location:-

- The site is of adequate size and is already developed.
- The shore shelves relatively steeply allowing an offshore submerged discharge to be constructed at adequate depth close to the shoreline.
- There are no physical, topographical, geological or hydrological constraints similar to those described for the northern site.
- It will be possible to adopt conventional designs and construction methodologies with minimum impact on the surrounding developments.
- The site is located further away from the main rift valley faults, ground conditions are solid rock and will not be prone to soil liquefaction and, due ground conditions and site topography, the eastern location has a significantly better seismic response spectral compared to the northern intake.

12.4. A preliminary comparison of the environmental impacts of the eastern and northern intake sites has been provided in the "Mid Term" report provided by the Red Sea Modelling Study and is summarised in Table 12.4 below. This further suggests that the eastern intake is also preferable from an environmental perspective.

Table 12.4: Environmental Comparison Alternative Intake Sites

	Nature and scale of Impacts			
	Currents	**Water Quality**	**Benthic Habitats**	**Coral Reef larvae**
Northern Intake (Depth 8m)	Significant modification of coastal currents	Small changes in water column are expected.	Impacts on the seagrass acting as a nursery ground.	Impact on area of accumulation for planktonic larvae.
Eastern Intake (Surface level)	Minor modifications of coastal currents up to 1km from the intake.	Limited suspended solids. Limited nutrients.	Limited impact on coral reefs already partially damaged by previous works.	Impact depending on depth of abstraction. Likely to be zero below the photic zone.
Eastern Intake (Depth 25m)	Minor modifications of coastal currents up to 1km from the intake.	Limited suspended solids. Limited nutrients. Assessment ongoing	Limited impact on coral reefs already partially damaged by previous works.	Some entrainment of larvae
Eastern Intake (Depth 120m)	Minor modifications of coastal currents up to 1km from the intake.	Limited suspended solids. Potential significant levels of nutrients. Assessment ongoing	Limited impact on coral reefs already partially damaged by previous works.	No or very limited entrainment of larvae

Colour code:- [yellow] Significant impact; [green] Minor/Limit impact; [grey] still being evaluated

The Red Sea Modelling Study subsequently confirmed that in order to minimize the impacts on the environment, the eastern intake site should be selected.

12.5. From a technical perspective the eastern intake is the preferred location for a combination of risk, design, construction, operational and social / environmental impact reasons. A preliminary economic evaluation included in the options screening and evaluation report indicated that the capital cost of a conveyance system based on the eastern intake would be greater than that for the northern intake. However, pump riser main associated with the eastern intake is much shorter than that for the northern intake and thus, when pumping heads and full lifecycle operating costs are taken into account there is no overall economic penalty in adopting the eastern intake.

12.6. Three generic types of intake works have been considered as follows:-

- A submerged offshore intake
- A closed lagoon formed by breakwater with embedded pipes
- An open channel intake

12.7. Based upon experience elsewhere and available oceanographic data for the Red Sea a subjective relative ranking of the benefits and environmental impacts of each type of intake has been carried out. It is concluded that a submerged offshore intake is the preferred solution for a combination of construction, environmental and operational reasons.

12.8. An outline design for a submerged intake at the eastern intake location has been developed based on the information provided in the Best Available Data Report produced in the framework of the Red Sea Modelling Study. According to this design, the intake structure has the following characteristics:-

- Distance of intake offshore = 80 m.
- Depth of intake below surface of the sea = 25 m.
- Height of intake above sea bed = 20 m.
- Flow velocity at entry to the intake = 0.3 m/sec%.
- Intake pipes = 2No. parallel pipes x 4.75 m diameter.
- Intake controls = Fixed wheel control gates at the downstream end of the intake channel controlled by the water level in intake reservoir.

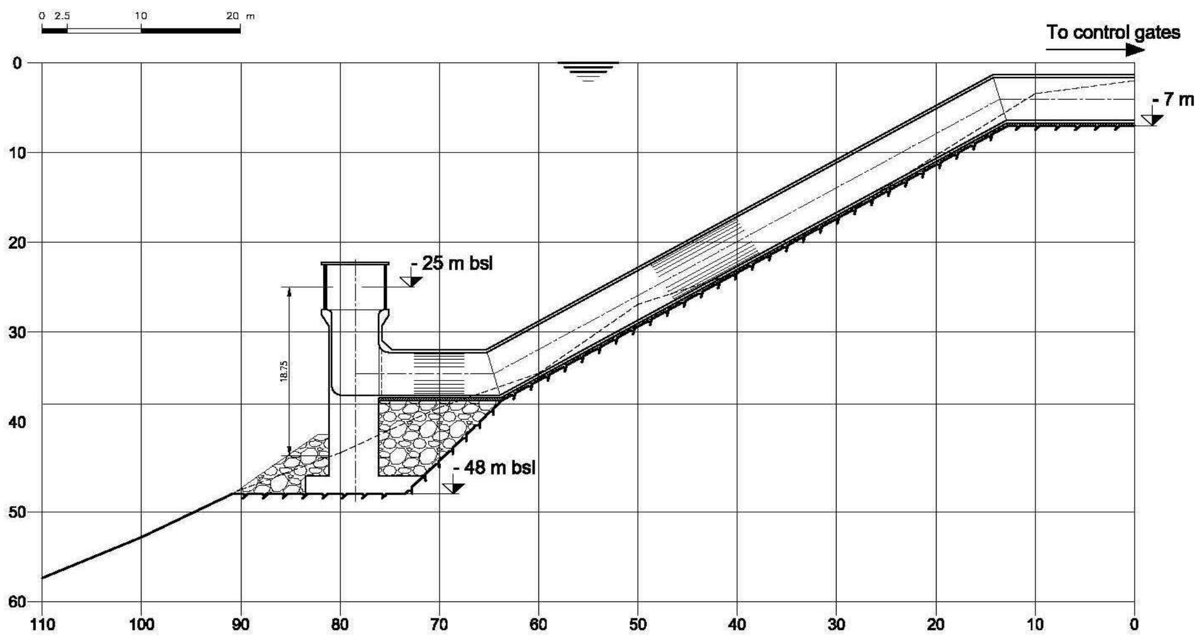


Figure 12.8: General Arrangement of Intake Works

12.9. The Red Sea Modelling Study subsequently recommended that the intake be located at a depth of at least 140 m. The reason of this recommendation is that with a structure at such a depth, only a negligible portion of the larvae reaching the region upstream of the intake will be removed. It was evaluated by the Red Sea Modeling Team that the larvae expected to be removed are at least one order of magnitude smaller than the present inter-annual fluctuations of the populations of corals and invertebrates at the local reefs. The Red Sea Modelling Study also concluded that additional larvae sampling is necessary to adjust the preferred depth with regards to the impacts on the coral larvae. The final selection of the intake depth will therefore have to be made in the next design phase of the project. However it must be noted that even in the case the intake depth is significantly increased as recommended by the Red Sea Modelling Study, this would not alter the conclusions on the overall feasibility of the project. In that case:

- The basic design concept would remain unchanged and the main modifications would be an increase of the length of the concrete pipes and a slight increase of their diameter to compensate the increase of the head losses in the pipes due to the increased length.

- The cost of construction of the intake would be substantially increased but given that this cost accounts for a very small portion of the total project cost this change will not have any significant impact on the conclusions of the Feasibility Study.

12.10. Bio-fouling in the sea water conveyance system is a concern and the intake design incorporates provision for injection of an anti-bio-fouling agent within the intake structure. A number of options have been considered in the main report and injection in the form of slug dosing with chlorine manufactured in situ from sea water (or dry salt) has been recommended.

13. CONVEYANCE SYSTEM – TUNNEL ALIGNMENT OPTION 00.1

13.1. The conveyance option 00.1 is primarily a low level gravity flow tunnel. The tunnel will commence at the eastern intake on the Gulf of Aqaba at an elevation just below sea level, it will be 163 km long falling at a gradient of 1/5,000 and will terminate in the eastern escarpment of the rift valley some 12 km south east of the Jordanian village of Fifa at an elevation slightly above -45 m. From the downstream tunnel portal the conveyance will consist of buried steel penstocks approximately 11 km long feeding the hydro plant located to the south of the Dead Sea at an elevation of -350 m.

13.2. The detailed alignment of the tunnel is dictated by topographic constraints, geological conditions and the presence of active faults. A major consideration has been to maintain a reasonable distance from the main Arava fault. At the upstream end the tunnel passes through igneous intrusive rocks, mainly granite, with numerous cross cut dykes and crosses a number of fault zones where the granite has been crushed to form mylonite. From around 65 km northwards the tunnel will be in sedimentary rocks comprising a series of sandstones, limestones, dolomites and shales.

13.3. It is anticipated that the tunnel will be excavated by mechanised tunnel boring machines giving a circular cross section and the finished internal diameter will be either 8.3 m or 8.6 m depending on the tunnel lining design adopted. In order to achieve a nominal construction duration of six years, in addition to the portals at either end of the tunnel, a further five access galleries will be necessary allowing simultaneous working on up to twelve faces (11 faces are expected to be used for the construction).

Flow in the tunnel will have a free surface and hence the tunnel will not be internally pressurised. This means that:-

- The tunnel lining need only be designed for external ground and groundwater pressures. A number of tunnel lining designs are proposed covering the full range of geological and groundwater conditions expected. Two typical examples are given in Figure 13.4 below.
- Where the tunnel is within the water table any leakage would be from outside into the tunnel and thus there is minimal risk of contaminating groundwater through leakage of sea water from the conveyance. However in locations where the tunnel is located above the groundwater table any leakage will be from inside to out with resultant contamination of the aquifer. In the case of conveyance option 00.1 this later situation only occurs over a limited length of the alignment. Specific design measures have been incorporated into the tunnel lining at these locations to reduce the risk to the lowest practicable level.

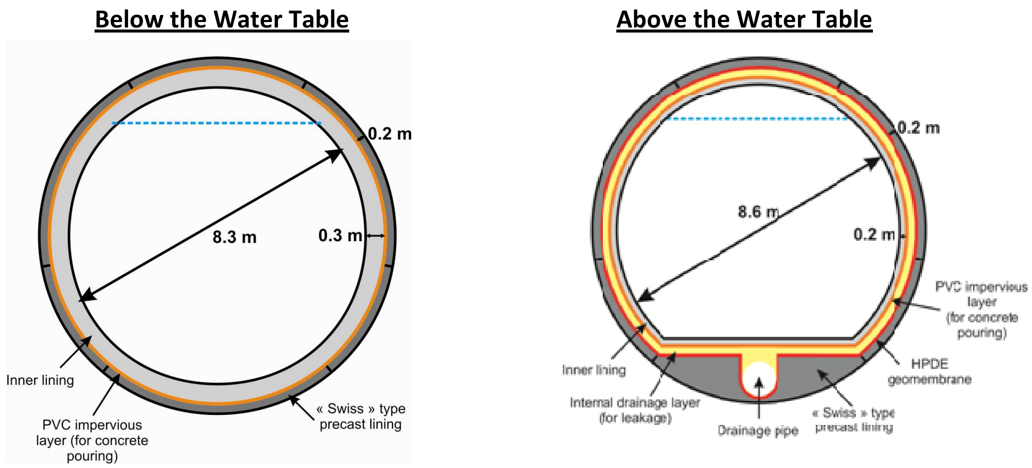


Figure 13.4: Typical Tunnel Lining Details for Tunnel Alignment Option 00.1

14. CONVEYANCE SYSTEM – TUNNEL / CANAL ALIGNMENT OPTION 220.1

14.1. The conveyance option 220.1 comprises the following elements:-

- A pump station at the eastern intake on the Gulf of Aqaba
- A short pumped riser main 4.4 km long from the pump station up to a high point at an elevation of +220 m in the escarpment behind the pump station.
- A sequence of gravity flow tunnels (three sections) and canals (two sections) 160.4 km long from the high point to a final tunnel portal at an elevation slightly above +180 m some 14 km south east of the Jordanian village of Fifa.
- Buried steel penstocks approximately 14 km long from the final tunnel portal to the hydropower plant located to the south of the Dead Sea at an elevation of -350 m.

14.2. The pump station will be located on the site of the existing abandoned thermal power station at the eastern intake location. The pump station will have a gross pumping head of 231.5 m and capacity of 64.7 m^3/second, corresponding to 2,000 million m^3/year with 98% availability. This will be delivered by 14 No. pumps each with a unit capacity of 13 MW.

14.3. Both above ground steel pipes and tunnel have been considered for the riser main section. Tunnel has been selected because unfavourable topography would necessitate extensive surge protection works associated with a pipeline and also because of lower head losses in the tunnel and hence lower operating costs. The design of this section provides for a circular tunnel with an internal diameter of 8.3 m lined with a welded steel liner to resist the high pumping pressures. The tunnel will rise at a gradient of 1:20.

14.4. The detailed alignment of the gravity flow tunnel and canal sections is dictated by topographic constraints, geological conditions and the presence of active faults. The three tunnel sections will be located within the eastern escarpment of the rift valley and the canal sections roughly follow the toe of the escarpment in the Wadi Araba / Arava Valley. A major consideration has again been to maintain a reasonable distance from the main Arava fault. The upstream tunnel section some 61 km long passes through igneous intrusive rocks, mainly granite, with numerous cross cut dykes and crosses a number of fault zones where the granite has been crushed to form mylonite. The middle and downstream tunnel sections pass mainly through sedimentary rocks comprising a series of sandstones, limestones, dolomites and shales. The canals will generally be constructed in surface alluvial deposits.

14.5. It is anticipated that the tunnel will be excavated by mechanised tunnel boring machines giving a round cross section and the finished internal diameter will be either 8.3 m or 8.6 m depending on the tunnel lining design adopted. In order to achieve a nominal construction duration of six years, in addition to the portals at either end of each tunnel section, there will also be a need for a further two intermediate access galleries allowing simultaneous working on up to ten faces (8 faces are expected to be used for the construction).

14.6. From the high point at the head of the short riser main section flow in the tunnel will be by gravity with a free surface and hence the tunnel will not be internally pressurised. This means that:-

- The tunnel lining needs only be designed for external ground and groundwater pressures. A number of tunnel lining designs are proposed covering the full range of geological and groundwater conditions expected. Two typical examples are given in Figure 14.6 below.
- Where the tunnel is within the water table any leakage would be from outside into the tunnel and thus there is minimal risk of contaminating groundwater through leakage of sea water from the conveyance. However in locations where the tunnel is located above the groundwater table any leakage will be from inside to out with resultant contamination of the aquifer. In the case of conveyance option 220.1 this later situation is expected to occur over almost the entire length of the tunnel alignment. Specific design measures have been incorporated in the tunnel lining to reduce the risk to the lowest practicable level.

Pressurised Pumping main Section **Gravity Section Above the Water Table**

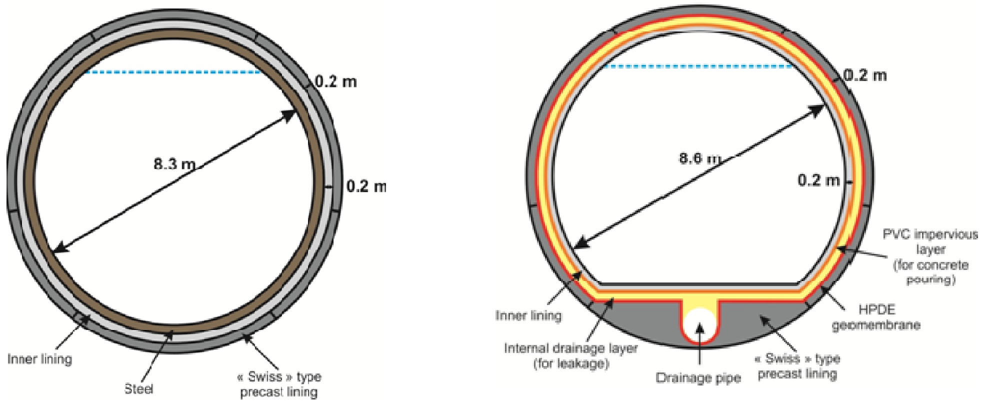


Figure 14.6: Typical Tunnel Lining Details (Conveyance Alignment 220.1)

14.7. The two canal sections will be built partly in cut and partly in fill to provide a regular gradient through undulating terrain and will be designed to substantially balance cut and fill volumes. Where the canal alignment cuts across the drainage path from side wadis one of three design solutions will be adopted depending on specific site conditions. These are a bridge over the canal where the canal is in cut, a storm drainage culvert under the canal where the canal is in fill and an inverted siphon on the canal alignment in intermediate cases.

14.8. The canal sections will be provided with parallel gravel access roads along both sides of the canal for maintenance purposes and fences will be provided on both sides outside of the access roads for safety and security purposes. A typical canal cross section is shown in Figure 14.8 below.

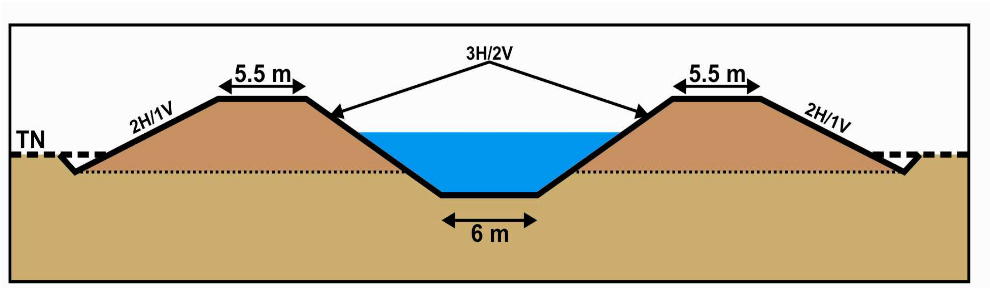


Figure 14.8: Typical Canal Cross Section

14.9. The canal sections are located above the Wadi Araba alluvial aquifer and therefore the risk of contamination to the aquifer from leakage of sea water must be reduced to the minimum practicable level. To achieve this, canal lining will include a double hydraulic barrier comprising from top to bottom:-

- A 4 mm bituminous membrane
- A 20 cm concrete slab
- A geotextile blanket (to protect the underlying gravel layer from contamination when placing the concrete slab above)
- A gravel layer (50 cm thick below the base of the canal and 20 cm thick on the lateral slopes)
- A 2 mm HDPE impervious geomembrane
- A 5 cm layer of shotcrete

14.10. This option would pose particular problems for the desalination pre-treatment design due to windblown sedimentation and re-suspension in the canal sections which could be prohibitive.

14.11. The energy requirements of the conveyance alternative 220-1 (pumping station + riser main + a sequence of gravity tunnels and canals) is an estimated 1,628 GWh/year. This value is for the water conveyance only.

15. CONVEYANCE SYSTEM – PIPELINE ALIGNMENT OPTION

15.1. A pipeline conveyance starting from the eastern intake will comprise the following elements:

- A pump station at the eastern intake.
- A pumped riser main section from the intake at sea level to a high point at an elevation of about +220 m on the Gharandal saddle which forms the watershed between the Dead Sea basin and the Gulf of Aqaba water catchments. Due to the extent of development and the rugged topography a short section of the riser main around the eastern and north eastern fringes of Aqaba will be in tunnel.
- A balancing reservoir at the high point.
- A gravity flow pipeline from the balancing reservoir at the Gharandal saddle to the hydropower plant at the southern end of the Dead Sea (the pipeline option combined with the high level desalination plant includes a second hydropower plant, cf. paragraph 17.4).

15.2. The pump station will be located on the site of the existing abandoned thermal power station at the eastern intake site. The pump station will have a gross pumping head of 273 m and a capacity of 64.7 m3/second, corresponding to 2,000 million m^3/year with 98% availability. This will be delivered by 14 No. pumps each with a unit capacity of 16 MW.

15.3. The tunnelled section of the riser main will be 25.5 km long starting at the pump station outlet and terminating at a location in the Wadi Araba about 2 km north of Aqaba airport. The tunnel alignment is mainly in granites cross cut with igneous dykes and passes through a 500 m wide faulted zone of crushed mylonitic granite. A length of 3.4 km at the downstream end of the tunnel alignment will be in alluvial deposits. The tunnel will be circular in cross section with a finished internal diameter of 5.5 m. In order to withstand the high internal pumping pressures the tunnel will have a steel lining varying in thickness between 27 mm and 35 mm. In order to minimise the surge protection requirements at the pump station a surge shaft will be provided at a suitable location along the tunnel alignment. A possibility to reduce the length of this tunnel by some 11 km has been identified with a potential net saving in the overall cost of the project of around US $500 million. If this alternative (presented in the paragraph 15.13 of the Main Report) is adopted, the outlet of the tunnel would be immediately to the north of the city of Aqaba and not to the North of the airport. It must be noted however that, due to the complex geological and geotechnical conditions, this cannot be confirmed until a much more detailed geotechnical investigation is conducted at the next stage (detailed design) of the project development. Hence we have determined the project feasibility based on the most pessimistic case where the alternative of a shorter tunnel would not be feasible.

15.4. From the upstream portal of the tunnel to the Gharandal saddle the riser main will comprise a series of buried steel pipelines 66.5 km long. A detailed optimisation of capital costs, friction losses, pipeline pressures, energy demands and operating costs has been carried out for a range of numbers and diameters of parallel pipelines. As a result it has been determined that the optimum configuration will be six parallel pipelines each 2.9 m diameter and with a wall thickness of 14.5 mm.

15.5. The regulating tank at the high spot is a key component in the hydraulic control of the system. It will serve to balance the flows between the pumped and the gravity flow sections of the conveyance and will also provide safety storage to avoid emptying of the tank in the event of a general pump trip. The required capacity will depend on the selected desalination configuration and will be 270,000 m^3 in the case of the low level desalination plant and 175,000 m^3 in the case of the high level desalination plant.

15.6. The gravity flow conveyance will also comprise a series of parallel buried steel pipelines 84 km long. The optimum configuration will be one of the following dependent on which desalination plant configuration is selected:-

Low level desalination plant: Four parallel pipelines with varying diameters between 2.4 m and 2.9 m and varying wall thicknesses between 14.5 mm and 25.5 mm.

High level desalination plant: Three parallel pipelines with diameters varying between 2.9 m and 3.0 m and wall thickness of 14.5 mm and 15 mm.

15.7. It is anticipated that pipe will be manufactured at two dedicated spiral welded pipe manufacturing plants set up on, or close to, the pipeline right of way. Pipe will be fabricated from X-70 grade steel with a three layer polyurethane external coating and an epoxy internal lining. Completed pipelines will also be protected by an impressed current cathodic protection system.

15.8. The Wadi Araba / Arava valley is a highly active seismic zone and it is unavoidable that the pipeline crosses a number of active faults. Where the pipeline crosses active faults the exact location of the fault must be determined during future detailed geotechnical site investigation programs. Special arrangements will be provided at these locations to accommodate small rotation and longitudinal deformation of the pipe as well as protecting the pipe from a degree of lateral displacement. This will be accommodated by spanning the fault either with the pipes suspended inside especially designed concrete boxes without any backfill or with the pipes installed above ground and provided with special fittings to allow slippage and rotation of the pipes on their supports, and by incorporating wave joints in the pipeline. In the event of moderate seismic activity the box and wave joints will absorb the movement without over stressing the pipe.

15.9. The pipeline alignment overlies the Wadi Araba / Arava Valley alluvial aquifer which is a valuable water resource and which is critical for both residents and economic activity in the area. It is essential that this aquifer is protected from contamination by leakage of sea water from the pipeline system. Two types of leakage are considered:-

1) Insidious small leakage – this type of leakage is too small to be detected by flow or pressure monitoring instrumentation and may never appear at the ground surface Flow from such leaks can go undetected for many years. Protection from this type of leakage will be by lining the trench with an impervious membrane to contain any small leakage within the trench. The trench bedding will comprise a free draining granular fill surrounding a collector pipe which will channel any leakage to collection tanks at localised low spots along the conveyance alignment where any flow can be monitored, collected and pumped out for removal to a safe location. The collector pipe will also be fitted with instrumentation to accurately locate inflows and to differentiate between sea water and rainwater. Those design arrangements are shown on the Figure 15.9 below.

2) Large catastrophic leaks: this type of leakage is very rare in well constructed and properly maintained pipelines and will be immediately apparent but large amounts of water can be discharged in a very short time. The total volume of leakage will depend on the detail design but could be up to a maximum of somewhere in the order of 400,000 m^3. In order to minimise leakage in such an event the pipeline will be provided with in-line isolation valves at regular intervals which will be linked to an instrumentation and control system that immediately closes the isolation valves in the event that abnormal flow or pressure changes are detected. Thus the potential maximum leakage is effectively limited to the volume of water between two isolation valves.

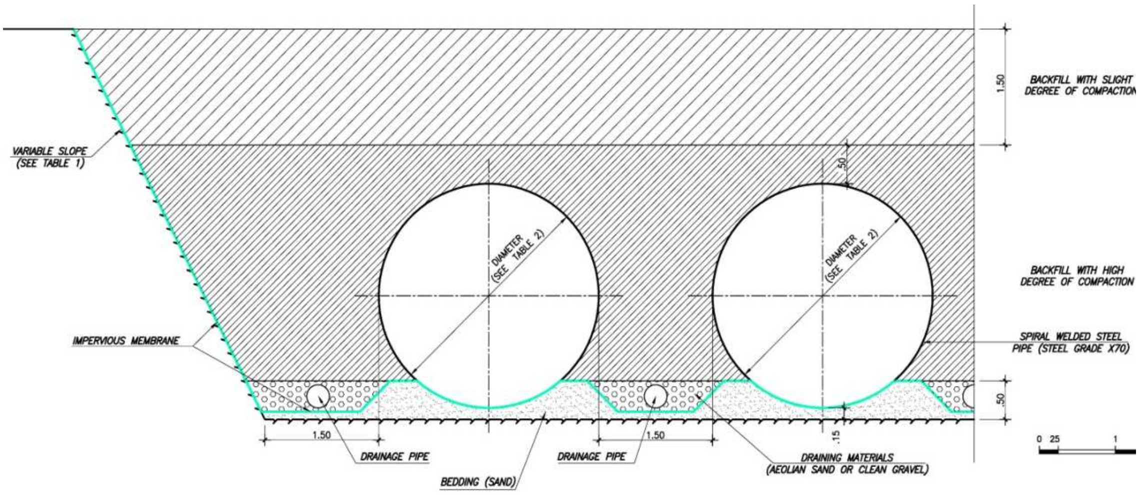


Figure 15.9: Pipeline Conveyance; Typical Cross-Section Showing Leakage Containment and Detection System

15.10. The energy requirement of the pipeline option (pumping station + riser mains + gravity pipe sections) is an estimated 1,920 GWh/year. This value is for the water conveyance only.

16. DESALINATION

16.1. Both high level and low level locations for the desalination plant have been evaluated for each of the three conveyance alignments. In all cases the low level desalination plant will be co-located with the hydropower plant to the south of the Dead Sea and to the west of Fifa village at an elevation of -350 m. In the case of the conveyance options 00.1 and 220.1 the location of high level desalination plant will be adjacent to the downstream portal of the conveyance tunnel, about 14 km south east of Fifa village on an excavated platform in the eastern escarpment of the rift valley. The elevations of these platforms will be -40 for conveyance option 00.1 and +180 m for option 220.1.

16.2. The selection of the location for a high level desalination plant on the pipeline conveyance option is less simple. The natural location would be at the site of the regulating tank between the pumped and gravity flow sections of conveyance. However this location is a long way from the potable water demand centres to be served and so would add to the cost of potable water transmission systems. A location has been selected further downstream on the gravity section of the conveyance which is at a lower elevation but which provides an optimal balance between the length of potable water transmission lines, the pumping head to deliver the potable water to the main demand centres and the need to maximise the hydrostatic head available to generate hydropower at the downstream end of the conveyance.

16.3. Operationally a break in pressure in the conveyance system is required at the inlet to the pre-treatment process. Thus, in order to maintain the maximum potential to generate hydropower, the pre-treatment works will always be located at the high level desalination plant location even when the main desalination process is at the low level location. In the case of the low level desalination plant configurations this gives rise to two separate flows in the penstock section of the conveyance – pre-treated feed water for the desalination plant and untreated Red Sea water to feed the hydropower plant.

16.4. The full range of established and emerging desalination processes currently in commercial production has been considered. However, amongst the better established technologies, only reverse osmosis is economically viable for large scale sea water plants where surplus heating is not available from some other industrial process such as power generation. The sea water quality in the Gulf of Aqaba is relatively good (see section 4 of the Main Report) and so pre-treatment has been limited to multi-media filtration although the addition of dissolved air flotation may be considered at the detailed design stage. Ultrafiltration technology could also be considered as a viable pre-treatment option in the next design stage of the project if this technology is more widely adopted which is likely to be the case. Post treatment of desalinated water will entail stabilization by injection of quicklime and CO_2, inhibition by addition of silica of phosphate blends and disinfection using chlorine manufactured in situ, probably from dry salt. The detailed definition of the post-treatment will require a “blending and mixing” type study to be carried out to ensure the required quality of water at the consumers taps whilst minimising the post treatment costs.

16.5. The process design is based on industry standard equipment and modular units designed to allow progressive phased development of the desalination plant in line with growth in potable water demand. The reverse osmosis process will be in two stages with energy recovery. The main components of the plant have been sized and quantified, and the preliminary designs have been developed for the six different configurations.

16.6. The average specific energy over the lifetime of operations to produce 1 m^3 of potable water is in the range of 1.73 kWh to 2.42 kWh for the low level desalination plant options and is in the range of 3.05 kWh to 3.33 kWh for the high level desalination options. As will be seen later, this apparent benefit for the low level options is offset by a greater long term potential for hydropower generation and lower pumping costs to deliver desalinated water to the demand centres associated with the high level desalination plant configurations.

16.7. The quality of the water produced after each stage of the RO process has been assessed and the quality of the reject brine (concentrate) discharged to the Dead Sea has also been assessed taking into account the residue of chemicals used during operation and maintenance of the treatment process. There will be minor seasonal variations in the process performance and the assessment of performance during the summer season is summarised in Table 16.7 below.

Table 16.7: Water Discharge Quality in mg/l (summer season)

Species/Parameter	Molecular formula	Seawater	Concentrate	Permeate	
				Pass 1	Pass 2 (Final)
Ammonium	NH_4	0.0	0.0	0.0	0.0
Potassium	K	424.4	828.8	5.3	0.7
Sodium	Na	12148.0	23739.2	130.5	14.4
Magnesium	Mg	1476.9	2894.2	3.7	0.2
Calcium	Ca	471.1	923.3	1.2	0.1
Strontium	Sr	0.0	0.0	0.0	0.0
Barium	Ba	41.0	77.2	0.1	0.0
Carbonate	CO_3	21.1	558.2	0.0	0.0
Bicarbonate	HCO_3	105.0	193.7	1.7	0.2
Nitrate	NO_3	1.0	1.9	0.1	0.0
Chloride	Cl	22670.0	42852.6	215.6	23.1
Flouride	F	1.0	1.9	0.0	0.0
Sulfate	SO_4	3183.0	5997.4	3.0	0.1
Silica	SiO_2	5.0	9.4	0.1	0.0
Boron	B	4.9	8.4	1.4	0.9
Carbon dioxide	CO_2	0.4	0.7	0.2	0.0
Total Dissolved Solids	TDS	41121.0	77625.6	369.0	44.0
Acidity	pH	8.2	8.3	7.1	8.4
Temperature	°C	30.0	30.5	30.8	30.8

16.8. Balancing storage for desalinated water equivalent to 5 hours operation up to a maximum of 250,000 m^3 will be provided at the outlet of the plant. Additional balancing and strategic storage will be necessary in the distribution networks at the demand centres served but this is outside the scope of the Feasibility Study.

17. HYDROPOWER PLANT

17.1. The head difference of 423 m between the Red Sea and the Dead Sea provides the potential to generate hydropower as part of a Red Sea – Dead Sea Project.

17.2. Ideally the hydropower plant should be located at the lowest elevation possible to maximise the potential for power generation. A suitable site has been identified immediately to the south of the chemical industry solar evaporation ponds, about 3 km east of the Israeli / Jordanian border and close to the Jordanian village of Fifa. The site lies within the boundary of the proposed Fifa protected area. The main considerations influencing the site selection are:-

- The topographic conditions
- The location of the international border.
- The location of major faulting.
- The presence of major flood paths from side wadis and the consequent flood risks.
- The presence of alluvial outwash fans.
- Established agricultural developments.
- Potential sink hole risks
- The developed areas of the southern Ghors townships.

17.3. In addition to the hydropower plant itself the site will also accommodate the incoming penstocks, an energy dissipation basin to be used in the event the hydropower plant has to be closed and the incoming flow is required to bypass the plant, the outgoing discharge canal to the Dead Sea, a 400/130 kv sub-station, and potentially, a low level desalination plant should this option be selected. As noted above there is a significant flood risk and the entire site will be protected by a 2 m high earthen embankment which can be blended into the natural terrain. This provides a probability of overtopping of approximately 5% in 200 years. A general layout of the hydropower plant area is shown in Figure 17.3 below (this figure is for the Low Level Desalination Plant configuration).

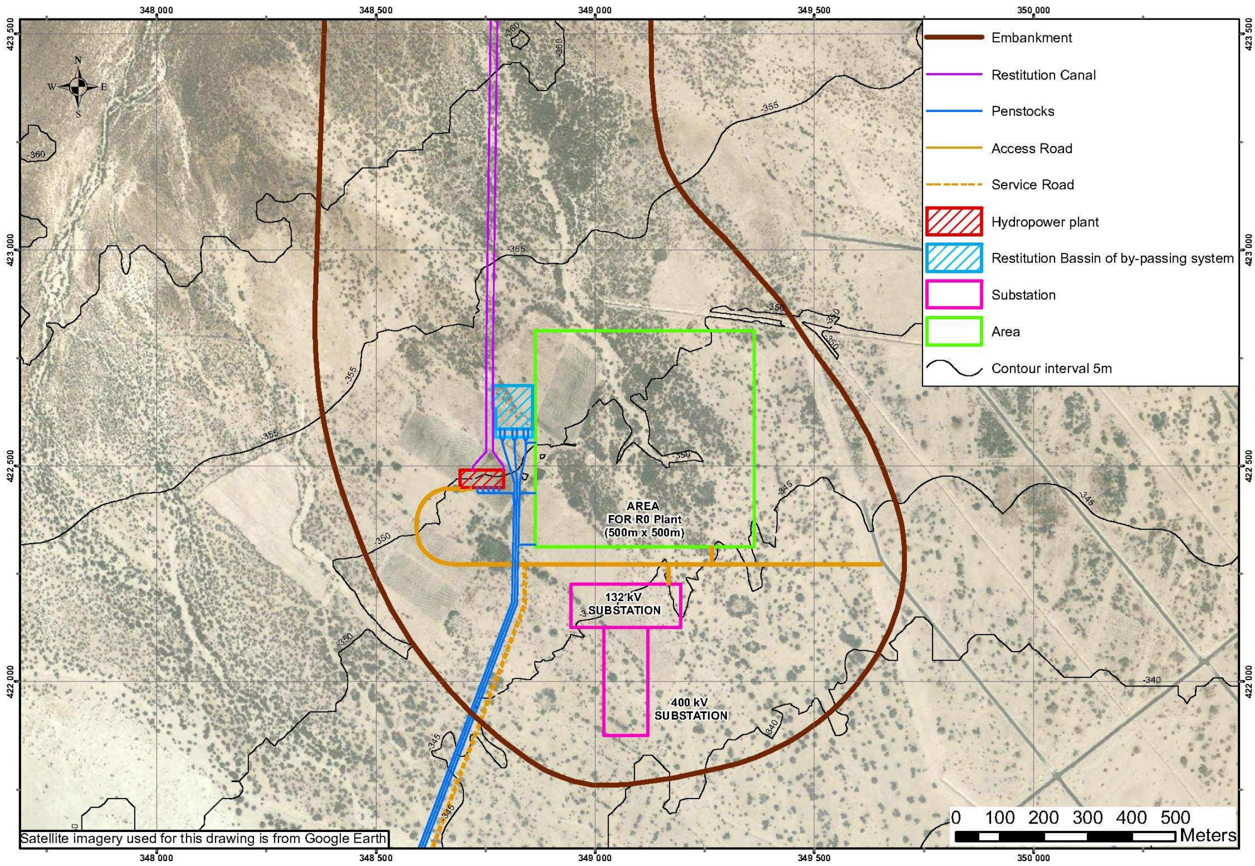


Figure 17.3: General Layout of the Hydropower Plant Area

17.4. Three potential conveyance configurations have been evaluated together with two possible desalination plant configurations for each, giving a total of six possible system configurations as listed in Table 17.4 below. The flows and hydrostatic heads available for the generation of power vary between each of these six configurations and also vary with time for each of the configurations. In the case of options 1 to 5 the best use of the available head and flow is obtained by a single hydropower plant at the lowest practicable level. However in the case of the pipeline conveyance configuration combined with a high level desalination plant, the plant is located downstream and at a lower elevation than the regulating tank. Thus, in this case, the optimum use of the available head will be achieved by adopting two hydropower plants; one immediately upstream of the high level pre-treatment plant with a second plant at the low level location. Each of these configurations has a different potential for hydropower generation.

Table 17.4: List of Hydropower Plant Options

Hydropower plant		Water Conveyance Option	Desalination Configuration
#1	0.1 LLDP	Alternative 0.1	Low Level Desalination Plant
#2	0.1 HLDP	Alternative 0.1	High Level Desalination Plant
#3	220.1 LLDP	Alternative 220.1	Low Level Desalination Plant
#4	220.1 HLDP	Alternative 220.1	High Level Desalination Plant
#5	PL LLDP	Pipeline Option	Low Level Desalination Plant
#6	PL HLDP-1	Pipeline Option	High Level Desalination Plant
#7	PL HLDP-2	Pipeline Option	High Level Desalination Plant

17.5. In the case of all high level desalination options the flow to the hydropower plant will comprise a combination of reject brine from the desalination plant and Red Sea water by-passing the desalination plant. The total flow to the hydropower plant will thus be the Red Sea water abstraction and flow rate less the quantity of desalinated water produced. Since the quantity of desalinated water produced will increase with time to match growth in potable water demands there will be a corresponding reduction in the volume of water available for generation of hydropower. In this case the flow available to generate hydropower is limited approximately to the flow of reject brine when the desalination plant production reaches its ultimate capacity plus a very small quantity of Red Sea water.

17.6. In the case of the low level desalination option the flow to the hydropower plant will consist entirely of Red Sea water bypassing the desalination plant and will not include the reject brine from the desalination process. The total flow to the hydro plant will thus be the Red Sea water abstraction and flow rate less the inflow to the desalination plant. Again, since the quantity of desalinated water produced will increase with time to match growth in water potable demands there will be a corresponding increase in the inflow to the desalination plant and a corresponding reduction in the volume of water available for generation of hydropower. In this case the flow available to generate hydropower is small once the desalination plant production reaches its ultimate capacity.

17.7. An economic evaluation shows that despite this decrease in hydropower generation potential it will always be economically beneficial to install the maximum power generating capacity at the outset even though some of this capacity gradually becomes redundant with time.

17.8. The total flows available for hydropower generation are summarised in Table 17.8 below.

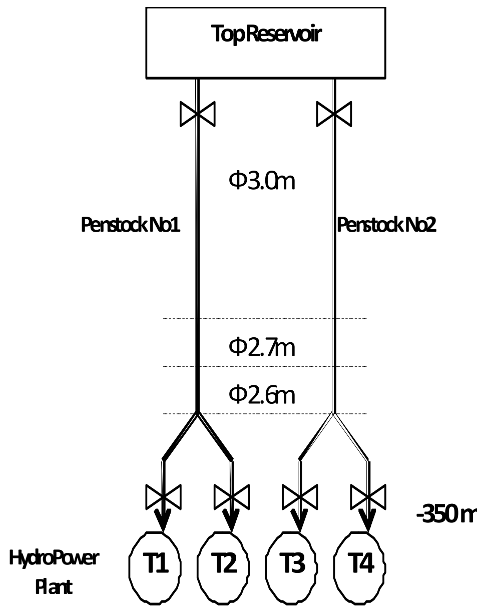
Table 17.8: Available Flows for Hydropower Generation

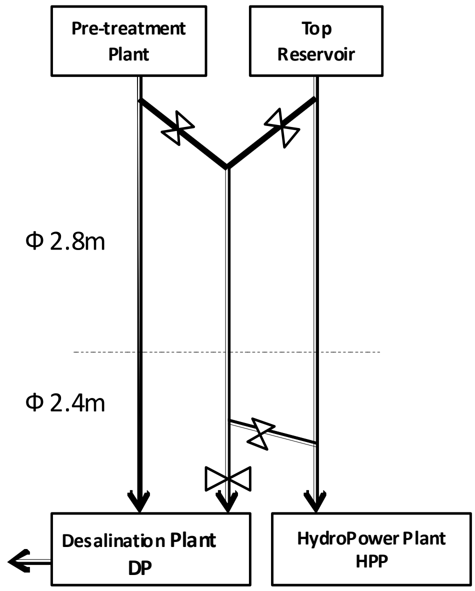
Year	Flow in main conveyance (MCM/yr)	Volume of desalinated water (MCM/yr)	Volume of brine (MCM/yr)	Volume of backwash & and over-flow from PT (MCM/yr)	Available inflows at hydropower plants: Low level desalination plant configuration (MCM/yr)	Available inflows at hydropower plants: High level desalination plant configuration (MCM/yr)
2020	2 000	350	396	23	1 254	1 650
2021	2 000	358	405	23	1 237	1 642
2022	2 000	366	414	24	1 220	1 634
2023	2 000	374	423	24	1 203	1 626
2024	2 000	382	432	25	1 186	1 618
2025	2 000	390	441	26	1 169	1 610
2026	2 000	398	450	26	1 152	1 602
2027	2 000	406	459	27	1 135	1 594
2028	2 000	414	468	27	1 118	1 586
2029	2 000	422	477	28	1 101	1 578
2030	2 000	430	486	28	1 084	1 570
2031	2 000	441	499	29	1 060	1 559
2032	2 000	452	511	30	1 037	1 548
2033	2 000	463	524	30	1 013	1 537
2034	2 000	474	536	31	990	1 526
2035	2 000	485	549	32	966	1 515
2036	2 000	496	561	32	943	1 504
2037	2 000	507	574	33	919	1 493
2038	2 000	518	586	34	896	1 482
2039	2 000	529	598	35	873	1 471
2040	2 000	540	611	35	849	1 460
2041	2 000	553	626	36	821	1 447
2042	2 000	566	640	37	794	1 434
2043	2 000	579	655	38	766	1 421
2044	2 000	592	670	39	738	1 408
2045	2 000	605	684	40	711	1 395
2046	2 000	618	699	40	683	1 382
2047	2 000	631	714	41	655	1 369
2048	2 000	644	729	42	627	1 356
2049	2 000	657	743	43	600	1 343
2050	2 000	670	758	44	572	1 330
2051	2 000	688	778	45	534	1 312
2052	2 000	706	799	46	495	1 294
2053	2 000	724	819	47	457	1 276
2054	2 000	742	839	49	419	1 258
2055	2 000	760	860	50	380	1 240
2056	2 000	778	880	51	342	1 222
2057	2 000	796	901	52	303	1 204
2058	2 000	814	921	53	265	1 186
2059	2 000	832	941	54	227	1 168
2060	2 000	850	962	56	188	1 150

17.9. In the case of the low level desalination plant configurations, as noted previously, there will be two separate flows downstream of the pre-treatment plant, namely the pre-treated water conveyed to the desalination plant and untreated water conveyed to the hydropower plant. Separate pipelines/penstocks will be required for each of these flows and, since both the flows vary over time, the optimum solution is:

- For the conveyance option 0.1 and 220.1: three parallel penstocks with complex upstream and downstream cross-over and valve arrangements such that in the early years of operation two penstocks will be dedicated to Red Sea water and one to pre-treated water with the situation being reversed at a later date as the ratio of these two flows changes.

- For the pipeline option: four pipes with the same type of valve and cross-over arrangements such that two pipes will be dedicated to Red Sea water in the early years of operation and three pipes from year 2043 onward.





High Level Desalination **Low Level Desalination**

Figure 17.9: Typical Penstock Arrangements

(for conveyance alternatives 0.1 and 220.1)

17.10. Francis and Pelton type turbines have both been evaluated and Pelton type are preferred for economic, hydraulic and maintenance reasons. The Pelton turbines better accommodate the possible major water hammer effects induced by the very long incoming pipes or penstocks and this must be regarded as a key criteria for the selection of the type of machines. The number of units has been determined taking into account the following parameters and criteria:

- The number of pipes or penstocks conveying the water to the hydropower plant.
- The nominal flow rate of each unit.
- The number of units must allow for generation energy throughout the lifecycle of the project at an acceptable level of efficiency.

17.11. As highlighted above the water flow available for generation of hydropower reduces with time for all scenarios. An economic evaluation has been carried out which none the less demonstrates that the optimum installation is that which maximises the power generation in early years thus resulting in surplus capacity in later years. The size and rating of equipment has therefore been determined on this basis.

17.12. Material selection for valves, turbines and other equipment in contact with sea water is a critical issue. There is only limited world wide experience of hydropower generation using sea water and this issue will need a thorough assessment at the detailed design stage.

17.13. A typical cross section of the hydropower plant is shown in Figure 17.13 below and the number and size of main equipment for each potential hydropower plant is shown in Table 17.13 below.

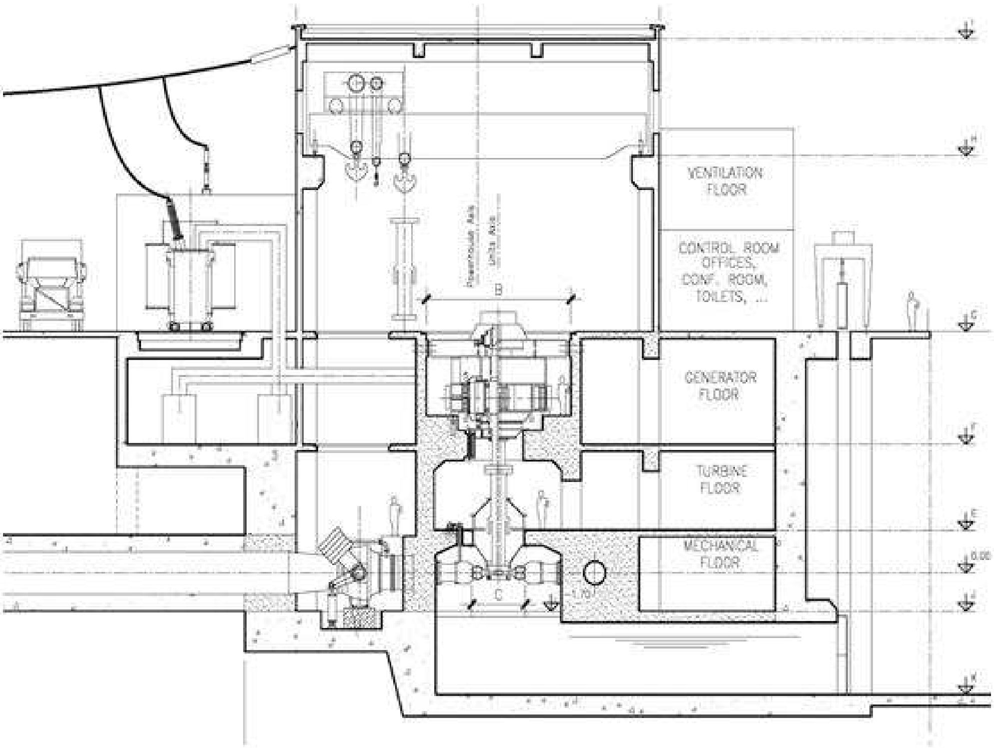


Figure 17.13: Typical Hydropower Cross Section

Table 17.13: Summary of Main Equipment Characteristics

		0.1 HLDP	220.1 HLDP	0.1 LLDP	220.1 LLDP	Pipeline LLDP	Pipeline HLDP 1	Pipeline HLDP 2
Rated Head		277 m	446 m	280 m	471 m	455 m	211 m	215 m
Number of units	Large units	4	4	4	4	4	3	3
	Small units	/	/	1	1	1	/	/
Total disch, capacity		58,1	58,1	44,2	44,2	44,2	70,4	58,1
Unit discharge capacity	Large units	14,52	14,52	10,17	10,17	10,17	23,46	19,37
	Small units	/	/	3,52	3,52	3,52	/	/
Total rating		146,4 MW	235,5 MW	112,6 MW	189,4 MW	183,0 MW	135,0 MW	113,8 MW
Unit Rating	Large units	36,6 MW	58,9 MW	25,9 MW	43,6 MW	42,1 MW	45,0 MW	37,9 MW
	Small units	/	/	9,0 MW	15,1 MW	14,5 MW	/	/
Specific speed (Ns)	Large units	58,1	51,5	55,2	48,1	49,7	56,8	53,8
	Small units	/	/	47,5	38,6	39,9	/	/
Actual speed (rpm)	Large units	300	375	333	428	428	187,5	200
	Small units	/	/	500	600	600	/	/
Turbine diameter	Large units	2,6	2,62	2,34	2,36	2,3	3,6	3,45
	Small units	/	/	1,56	1,68	1,65	/	/
Inlet valve diameter	Large units	1,45	1,45	1,25	1,25	1,25	1,85	1,7
	Small units	/	/	0,75	0,75	0,75	/	/
Generator apparent power	Large units	43,1 MVA	69,3 MVA	30,5 MVA	51,3 MVA	49,6 MVA	52,9 MVA	44,6 MVA
	Small units	/	/	10,5 MVA	17,7 MVA	17,1 MVA	/	/
Stator voltage	Large units	5,5 kV	10,5 kV	5,5 kV	10,5 kV	10,5 KV	10,5 kV	10,5kV
	Small units	/	/	5,5 kV	5,5 kV	5,5 kV	/	/

17.14. The potential power generation from each alternative hydropower plant option is summarised in Table 17.14.

Table 17.14(a): Energy Generated Annually by Alternative Hydropower Plants

Year	Energy Generated By Each Hydropower Plant (GWh)					
	01 LLDP	0.1 HLDP	220.1 LLDP	220.1 HLDP	PL LLDP	PL HLDP-1 & 2
2020	842	1,059	1,424	1,718	1,146	1,817
2030	739	1,021	1,260	1655	1,119	1,797
2040	550	967	919	1563	981	1766
2050	391	896	668	1,445	588	1,717
2060	134	764	231	1,237	240	1,642

Table 17.14(b): Net Energy Demand of the Alternative Project Configurations

Configuration	Power Balance in 2020			Power Balance in 2060		
	Generated	Consumed	Balance	Generated	Consumed	Balance
01 LLDP	842	2,229	-1,387	134	5,450	-5,316
01 HLDP	1,059	2,337	-1,278	764	5,645	-4,881
220 LLDP	1,424	3,612	-2,188	231	6,579	-6,348
220 HLDP	1,718	3,736	-2,018	1,237	6,718	-5,481
Pipeline LLDP	1,146	3,895	-2,749	240	7,061	-6,821
Pipeline HLDP	1,817	4,347	-2,530	1,642	7,782	-6,140

Note: The energy consumed and energy balance include energy required to pump potable water to Amman but do not include energy required to pump potable water to either Israel of Palestinian Authority.

18. RESTITUTION OF THE DEAD SEA

18.1. The economically preferred discharge to the Dead Sea would be via an open canal from the hydropower plant to the southern end of the northern basin of the Dead Sea. However, concerns have been raised that locating the discharge in this area could have serious adverse impacts on the operations and profitability of the chemical abstraction companies. An assessment has been made based on the one dimensional thermo-dynamic model described in Section 6 of the report combined with the results available to date from the Dead Sea Modelling Study. This suggests that if the project discharge point is located to the east of the Lisan peninsula such that the peninsula separates the project discharge from the chemical company intakes, and if the chemical companies lower their intakes to 50 m or more below the Dead Sea surface level then any impact to their operations will be minimal. This conclusion will need to be verified when the final results of the modelling and analysis undertaken in the Dead Sea Modelling Study.

18.2. Alternative alignments for the discharge canal from the Hydropower plant to the Dead Sea have been considered, both to the east and to the west of the chemical company evaporations ponds and also between the two sets of ponds. However, topography, geotechnical conditions and existing developments make both the eastern and western potential alignments impracticable. The recommended route for the discharge canal therefore follows an alignment northward from the hydropower plant to link up with the "Truce Canal" running along the national boundary between the Arab Potash Company and Dead Sea Works evaporation ponds, and thence eastwards across the neck of the Lisan Peninsula. This alignment is shown as the green line labelled Alternative 0 on Figure 18.2 below.

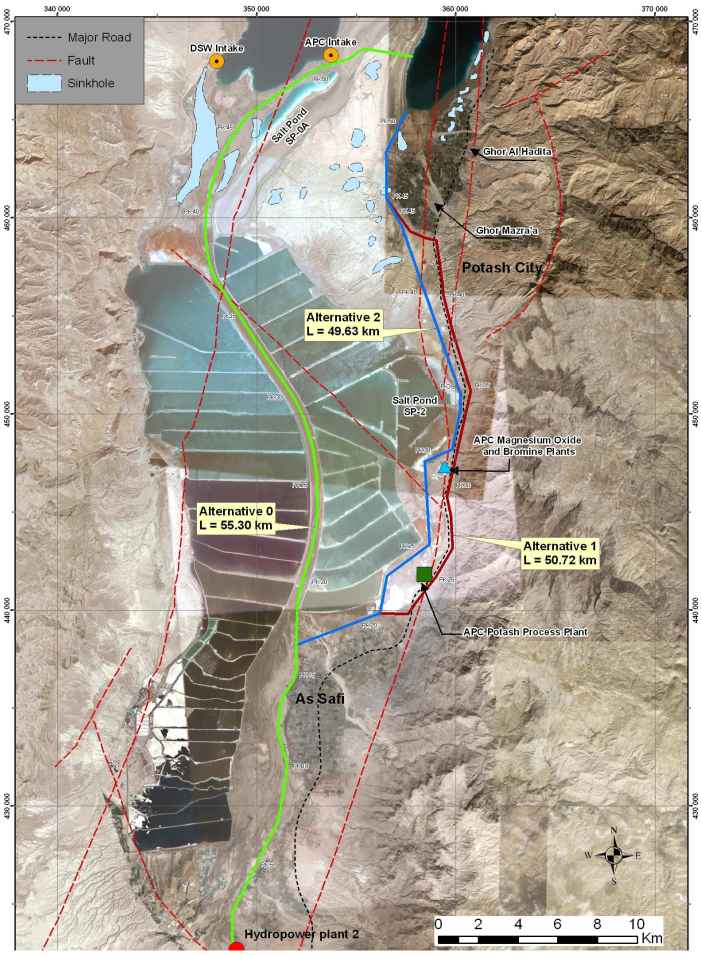


Figure 18.2: Alternative Alignments Considered for the Discharge Canal

18.3. It is recognised that concern has been expressed about the risk of this arrangement to the chemical industry embankments which also form the existing embankments of the Truce Canal. It is therefore proposed that the project discharge flow will be conveyed through a channel created by two lateral embankments built in the central part of the Truce Canal allowing the flow to be kept at a significant distance from the chemical companies' embankments as shown in Figure 18.3 below. Chemical company embankments will be raised such that the two outer channels have the capacity to carry an appropriate design flood flow.

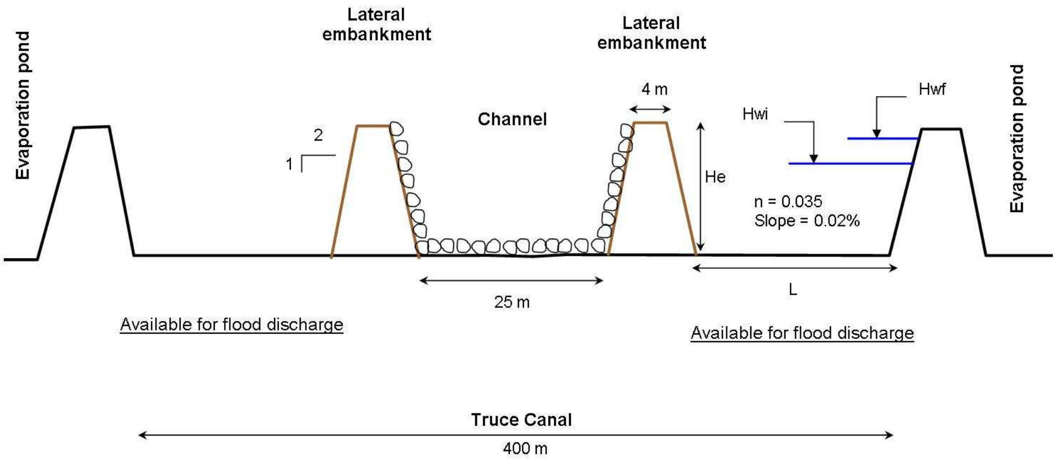


Figure 18.3 – General Arrangement of Discharge Channel Along the Truce Canal

18.4. Concerns have been expressed by the chemical companies regarding the recommended alignment for the discharge canal and so the two most promising alternative alignments have been re-evaluated in more detail. This re-evaluation confirms that neither is feasible for the following reasons:-

- An alignment between the Jordanian Dead Sea highway and the Arab Potash Company evaporation ponds would necessitate the modification of at least one existing evaporation pond to allow construction of the discharge canal. It would also pass through both the main potash processing plant site, the magnesium oxide and bromine plant site and the agricultural lands to the west of Ghor Mazra and Ghor Haditha. Furthermore, to allow gravity flow, the canal would have to be constructed in cuttings over 20 m deep at several locations and up to a maximum of 50 m deep very close to the township of Ghor Mazra. This alignment is shown as a blue line labelled Alternative 2 on Figure 18.2 above.
- An alignment east of the Jordanian Dead Sea Highway traverses higher ground. A discharge canal on this alignment would have to be constructed in an excavated cutting over 80 m deep in places for a length of some 30 km or would have to incorporate a tunnel some 30km long in extremely poor ground conditions to allow gravity flow; or alternatively it would have be a pressurised pumped conveyance. This alignment is shown as a red line labelled Alternative 1 on Figure 18.2 above.
- The alignment of both Alternatives 1 and 2 runs over a significant distance very close to major faults that have been identified or that are very likely to be present in this area.

18.5. The Dead Sea level is projected to fall to a level of -434 m by the year 2020 which is the earliest date at which a project could be commissioned. As demonstrated in Section 11.2 of this report, under the recommended flow conditions for the Base Case Plus, the Dead Sea would be stabilised at a level of around -416 m taking account of the most probable climate change projections, which is some 10 m above the current level at the end of 2011 and this level will be reached around the year 2054.

18.6. It should be noted that to stabilise the Dead Sea at any level other than -416 m, would require the ultimate capacity of the desalination plant to be reduced.

(1) In order to raise the target level of the Dead Sea above -416 m the long term discharge to the Dead Sea would have to be increased. This can only be achieved, without increasing the size and capacity of the conveyance system, by reducing the ultimate output of the desalination plant and allowing an increased flow of Red Sea water to by-pass the desalination plant and flow directly to the Dead Sea.

(2) In order to lower the target level of the Dead Sea below -416 m the long term discharge to the Dead Sea would have to be reduced. However, when the desalination plant is operating at full capacity the discharge to the Dead Sea is almost exclusively reject brine from the desalination process. Thus the only way to reduce the discharge to the Dead Sea would be to reduce the ultimate throughput of the desalination plant.

18.7. The general environmental degradation caused by the decline in Dead Sea level will progressively cease following commissioning of the project and in some cases will be partially reversed.

18.8. On the basis of the results and conclusions available to date from the modelling and Additional Studies of the Dead Sea it is concluded that:-

- A project discharge into the bay on the west side of the Lisan Peninsula would have the least impact on the chemical and tourist industries located on the Dead Sea.
- The project would result to a Dead Sea water mass reverting to a more stable layering in the Dead Sea with less frequent turnovers than at the present.
- The chemical composition of the main body of the Dead Sea water beneath a diluted upper layer of mixed Red Sea and Dead Sea water will remain largely unaffected by the project and will continue to gradually change as it has done over the last 50 years or so.
- The additional dilution of the upper layer caused by the project will be less than was the case when the full flow of the Jordan River entered the Dead Sea and the buoyancy experienced by bathers would be affected only marginally.
- The presence of phosphate in the mixed Red Sea and Dead Sea waters is necessary to sustain algae growth. The concentration of phosphate in the mixed waters might be higher than the current levels in the Dead Sea due to the chemicals used in the desalination process. However, according to the available results of the Dead Sea Modelling Study, phosphate is likely to co-precipitate with gypsum and as a consequence will not be available for the biological process. The mixing of Red Sea and Dead Sea waters is therefore not expected to increase algae growth but this needs to be confirmed.
- Without the production and ultimate decay of large quantities of algae there will be no increase in the production of hydrogen sulphide.
- Mixing of Red Sea water in the Dead Sea will lead to the precipitation of gypsum but in what quantity and how this will be manifested is still under discussion. However, it may be possible to mitigate the impact by seeding the discharge water and discharging it to a confined settlement lagoon before discharge to the main body of the Dead Sea, the lagoon acting as a settlement pond to minimise the discharge of gypsum to the main body of the Dead Sea.

19. POTABLE WATER TRANSMISSION - JORDAN

19.1. Potable water will be delivered to Abo Alanda on the southern outskirts of Amman. The transmission main from the desalination plant to Amman must traverse the rugged mountainous terrain of the eastern escarpment of the rift valley before reaching the highland plateau to the south of Amman. Three possible alignments have been identified and evaluated. Alternative Alt-2, although the shortest of the three alternatives, has been eliminated due to relatively more difficult terrain and adverse geological and geotechnical conditions. A full evaluation and comparison has been carried out for of Alt-1 and Alt-3. It has been determined that Alt-1 would be preferable on purely technical grounds but the cost and economic analysis demonstrates that, after making appropriate cost provisions for the less favourable conditions of Alt-3, both the capital cost and the full life cycle net present cost of this alternative are significantly better than those for Alt-1. Therefore Alt 3 as described below is recommended.

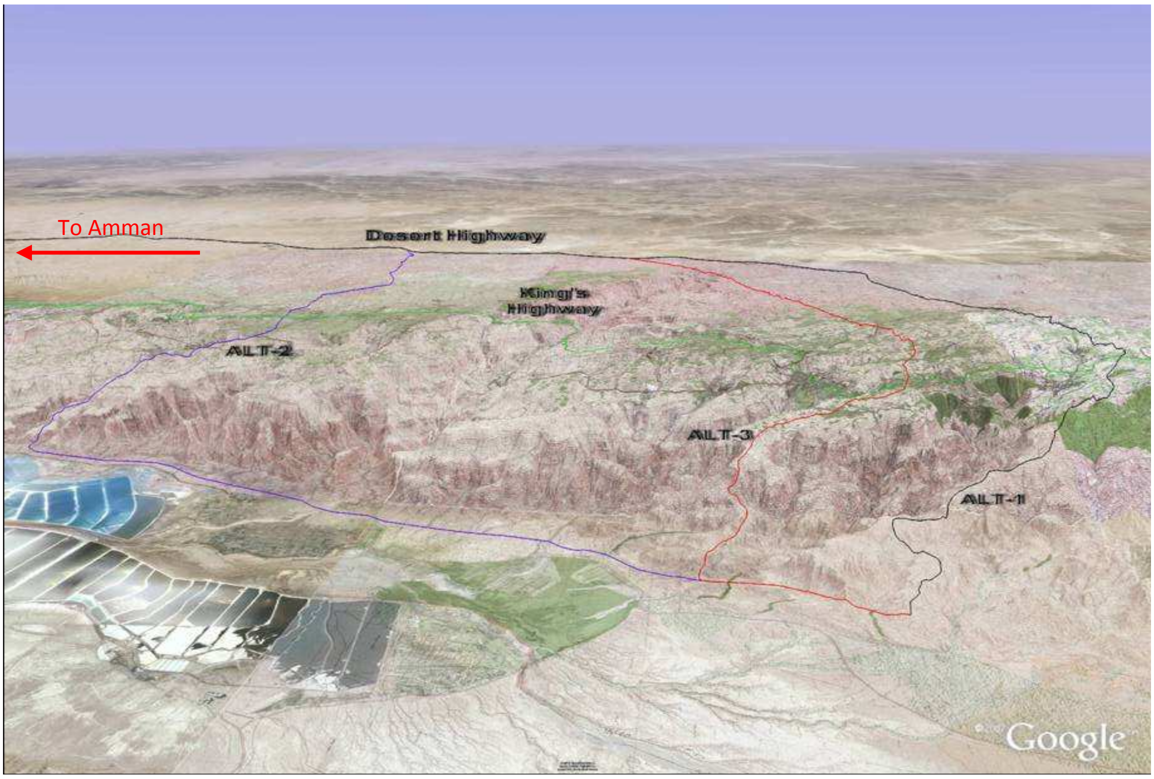


Figure 19.1: Alternative Alignments for the Potable Water Transmission System to Jordan

19.2. The main characteristics of the recommended Alt-3 configuration are summarized as follows:-

- The alignment is approximately 200 km long. It initially runs northwards within the Wadi Araba/Arava Valey from the desalination plant to a point close to Fifa village. At Fifa it turns eastward climbing the escarpment for some 21 km before skirting around the western and southern outskirts of Tafileh. From Tafileh the alignment continues eastwards for a further 40 km crossing Wadi Hasa to the west of Hisa village. After crossing Wadi Hasa the alignment turns northeast for a further 10 km, crossing the railway and the Desert Highway. After crossing the desert highway the alignment turns northwards and runs approximately parallel to, and eastward of, the highway all the way to the terminal point at Abo Alanda to the south of Amman.
- The pumped riser main will comprise four pumping stages with a static head of 1,478 m and a total pumping head varying between 1,561 m and 1,629 m over the life of the project. The pipeline will consist of twin pipes varying in diameter from

2010 mm to 2024 mm with a total length of 34 km. The pipeline will be constructed in two stages with the second stage required to meet demand in 2030.

- Pump units will be of the horizontal, split volute, single stage type. Each pump will have a capacity of 9,132 m^3/hr. On commissioning each pump station will comprise four duty and one standby pumps. An additional pump will be added approximately every ten years to keep pace with growth in potable water demand. The ultimate design comprises seven duty and one standby pump to satisfy a maximum demand of 560 million m^3/year. Total installed power will be 187 MW at commissioning and 334 MW at full capacity. Energy demand on commissioning will be 1,216 GWh/yr and at maximum capacity will be 2,925 GWh/year.
- The Gravity Main will commence from a balancing tank at the high point in the alignment and will incorporate a small intermediate regulating tank. The pipeline will comprise twin pipelines 144 km long. Pipe diameter from the balancing tank to the intermediate regulating tank will be 1520 mm and downstream of the intermediate regulating tank will be 2,270 mm.

20. POTABLE WATER TRANSMISSION – ISRAEL

20.1. An outline concept for a potable water transmission pipeline with a capacity of 60 million m^3/year to the northern Arava and Dead Sea Basin area of Israel has been included in the Options Screening and Evaluation report, and later in the Draft Report on Sub-Studies B and D. Following issue of the Draft Report on Sub-Studies B and D it has been advised that this concept does not reflect the Israeli requirements and that Israel does not wish the Consultant to evaluate appropriate flows and demand centres or to study a potential potable water supply system to deliver water to Israel.

21. POTABLE WATER TRANSMISSION – PALESTINIAN AUTHORITY

21.1. An outline concept for a potable water transmission pipeline to supply 30 million m^3/year of potable water to Jericho and surrounding areas has been included in the Options Screening and Evaluation report, and later in the Draft Report on Sub-Studies B and D. It has subsequently been agreed that 60 million m^3/year will be allocated to the Palestinian Authority for the purposes of determining the feasibility of the project. It is also noted that the final allocation of water from the project will be subject to further negotiation and agreement between the Beneficiary Parties if a decision is taken to implement the project. However no indication has been provided as to what demand centres within the Palestinian Authority will be provided with water. It is already clear that it will be significantly cheaper to supply Gaza with desalinated Mediterranean water than from the Red Sea Dead Sea project, particularly given both the close proximity of Gaza to the existing desalination Israeli Ashkalon desalination plant and the very recent announcement that approval has been granted for the implementation of a Palestinian desalination plant in Gaza.

22. POWER SUPPLY AND TRANSMISSION

22.1. Based on the preliminary designs developed for the six potential project configurations the maximum net energy demands (i.e. power and energy consumed less power and energy generated at the hydropower plant) in 2020 and 2060 have been assessed as set out in Table 22.1 below.

Table 22.1: Max. Project Net Power Demands (Consumption less Hydropower Generated)

	2020		2060	
Red Sea Area	230 MWe	1900 GWh	230 MWe	1900 GWh
Dead Sea Area	220 MWe	1350 GWh	650 MWe	6,000 GWh

22.2. Potentially the project could purchase the required power from the national grid in Jordan or standalone dedicated power plant(s) could be included in the overall project infrastructure. Since the core expertise of the entity that will operate the project will be in water supply and not power generation and since, as is demonstrated below, the planning for the Jordanian national grid can accommodate the requirements of the project, it is concluded that it would be preferable to purchase power from the national grid.

22.3. Recent annual power generation in Jordan including imported power is shown in Table 22.3 below. It should be noted that for the year 2008 the capacity factor (total electricity produced relative to the total possible amount of electricity that could have been produced over the same period) amounts to 65.6% (NEPCO 2008).

Table 22.3: Annual Power Generation in Jordan (including imports)

	2005	2006	2007	2008	Averaged Growth
Generated energy (GWh)	10,636	11,634	13,209	14,385	10.6%
Maximum Peak Load (Mwe)	1,751	1,901	2,160	2,260	8.9%

22.4. The installed power generation capacity in Jordan in 2010 is 2,505 MW and this is supplemented by connection to neighbouring country grids with a capacity to import a further 770 MW. Future expansion is provided for by definitive short term plans and speculative longer term plans up to 2037. The proposed new capacity from these two plans combined is summarised in Figure 22.4 below.

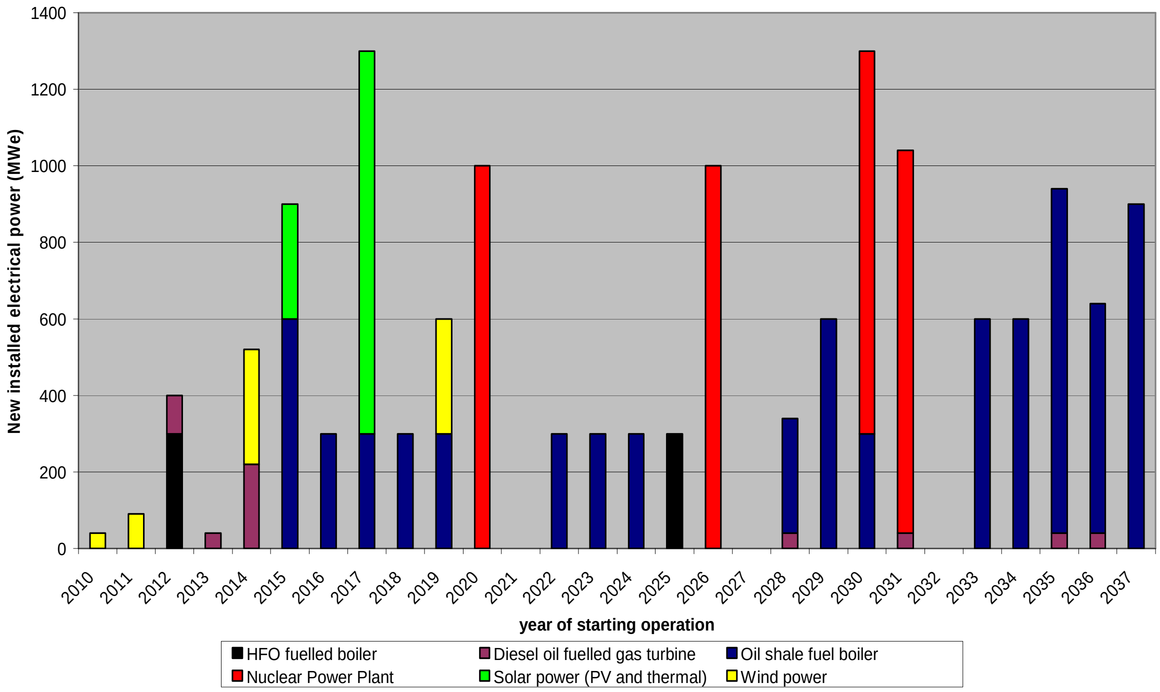


Figure 22.4: Planned Increments of Power Generation Capacity in Jordan

22.5. The projected future power demands in Jordan published by NEPCO together with the potential project net demands are shown in Figure 22.5 below.

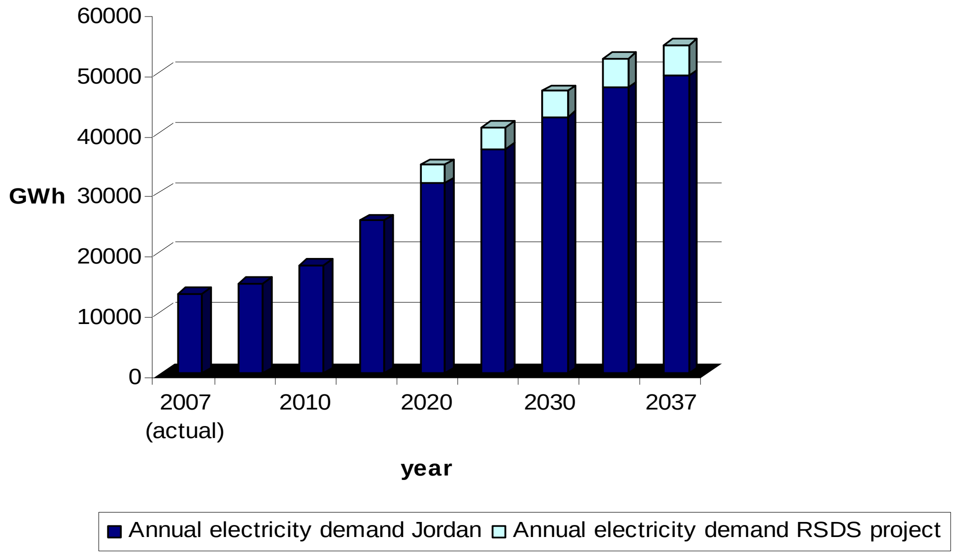


Figure 22.5: Projected Power demands in Jordan for 2010 to 2037

22.6. From the above projections it is clear that all the generation expansion plans must be realized to fulfil the future demand for electricity in Jordan. For instance the total installed capacity will be 3,666 MWe at the end of 2013 and the expected annual electricity demand in 2014 will be 24807 GWh, which gives a capacity factor of 77% in 2014. However, if these plans are achieved the potential power demands of the project in 2020 will be met. Future planning will need to take account of the longer term growth in demand from the project.

22.7. A review of the national grid infrastructure in Jordan shows that the most appropriate connections to the grid will be via new 400/132 kV sub-stations located at south of

Aqaba connected to the intake pump station by a new 132 kV transmission line, and by a new 400kV transmission line connection from the existing sub-station at Qatraneh to the desalination plant and the potable water supply pump stations in Jordan. This later connection will also be used to export hydropower to the national grid. Schematics of the two connections are shown in Figures 22.7a and 22.7b below.

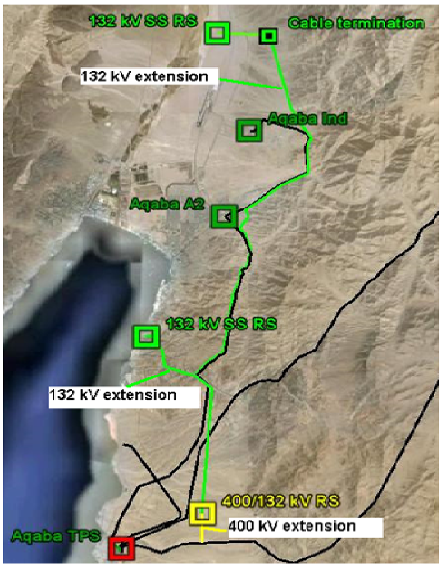


Figure 22.7a: Connection to the Power Grid South of Aqaba

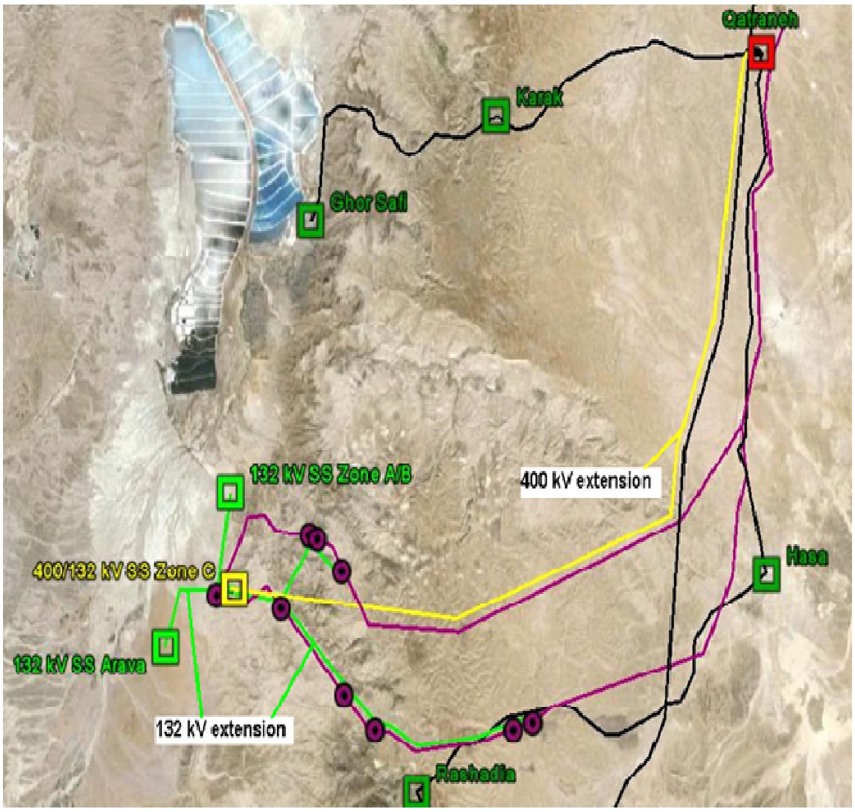


Figure 22.7b: Connection to the Power Grid at the Dead Sea

22.8. The region has substantial capacity for renewable wind and solar energy and the potential to meet the project power demands entirely from renewable sources such as wind and solar power has been reviewed. However, given the continuous 24/7 power requirements of the project it is necessary to have conventional back up power available. The long term national power development program in Jordan includes substantial new renewable generating capacity and the power purchase agreements negotiated, if the project proceeds, can be structured to promote this in order to mitigate the carbon footprint of the project.

22.9. The respective carbon footprints of the six project configurations considered have been evaluated based on the amount of renewable energy generated within the project and the amount of energy imported from the Jordanian national grid for each alternative. The carbon footprint of imported energy is based on the ratios of different generation types indicated in the NEPCO generation plan.

	CO2 Emission (thousands of tons)					
Year	0-1 HLDP	0-1 LLDP	220-1 HLDP	220-1 LLDP	PL HLDP	PL LLDP
2020	650	706	1027	1114	1288	1399
2030	1 078	1 194	1 471	1 668	1 784	1 877
2040	1 695	1 866	2 123	2 426	2 498	2 675
2050	2 328	2 533	2 730	3 097	3 141	3 338
2060	3 115	3 392	3 497	4 050	3 917	4 352

	Value of CO2 Emission (millions USD)					
	0-1 HLDP	0-1 LLDP	220-1 HLDP	220-1 LLDP	PL HLDP	PL LLDP
2020	11	12	17	19	22	24
2030	18	20	25	28	30	32
2040	29	32	36	41	42	45
2050	40	43	46	53	53	57
2060	53	58	59	69	67	74

Values are worked out assuming 17 USD per ton

Table 22.9 – Carbon Footprint of Alternative Configurations

23. ENVIRONMENTAL AND SOCIAL BASELINE AND IMPACTS

23.1. This section of the report addresses the onshore environmental and social baseline and potential impacts of the project. The environmental baseline and potential impacts on the Red Sea have been considered earlier in Sections 4 and 12 and those of the Dead Sea in Sections 5 and 18 of this report.

23.2. Dedicated social and environmental surveys have been carried out under the Feasibility Study throughout the region to assess the current conditions and to evaluate potential impacts. The assessment also draws on feedback from the ongoing public consultation and communications process. This work is being supplemented by a more detailed Environmental and Social Assessment being carried out by others under a separate contract with the World Bank.

23.3. Impacts on the physical environment relate particularly to the following receptors: soils affected by construction activities (excavations, erosion phenomena, pollution, waste disposal), groundwater located nearby the scheme (potential risks of pollution), air quality (affected by construction activities and dust emissions), wadis (disruption of), visual and landscape. Most of the concerns related to soils, water and air quality can be addressed by best practice construction-phase mitigation methods.

23.4. The key onshore biological issues include flora, terrestrial fauna, avi-fauna (resident and migrant), protected areas and connectivity of habitats during the construction and operation phases. Receptors of significance relate particularly, but not exclusively, to the following areas in Jordan: the existing biosphere reserve of Dana and the existing Important Bird Areas (IBAs); the proposed protected areas of Qatar, Rahma, Masuda and Fifa, including the associated Special Conservation Areas (SCAs); other areas identified in the ecological survey with special importance with respect to habitat, animals, or birds migration.

23.5. The main impacts on the biophysical environment occur during the construction phase. Furthermore as there will be no infrastructure except freshwater transmission lines in Israel and in the Palestinian Authority, the direct impacts occur mainly in Jordan.

23.6. All project configurations considered potentially have some moderate (or higher) impacts on flora, birds, protected areas and connectivity during construction. The main impacts are highly site-specific, with the wadi 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. During operation, the only serious concerns are (i) the impact of leakage from the conveyance on the groundwater resources, and (ii) the potential ecological trap (restricting movement of mammals and attracting birds) from the canals in the high level tunnel option. Points of particular note with respect to the potential impacts on protected areas are:-

- In the case of all conveyance alignments considered, the hydropower plant (a short section of the penstocks) and the potential low level desalination plant are all located within the boundaries of the proposed Fifa reserve. This reserve has been proposed to preserve a sample of natural Tamarisk tree habitat. Discussions with the Royal Society for Conservation of Nature in Jordan have indicated that the boundaries can be adjusted to maintain the planned area of preservation with a suitable buffer zone.
- In the case of both the low level tunnel and the high level tunnel and canal alignments, there will be no construction activities or permanent works within established or proposed protected areas except for the proposed Fifa reserve as noted above. Tunnelling will take placed deep below a number of reserves but the depth of the tunnel and the nature of the rock is such that there should be no perceptible impacts (vibration, noise, subsidence etc) at the surface. However it should be noted that there would be a temporary construction site located very close to the boundary of the established Dana Reserve and the potential high level desalination plant would be a large permanent facility within 3 km of the boundary of the Dana Reserve. Potential visual intrusion is being addressed in the Environmental and Social Assessment Study undertaken by others.
- The pipeline conveyance alignment passes through a number of important bird areas. The main significance of these important bird areas is the passage of migratory birds in transit between Europe and Africa. Impacts will be limited to the construction period and no long term effects are foreseen. This conveyance alignment also passes through the Qatar salt flats which is a proposed protected area. Discussion with the Jordanian Royal Society for the Conservation of Nature has identified that the sensitivity of this location is around the margins and that the proposed alignment through the middle will have least impact, provided construction methods do not significantly impact the water table level.

23.7. 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 / relations; cultural heritage. The potential socio-economic impacts of moderate and major significance in Jordan are listed below:

- Land will be acquired for the conveyance. Land acquisition may affect a small number of individual buildings/assets directly, or could affect the access of communities to certain areas; both could be significant impacts to the communities or individuals affected.
- Cumulative nuisance impacts from pipeline or tunnel or freshwater line construction could negatively impact communities at certain locations (e.g. located near to intense construction activities, such as tunnel entrances). These include traffic safety impacts to communities (increased risk for road accidents), potential for inappropriate disposal of general and hazardous waste (additional burdening of the waste facilities in the area could result in an impact of moderate significance), potential overloading of existing social services (the establishment of workers camps will require social infrastructure which might put pressure on the already poor infrastructure of these areas).
- Cumulative impacts to existing infrastructure/ resources with other projects being constructed concurrently: during the construction phase of the project, several other major construction projects are expected to be underway, which could result in cumulative increases in the use of roads and the port for imported materials, etc.
- 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 both the importance of tourism in the Dead Sea region and the sensitivity of the communities/industry that rely on it, and also given its regional profile.
- 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.

23.8. The potential socio-economic impacts of moderate and major significance in Israel are listed below:

- Visual impacts at Masada: there will be some visual impacts during the freshwater pipeline construction, depending of the exact routing. Given Masada's importance as a tourist destination in Israel, coordination should be considered so as to minimize any possible effect on the quality of the site.
- Lack of community support could be used by various opponents of the project to create significant opposition at the decision making or planning approvals 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.
- Leakage of saltwater from the conveyance into groundwater supplies (especially the pipeline conveyance option, given its situation within a potentially active fault area) could cause deterioration in well water quality, and this is an issue of concern for communities. In this respect, 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.

23.9. The potential socio-economic impacts of moderate and major significance in the Palestinian Authority are listed below:

- Land acquisition, affecting agricultural activity: installation of the freshwater conveyance may traverse farm lands that are adjacent to road 90 at the entrances of Jericho city. This would affect landowners/farmers that use the land.
- Effects to the following sectors: agriculture, industry and tourism. The nature of the potential impact in these areas also depends on the chosen pathway of the freshwater line; surrounding Jericho city and Aqbet Jaber Camp, there are areas of agriculture as well as some storage, wholesale and retail trading, and industrial buildings in this area.

23.10. 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. (In the case of the impacts to the Dead Sea this remains to be confirmed at discharges greater than 400 million m3 /year regarding the issue of red algae blooms.) A comparison of the project infrastructure options considered purely on the basis of a relative assessment of environmental and social impacts is summarised in Table 23.10 below.

Table 23.10: Summary Comparison of Relative Environmental and Social Preferences for the Project Configurations Options Considered

Project Element	Environmental Preference	Socio-Economic Preference
Intake	Eastern location	Eastern location
Conveyance	Low level tunnel or pipeline	Low level tunnel or pipeline
Desalination Plant	High level tunnel and canal	No significant difference
Potable Water Transmission to Jordan	All options have similar impacts	Option 3 (Tafila route)

24. COSTS AND NET PRESENT VALUE CALCULATIONS

24.1. A set of unit costs for construction works has been developed by identifying costs from other projects of a similar scale located in remote arid regions. All costs have been normalised to $US at December 2009 prices by appropriate application of published exchange rates and price indexes. This has been supplemented by detailed discussions with specialist contractors who have provided budget estimates for works such as tunnel excavation and lining, pipe supply and pipeline construction.

24.2. The construction unit costs have been applied to quantities derived from the designs to provide capital costs for each of the six project configurations under consideration. The capital costs thus derived are shown in Table 24.2 below (it should be noted that at this stage the costs are presented for comparative purposes and do not include all the costs of connections to the national grid, project management costs or institutional establishment costs which are essentially similar for all options considered):-

Table 24.2: CAPEX Costs (Dec. 2009 Prices) for Six Project Configurations (US $ million)

	Alternative 0.1 with HLDP	Alternative 0.1 with LLDP	Alternative 220.1 with HLDP	Alternative 220.1 with LLDP	Pipeline option with HLDP	Pipeline option with LLDP
Intake works	23,00	23,00	23,00	23,00	23,00	23,00
Pumping station	/	/	247,41	247,41	294,94	294,94
Main water conveyance	5 330,38	5 380,62	5 131,21	5 222,18	4 689,98	5 235,36
Tunnel	*5 223,32*	*5 223,32*	*4 325,94*	*4 325,94*	1 886,55	1 886,55
Canal	/	/	*578,34*	*578,34*	/	/
Steel pipes	*107,07*	*157,31*	*226,93*	*317,91*	*2 803,44*	*3 348,81*
Desalination facilities	2 562,84	2 499,13	2 722,35	2 579,71	2 436,85	2 434,49
Hydropower plants	136,09	111,37	144,45	128,54	241,38	124,82
Restitution canal	266,93	266,93	266,93	266,93	266,93	266,93
Sub-total	***8 319,24***	***8 281,05***	***8 535,35***	***8 467,77***	***7 953,09***	***8 379,55***
Water transmission line to Amman	1 904,48	1 894,13	1 872,28	1 894,13	2 015,74	1 894,13
Total	**10 223,72**	**10 175,18**	**10 407,63**	**10 361,90**	**9 968,83**	**10 273,68**

24.3. The total net present cost has been developed for each of the six alternative configurations considered on the following basis:-

- Initial construction is completed over a six year period from 2014 to 2020.
- Project operations commence in 2020.
- The installation of the desalination plant and the potable water transmission pipeline to Amman are phased to match the growth in potable water demands as set out in Sections 13 and 16.
- The net present cost includes net energy costs for 50 years from 2020 to 2070.
- Energy costs are based on net energy demands (i.e. total energy consumed less energy generated).
- Energy cost is $US 60.00 per MWh (a sensitivity analysis has also been carried out using costs of $ 45 and $ 75).
- Other operating costs have not been included in the net present cost as these are relatively small and are very similar for all six configurations.
- Rehabilitation of electrical and mechanical equipment equivalent to 80% of the initial installed cost after 30 years.
- The discount rate used is 10% (a sensitivity analysis has also been carried out using a discount rate of 5%).

24.4. The total net present costs determined on the basis outlined above are set out in Table 24.4 below.

Table 24.4: Total Net Present Costs for the Six Configurations Considered

	Alternative 0.1 with HLDP	Alternative 0.1 with LLDP	Alternative 220.1 with HLDP	Alternative 220.1 with LLDP	Pipeline option with HLDP	Pipeline option with LLDP
TNPC for an energy value of 60 USD/MWh	13 416,80	13 498,37	14 064,37	14 256,35	13 808,52	14 448,59
TNPC for an energy value of 75 USD/MWh	13 739,43	13 852,00	14 502,23	14 747,36	14 337,07	15 011,74
TNPC for an energy value of 45 USD/MWh	13 094,18	13 144,74	13 626,50	13 765,34	13 279,97	13 885,45

Notes:-The net present costs presented here are for comparative purposes only and do not include any operating and maintenance costs except for energy cost. The other operations and maintenance costs are essentially similar for all project configurations considered.

24.5. The full cost of a project based on the pipeline conveyance combined with a high level desalination plant which is the recommended solution as demonstrated in Section 25 below is set out in Table 24.5 below. In this table:

- The cost of the pumping station does not include the cost of the connection to the transmission grid (this connection cost is included in the figures presented for the pumping station in the table 24.2).
- The costs correspond to the project with its full ultimate capacity installed.
- Operation and maintenance costs include energy costs, staff costs, maintenance costs and any other cost necessary for the operation of the project.

Table 24.5: Full Cost of the Pipeline with High Level Desalination Plant Configuration

Cost items	CAPEX (MUSD)	Annual Operation and Maintenance costs (MUSD)					Average annual renewal costs (MUSD)
		2020	2030	2040	2050	2060	
Intake works	23,00	/	/	/	/	/	/
Pumping station	230,94	/	/	/	/	/	1,51
Main water conveyance (tunnel and steel pipes)	4 689,98	132,91	132,91	132,91	132,91	132,91	1,04
Desalination facilities	2 436,85	120,11	146,66	180,72	223,08	277,91	19,27
Hydropower plants	241,38	6,23	6,23	6,23	6,23	6,23	2,21
Restitution canal	266,93	/	/	/	/	/	/
Connection to the transmission grid	265,56	5,31	5,31	5,31	5,31	5,31	0,80
Project Management	244,64	/	/	/	/	/	/
Institutional Structure	7,8	17,595	17,595	17,595	17,595	17,595	/
Sub-total	8 407,09	282,16	308,71	342,77	385,13	439,96	24,81
Water transmission line to Amman	2 015,74	84,43	106,68	127,67	159,82	192,29	3,49
Connection to the transmission grid	131,44	2,63	2,63	2,63	2,63	2,63	0,39
Project Management	64,42	/	/	/	/	/	/
Sub-total WTL to Amman	2 211,60	87,06	109,31	130,30	162,45	194,92	3,88
Total	**10 618,69**	**369,22**	**418,02**	**473,07**	**547,58**	**634,88**	**28,70**

Note: A provision of 500 to 750 millions US Dollars should be added to the CAPEX provided in the above table to cover the construction costs of the water transmission line to Israel and to the Palestinian Authority

25. PROJECT INTEGRATION

25.1. Up to this point in the report the range of options available for each component of the potential project infrastructure have been evaluated in isolation. When put together six potentially viable integrated project configurations are identified as set out in Table 25.1 below.

Table 25.1: Summary of the Preferred Technically Viable Project Configurations

(Note: Project components that vary across the options considered are shaded in pink. The components not shaded are constant across all six configurations considered).

Element	00.1 + HLDP	00.1 + LLDP	220.1 + HLDP	220.1 + LLDP	Pipeline+HLDP	Pipeline+LLDP
Red Sea water transfer	2,000 m^3/year	2,000 m^3/year	2,000 m^3/year	2,000 m^3/year	2,000 m^3/year	2,000 m^3/year
Initial desal. Output (2020)	350 million m^3/year	350 million m^3/year	350 million m^3/year	350 million m^3/year	350 million m^3/year	350 million m^3/year
Ultimate desal. Output (2060)	850 million m^3/year	850 million m^3/year	850 million m^3/year	850 million m^3/year	850 million m^3/year	850 million m^3/year
Intake	Submerged intake. Eastern location.	Submerged intake. Eastern location.	Submerged intake. Eastern location.	Submerged intake. Eastern location.	Submerged intake. Eastern location.	Submerged intake. Eastern location.
Pump Station & pumping energy required	No pump station	No pump station	190 MW pump station at eastern intake. 1,628 GWh/year	190 MW pump station at eastern intake. 1,628 GWh/year	229 MW pump station at eastern intake. 1,920 GWh/year	229 MW pump station at eastern intake. 1,920 GWh/year
Conveyance	Low level gravity flow tunnel	Low level gravity flow tunnel	High level pumped tunnel and canal	High level pumped tunnel and canal	Pipeline conveyance	Pipeline conveyance
Desalination configuration	SWRO. High level	SWRO. Low level	SWRO. High level	SWRO. Low level	SWRO. High level	SWRO. Low level
Hydropower Plant	One plant near FifaVillage	One plant near FifaVillage	One plant near FifaVillage	One plant near FifaVillage	Two plants: one at RO plant, one near Fifa village	One plant near FifaVillage
Hydropower generated in 2020	1,059 GWh/year	842 GWh/year	1,718 GWh/year	1,424 GWh/year	1,817 GWh/year	1,146 GWh/year
Hydropower generated in 2060	764GWh/year	134GWh/year	1,237GWh/year	231GWh/year	1,642GWh/year	240GWh/year
Discharge works	Open channel at surface level into the bay to the east of Lisan Peninsula.	Open channel at surface level into the bay to the east of Lisan Peninsula.	Open channel at surface level into the bay to the east of Lisan Peninsula.	Open channel at surface level into the bay to the east of Lisan Peninsula.	Open channel at surface level into the bay to the east of Lisan Peninsula.	Open channel at surface level into the bay to the east of Lisan Peninsula.
Discharge flow to Dead Sea in 2020	1,650 million m^3/year	1,650 million m^3/year	1,650 million m^3/year	1,650 million m^3/year	1,650 million m^3/year	1,650 million m^3/year
Discharge flow to Dead Sea in 2060	1,150 million m^3/year	1,150 million m^3/year	1,150 million m^3/year	1,150 million m^3/year	1,150 million m^3/year	1,150 million m^3/year
Restitution of Dead Sea	Target Level: – 416m Target Year: c. 2054	Target Level: – 416m Target Year: c. 2054	Target Level: – 416m Target Year: c. 2054	Target Level: – 416m Target Year: c. 2054	Target Level: – 416m Target Year: c. 2054	Target Level: – 416m Target Year: c. 2054
Potable water supply to Jordan	Alternative route 3 via Tafileh	Alternative route 3 via Tafileh	Alternative route 3 via Tafileh	Alternative route 3 via Tafileh	Alternative route 3 via Tafileh	Alternative route 3 via Tafileh
Potable water supply to Israel	60 million m^3/year to mid and southern Arava	60 million m^3/year to mid and southern Arava	60 million m^3/year to mid and southern Arava	60 million m^3/year to mid and southern Arava	60 million m^3/year to mid and southern Arava	60 million m^3/year to mid and southern Arava
Potable water supply to Palestinian Authority	60 million m^3/year. Location still to be determined.	60 million m^3/year. Location still to be determined.	60 million m^3/year. Location still to be determined.	60 million m^3/year. Location still to be determined.	60 million m^3/year. Location still to be determined.	60 million m^3/year. Location still to be determined.
** Net energy balance of system in 2020	-1,278 GWh/year	-1,387 GWh/year	-2,018 GWh/year	-2,188 GWh/year	-2,530 GWh/year	-2,749 GWh/year
** Net energy balance of system in 2060	-4,881 GWh/year	-5,316 GWh/year	-5,481 GWh/year	-6,348 GWh/year	-6,140 GWh/year	-6,821 GWh/year

** Includes energy requirements for the potable water transmission system to Amman but does not include energy to pump potable water to Israel or the Palestinian Authority.

25.2. It can be seen from the earlier Tables 24.2 and 24.4 that the ranges of both capital and net present costs across the six options are small and that all costs fall within the limits of accuracy of the current cost estimating process based on preliminary designs. The comparative costs in percentage terms for each option are set out in Table 25.2 below.

Table 25.2: Relative Costs of Technically Viable Configurations

Configuration	Capital Cost	Whole Life Cycle Net Present Cost
00.1 - Low level gravity flow tunnel with high level desalination plant.	+2.6%	0
00.1 - Low level gravity flow tunnel with low level desalination plant.	+2.1%	+0.6%
220.1 High level Pumped tunnel and canal with high level desalination plant.	+4.4%	+4.8%
220.1 High level Pumped tunnel and canal with low level desalination plant.	+3.9%	+6.3%
Pipeline conveyance with high level desalination plant.	0	+2.9%
Pipeline conveyance with low level desalination plant.	+3.1%	+7.7%

25.3. It is thus clear that cost may not be the dominant criteria in determining the optimum system configuration and other factors need to be included in the evaluation. A qualitative assessment of these other factors is set out in Table 25.3 below.

Table 25.3: Qualitative Assessment of Technically Viable Configurations

Criteria	Comparison
Environmental and Social Impacts	1) The impacts at the eastern intake will be less than for the northern intake on the basis of visual intrusion, surrounding land use and the location of an important bird observatory close to the northern intake. 2) The impact at tunnel portals will be high because of their location in confined and sensitive sites at the mouths of side wadis. However the impacts will only occur at small localised sites at intervals along the conveyance alignment. Impacts along the pipeline route will be lower than at the tunnel portals but will be experienced over a much wider area. The impacts along the canal sections will be greater than either tunnels or pipelines, mainly due to the long term barrier effect. 3) The low level desalination plant is located in a sensitive area and the impacts here will be greater than for the high level desalination plant. 4) The impacts along alignment 3 for the potable water transmission pipeline to Amman are assessed to be less than for alignment 1 or 2.
Potential for phased development of the sea water conveyance system	The pipeline conveyance configurations can readily be developed in phases. The tunnel and canal conveyance configurations cannot practicably be developed in phases.
Duration of construction	The nominal construction period for all options is six years.
Simplicity of operations and control systems.	The gravity pipeline with no pump station will be the simplest system to operate. The high level tunnel and canal system with pump station will require the most complex control system. The operation of the pipeline conveyance will lie somewhere between these other two.
System reliability	The tunnel and the tunnel/canal conveyance systems will be a single conduit and if any faults or problems occur, or if the system has to be taken out of service for maintenance, the entire system will have to be closed. Conversely the pipeline conveyance will be a series of parallel pipelines with cross connections such that the system can remain in operation at or near to full capacity if a fault develops in a single pipeline and can be shut down one pipeline at a time for planned maintenance. On the other hand, the absence of pumping station in the conveyance alternative 0.1 increases the reliability of the conveyance system.
Vulnerability to malicious acts	The pipeline being readily accessible over its entire length and being close to the ground surface is particularly vulnerable to malicious acts. The low level tunnel will be deep below the surface and not readily accessible and so will be much less vulnerable in this respect. The tunnel canal conveyance will lie somewhere between these two extremes.

25.4. The key risks inherent in each potential system configuration have similarly been assessed and a qualitative assessment is set out in Table 25.4 below.

Table 25.4: Qualitative Assessment of Risks

Risk	Comparison
Small long term insidious leakage of sea water	Pipelines are prone to this type of leakage which can continue undetected for many years. This risk also exists with tunnels except when below the water table and subject to high external water pressure. However, the design of protective measures described in the report means that the mitigated risk is similar and very low for all configurations
Sudden catastrophic leakage of sea water	The most likely cause of such a failure is as a result of seismic activity. Tunnels in hard rock are recognised as one of the man-made structures least prone to seismic failure. Furthermore where the tunnel is below the water table the possibility of leakage in such an event is much lower and 80% of the low level gravity flow tunnel is below the water table.
Over-run of construction schedule	Due to the inherent uncertainty of ground conditions, excavation rates and construction durations for tunnels are much less certain than for pipelines.
Over-run of construction costs	Due to the inherent uncertainty of ground conditions, cost over-runs and cost claims during construction are much more likely for tunnels than they are for pipelines.
Reliability of potable water supply	The main difference in the configurations in this respect is that in the event of a prolonged shut down in the hydropower plant the high level desalination plant would also have to be shut down. This would not be the case for the low level desalination plant.

25.5. Finally a weighted multi-criteria scoring system has been adopted to determine the recommended optimum project configuration based on an integrated evaluation of capital cost, whole lifecycle costs, technical and environmental merits and risks. This evaluation is summarised in Table 25.5 on the next page. It has to be acknowledged that this process depends on a subjective allocation of scores and weightings and could potentially be manipulated. The scoring and weighting presented in Table 25.5 represent the collective consensus of the Consultant’s study management team.

25.6. It can be seen that based on the proposed weighted multi-criteria scoring system the optimum system configuration is the pipeline conveyance combined with a high level desalination plant. This configuration has the lowest total capital cost but it does not have the lowest whole life cycle net present costs.

25.7. It should also be noted that in this evaluation the potential for phased development has been weighted as an essential criteria. If this criteria were weighted as being of minor significance then the total score of the low level conveyance system combined with a high level desalination plant which has the lowest whole life cycle net present costs would be very similar to the total score of the pipeline option combined with the high level desalination plant.

25.8. As noted previously, a potential opportunity has been identified that could reduce the capital cost of the pipeline by some $500 million but this can only be verified through a detailed geotechnical site investigation program at the next phase of development. If this potential saving were to materialise the pipeline conveyance solution would not only represent the lowest capital cost by a significant margin but would also represent the lowest whole lifecycle discounted net present cost solution. In this case the pipeline solution would also emerge as the clearly preferred option in the weighted multi-criteria scoring system regardless of the weighting given to the flexibility for phasing.

Table 25.5: Multi-Criteria Comparison of Technically Viable Options

Project configuration		0.1 with HLDP		0.1 with LLDP		220.1 with HLDP		220.1 with LLDP		Pipeline with HLDP		Pipeline with LLDP	
Evaluation criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
1. Performance criteria													
1.1 Investment cost	3	5	15	5	15	4	12	4	12	5	15	4	12
1.2 Total Net Present Cost	2	5	10	5	10	4	8	3	6	4	8	3	6
1.3 Energy profile (net energy balance, carbon footprint and etc.)	2	3	6	3	6	2	4	2	4	2	4	1	2
1.4 Environmental impacts	3	4	12	3	9	2	6	1	3	4	12	3	9
1.5 Potential for phased development and adaptability to future uncertainties.	3	1	3	1	3	1	3	1	3	4	12	4	12
1.6 Duration of construction	1	3	3	3	3	3	3	3	3	3	3	3	3
1.7 Operation of conveyance	1	4	4	4	4	2	2	2	2	3	3	3	3
1.8 System reliability	2	4	8	4	8	3	6	3	6	4	8	4	8
1.9 Vulnerability to malicious acts	1	4	4	4	4	2	2	2	2	2	2	2	2
2. Risks													
2.1 Risk of small salted water leaks due to default of watertighness	2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2
2.2 Risk of large catastrophic salted water leaks	3	-1	-3	-1	-3	-2	-6	-2	-6	-3	-9	-3	-9
2.3 Risk of extention of duration of construction	2	-4	-8	-4	-8	-3	-6	-3	-6	-2	-4	-2	-4
2.4 Risk of additional unexpected investment cost	3	-4	-12	-4	-12	-3	-9	-3	-9	-2	-6	-2	-6
2.5 Risk associated with reliability of potable water supply	3	-2	-6	-1	-3	-2	-6	-1	-3	-2	-6	-1	-3
Total score		**21**	**34**	**21**	**34**	**12**	**17**	**11**	**15**	**21**	**40**	**18**	**33**

Weight	
3	Criteria is an essential requirement High impact if risk materialises
2	Criteria is important but not esential Moderate impact if risk materialises
1	Criteria is of minor significance Low impact if risk materialises

Score			
5	Excellent performance	-5	Very high risk
4	High performance	-4	High risk
3	Standard performance	-3	Moderate risk
2	Poor performance	-2	Low risk
1	Very poor performance	-1	Negligible risk

Note: Benefits and impacts not covered by the table above such as amount of potable water produced, amount of discharge to the Dead Sea, restitution of the Dead Sea project design life, institutional capacity and the like are essentially the same for all six alternative project configurations.

26. IMPLEMENTATION SCHEDULE AND LOGISTICS

26.1. Given the urgency of the problems the Red Sea – Dead Sea Water Conveyance is seeking to address, an aggressive indicative project implementation schedule is proposed. The duration of design and construction activities are based on recent experience with projects of a similar nature and consultation with specialist international construction contractors. The duration of pre-contracting activities proposed are the minimum consider feasible for each activity with no schedule float or contingencies provided.

26.2. The schedule critical path for the development of the recommended optimum project configuration runs through the following activities:-

- Completion of the Study Program.
- Multi-national governmental decision to proceed with the project or not.
- Further geotechnical site investigations.
- Obtaining Finance.
- Award of contracts for the design, procurement and construction of the conveyance pipeline and the conveyance tunnel around Aqaba (there are two parallel critical paths at this stage).
- Construction of both the pipeline conveyance and the Aqaba by-pass tunnel.
- Start up and commissioning.

26.3. Based on the foregoing, schedule start up and commissioning of the project is programmed to commence in October 2020. The key critical path and other substantial milestone dates are set out in Table 26.3 below. As already noted, this represents a somewhat optimistic schedule, especially with respect to the pre-construction activities, and so a parallel set of milestone dates representing a more realistic schedule is also shown. It is recommended that, despite the urgent needs that the project is developed, the more realistic schedule be adopted as the project development target.

Table 26.3: Key Schedule Milestones

Milestone		Date	
		Optimistic Schedule	Realistic Schedule
1	Final Feasibility Study Report	Jun-11	Oct-11
2	Beneficiary Go / No Go Decision	Sep-11	Dec-11
3	Enabling Legislation enacted by all Beneficiary Parties	Mar-12	Sep-12
4	Geotechnical site investigation contract awarded	May-12	Dec-12
5	Implementation organisational structure in place	Sep-12	Jun-13
6	Project Management Consultant appointed	Sep-12	Jun-13
7	Contract for desalination pilot trials awarded	Sep-13	Sep-13
8	Financing commitments secured	Sep-13	Sep-14
9	EPC contract for conveyance tunnel awarded	Jan-14	Mar-15
10	EPC contract for conveyance pipelines awarded	Mar-14	Jun-15
11	Results of desalination pilot trials available	Jan-15	Jan-15
12	EPC contract for sub-station and power transmission awarded	Jan-15	Mar-16
13	EPC contract for desalination plant awarded	Mar-15	Jun-16
14	EPC contract for pump station awarded	Jun-15	Sep-16
15	EPC contract for hydropower plant awarded	Jan-16	Mar-17
16	EPC contract for intake works awarded	Jan-17	Mar-18
17	Start up and commencement of commissioning	Oct-20	Apr-22

26.4. A review of the main supporting infrastructure within Jordan including port facilities, airports, roads and road transport facilities and regulations has been carried out. In general terms the infrastructure is adequate to support the project but a number of specific concerns have been identified. The key concerns are:-

- The relocation and redevelopment of the port facilities in Aqaba may well overlap with the proposed potential project construction period leading to disruption and congestion in the port during this period. It is however noted that the existing port facilities with some relatively minor additional equipment are adequate for the project needs and that the port of Eilat is also available for cargo imports.
- It is unclear whether there will be adequate craneage capacity in the redeveloped port facilities to offload and handle the largest loads envisaged. This will have to be addressed with the port authorities in the event a decision is taken to proceed with the project. If necessary provision of the required additional cargo lifting and handling equipment can be included in the contract for construction of the water conveyance.
- There is currently (2010) no safe road access linking the proposed new port facilities to the Wadi Araba / Arava Valley suitable for extra-ordinary large and heavy loads in the port redevelopment proposals. This problem is of more immediate concern to Arab Potash Company and they are currently working with the authorities to find a solution. In the event a decision is made to implement the project this will clearly give added impetus to the process.

27. PROTOTYPE PROJECT AND PHASED DEVELOPMENT

27.1. Red Sea water and Dead Sea water have very different chemistries. During the execution of the Feasibility Study concerns were raised that studies and mathematical modelling alone would not be adequate to determine with any degree of confidence what the impacts would be of introducing large quantities of Red Sea water into the Dead Sea. The concepts of an initial pilot project and later a phased development, with the first phase acting as prototype project, have been raised during the implementation of the Feasibility Study.

27.2. The terms “pilot project”, “prototype project” and “phased development” have been used interchangeably in many of the discussions during the Study Program and this has caused some confusion. The following definitions have been adopted for the purposes of his report:-

- Pilot Project – A relatively small scale arrangement set up to test a process or to verify the effects of a process. This could be a temporary arrangement which would have the possibility to be removed at the end of the testing program.
- Prototype Project – The same as a pilot project.
- Phased Development – Development of the full scale project in distinct stages over a period of time. Each stage is permanent and forms a distinct part of the ultimate full scale project.

27.3. Pilot or Prototype Project

27.3.1. A small scale, standalone pilot project could be implemented relatively simply and quickly. Such a prototype solution could be implemented to provide results during the detailed design stage without significantly delaying the overall project implementation schedule. Subject to satisfactory results from such a pilot project the full scale project could be developed immediately, or alternatively this could be followed up with a phased development of the main project as set out below.

27.3.2. The major challenge in developing either a pilot project or a small scale prototype project is to establish the appropriate size, scale and duration necessary such that the pilot or prototype provides a realistic physical indication of the effects of the full scale project. The scaling of a pilot project would best be done building on the results of the Dead Sea Modelling Study.

27.3.3. In order to replicate the effects of the full scale project, a small standalone temporary pilot project would need to discharge into an enclosed body of Dead Sea water. This receiving body would have to be of an appropriate volume, surface area and depth such that the pilot project constitutes an appropriately scaled down version of the full scale project. Such a receiving body of Dead Sea water could be created by isolating the bay to the east of the Lisan peninsula at the southern end of the Dead Sea, with either an earth and rockfill embankment or a geotextile membrane curtain across the mouth of the bay to create an enclosed receiving body of Dead Sea water.

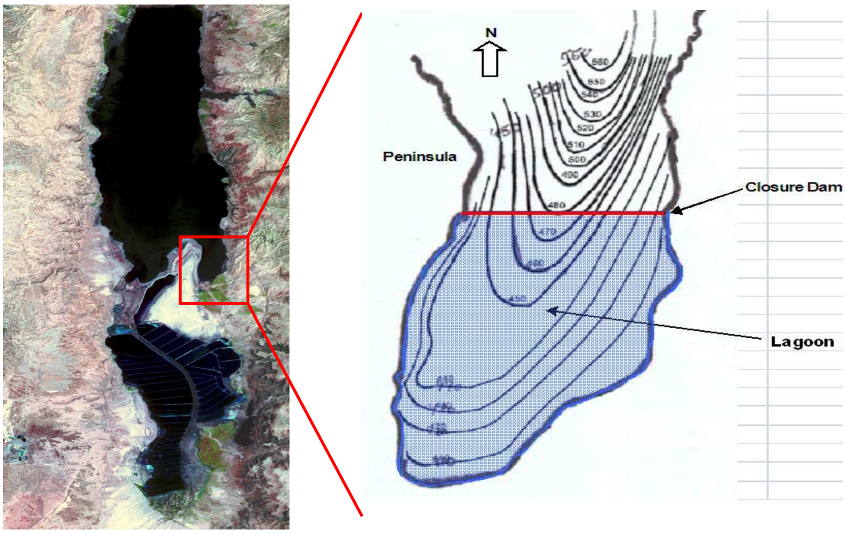


Figure 27.3: Proposed Receiving Lagoon for Pilot Project

27.3.4. Such an approach could be designed to provide some significant verification of the evaluation of the impacts of mixing Red Sea and Dead Sea water that has been developed under the Dead Sea Modelling Study.

27.3.5. The Dead Sea Modelling Study has however identified the following possible limitations of the concept outlined above:

- The full scale stratification regime might not be able to develop.
- The effects of the chemical industries activities will not be taken into account.
- A small scale system will not have the characteristic fetch and current set up of the whole Dead Sea which are key factors in the dynamics of this water body.

27.4. <u>Phased Development</u>

27.4.1. The recommended solution for the full scale project is based on a pipeline conveyance with six parallel pipes for the pumped riser main and three parallel pipes for gravity flow section. This readily lends itself to a wide range of possible phasing. However, most of these phasing options would compromise one or more of the project objectives. In essence, for any first phase development with a Red Sea water capacity of less than about 1,400 million m^3/year, the level of the Dead Sea will continue to fall and the associated environmental degradation will also continue until such time as further phases are commissioned. Furthermore any first phase development with a Red Sea water capacity of less than around 950 million m^3/year will not be able to fully satisfy the agreed potable water demands from the project. These issues have implications for both the economic and financial feasibility of the project. Three possible phased development options have been considered as follows:-

- The sized first phase that is compatible with the configuration of the ultimate full scale project.
- The minimum phasing that would allow the agreed demands for potable water from the project to be satisfied.
- The minimum phasing that would allow the agreed demands for potable water from the project to be satisfied and which would also largely satisfy the project objective to prevent further environmental degradation of the Dead Sea.

27.4.2. Phase Development Option 1: The smallest practicable first phase would be to initially build only one single pipeline on each section with the remainder of the pipes being added in future phases. Such a first phase would have a capacity of about 333 million m^3/year of Red Sea water producing about 150 million m^3/year of desalinated water and 183 million m^3/year of brine. Given the objectives of the phase development this first phase would have to be operated for several years before a decision could be made as to whether the feedback is acceptable or not. If acceptable there would then be a further period of time necessary to develop, design and build the next phase. Up to ten years may well be necessary from commissioning the first phase to commissioning the second phase. This option has four extremely serious downsides as follows which mean that it fails to meet any of the objectives of the project and is not feasible :-

- During the ten year life of the first phase the available supply of desalinated water will only be in the range of 30% to 40% of the agreed projected demand for desalinated water from the project.
- The level of the Dead Sea would continue to fall at almost the same rate as is experienced now for the entire duration of the first phase of this option, and this situation may continue into the second phase of a multiple staged development as shown in Figure 27.4 below. With this option there would be no discernable environmental benefits from the project throughout the lifetime of the first phase and maybe for longer. This would undoubtedly make it very difficult indeed, and probably impossible, to raise the necessary finance to fund the environmental component of the project.
- The discharge to the Dead Sea during the first phase will be some 183 million m^3/year of brine. If this is discharged to the main body of the Dead Sea it is too small an amount to give any real indication of the likely impacts of mixing Red Sea and Dead Sea water under the ultimate full scale project. It is understood that the team carrying out the Additional Study of the Dead Sea believe that a discharge flow of a least 400 million m^3/year is necessary for this purpose (the authors of this report believe the figure may be even higher). Conversely, if the discharge flow from this first phase were to be discharged to an enclosed lagoon of Dead Sea water, such as that described for the pilot project in paragraph 27.3 above, the flow would be too large and the conditions and salt loadings in the lagoon would not represent the conditions that would prevail under the full scale project. Thus this option would not satisfy the reason for adopting a staged approach in the first place.
- Finally the economics of this phasing option do not work. The revenue generated from the small amount of potable water produced in the first phase would not even cover the interest on the finance needed to build the first phase, let alone cover any of the operating and maintenance costs. The project would in fact make a cumulative loss of somewhere between $3 billion and $4 billion over the life of the first phase. Whilst it may theoretically be possible to recover this loss under later phases of the project this would make the project totally unacceptable to any financial institution or for contractor finance; especially since the probability of the future phases going ahead will remain uncertain until the impacts of operating the first phase are known. In short this option is not financeable.

27.4.3. Phase Development Option 2: A phased development of the project that would meet the agreed desalinated potable water demands from the project continuously from the date of commissioning the project would require a first phase with a minimum capacity of 955 million m^3/year of Red Sea water and a second phase to be commissioned 10 years later with a minimum capacity of 1,200 million m^3/year of Red Sea water. This could be achieved by building three parallel pumped riser pipes and two parallel pipelines on the gravity flow section for the first phase and adding one further pipeline to the pumped riser main for the second phase. This option has several advantages over the Phase Development Option 1 described above as follows:-

- It provides the necessary volume of discharge to the Dead Sea to give a good indication of the likely impacts of the ultimate full scale project.
- It satisfies the agreed demand for potable water from the project.
- The revenue from the sale of potable water means that the economic and financial feasibility of this option would be similar to (or possibly even marginally better than) that of building the full scale project at the outset. However, the uncertainty about whether future phases will go ahead, or even if the first phase will be allowed to continue following evaluation of impacts on the Dead Sea mean that it will be extremely difficult, if not impossible to finance this option.

However under this phasing option the Dead Sea water level will continue to fall at a rate of about 300 mm per year for the duration of the first phase and will fall marginally further during the second phase as shown in Figure 27.4 below. Whilst this is not nearly so serious as the corresponding situation for the phasing Option 1 it will still make it more difficult to raise the necessary financing and fund the environmental component of the project.

27.4.4. Phased Development Option 3: A phased development that would satisfy the agreed demands for potable water from the project and which would also maintain the Dead Sea at a near stable level for the duration of the first phase would require to have a capacity of about 1,500 million m^3/year of Red Sea water. This constitutes some 75% of the full scale project. Such a first phase would meet the original objectives of the project and would also undoubtedly demonstrate the effects of a full scale project on the Dead Sea but would represent a very high sunk cost in doing so.

27.4.5. Any phasing option will have a beneficial impact on both the initial capital cost of the project and hence the amount of initial funding required and also the whole lifecycle discounted net present cost (due to deferral in time of the capital cost of future phases) as indicated in Table 27.4 below. However, where phasing has the effect of reducing the volume of potable water produced in the early phases of development this can outweigh the economic and financial benefits of deferring capital cost. As noted above this is the case for phased development Option 1.

Table 27.4: Comparison of Approximate Costs for Various Phasing Options

$ Billion					
Cost	Full Project	Pilot Project Followed by Full Project	Phased Development Option 1	Phased Development Option 2	Phased Development Option 3
Pilot	Nil	0.2	Nil	Nil	Nil
Initial Phase	7.1	7.1	3.7	5.6	6.6
Total Installed Cost	8.4	8.4	8.6	8.6	8.6
Net Present Cost	12.4	12.6	9.0	10.9	12.0

Note: Cost excludes potable water transmission systems.

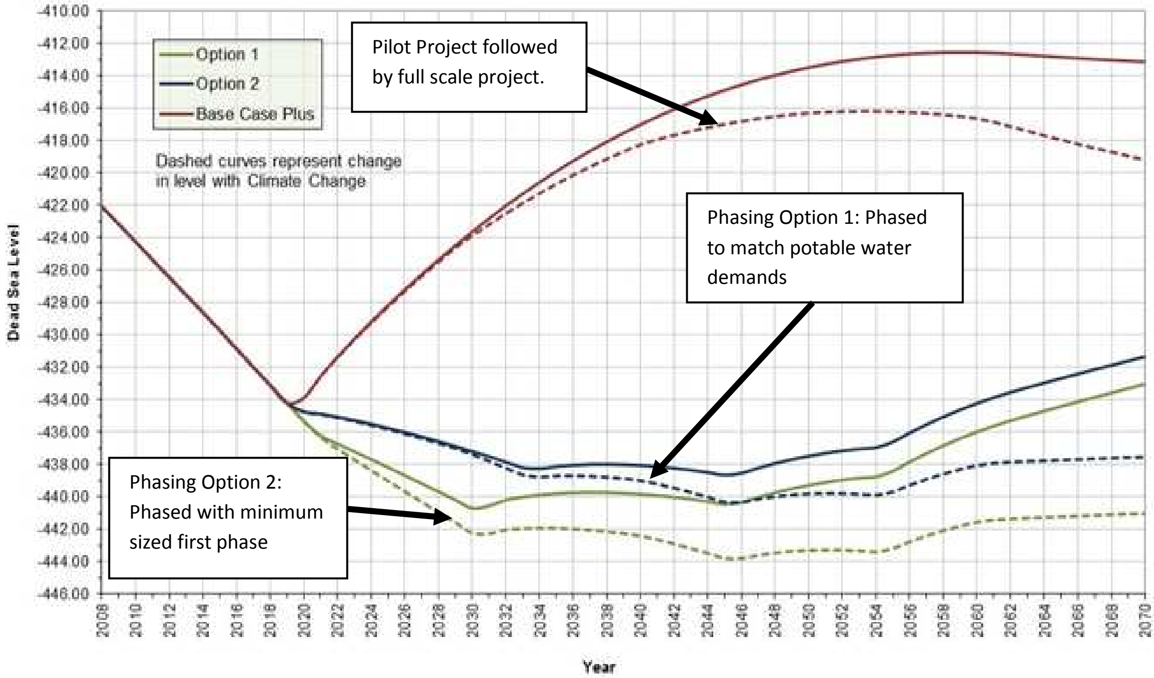


Figure 27.4: Projected Dead Sea Water Levels for Phasing Options 1 and 2

28. ECONOMIC EVALUATION

28.1. The economic evaluation looks at three aspects; a benefit - cost analysis of the project; an evaluation of the unit cost of desalinated water produced by the project; the impact of the project on the regional macro economics.

28.2. The benefit – cost analysis evaluates tourism, the chemical abstraction industry, the water sector, the electricity sector, public infrastructure and intangible or non-use aspects of the project. The benefits are determined by evaluating what happens to each of these sectors over the next 50 years both without the project or any alternative to the project and then with the project.

Tourism: Historic data on tourist numbers was derived from the available data in as far as these are available. Data was also collected for a wide range of parameters affecting tourist numbers. A number of multivariate time series models were tested and a regression analysis was carried out to isolate the level of the Dead Sea from all other factors affecting tourist visits to the region. This exercise was carried out for both international tourists and domestic tourists separately and it showed that whilst the number of domestic tourists appears to be unrelated to the Dead Sea level a significant correlation was found between the level of the Dead Sea and the number of international visitors. Based on this correlation the loss in tourist visitors in the event no action is taken to stabilise the level of the Dead Sea has been determined. Similarly the gain in the number of tourist visitors if the project goes ahead and the Dead Sea level has also been determined. The individual consumer surplus for visits to the Dead Sea has been determined previously (Bekker and Katz, 2006). This has been inflated to current values and applied to the difference in the number of tourist visits to obtain a benefit to the tourist industry if the project is implemented. A discounted net present value of US $3.5 billion has thus been determined for the benefit to tourism.

Chemical Industry: The declining level of the Dead Sea has two negative and one positive impacts for the chemical industry. As the water level drops and the shoreline recedes the pumping head to pump water up from the main body of the Dead Sea to the chemical company solar ponds increases and the pump station has to be relocated periodically to “chase” the receding shoreline. However as the Dead Sea declines the salinity becomes more concentrated and this improves the efficiency of the solar evaporation process. The impact of the project will be to reduce the pumping head required to pump water up to the evaporation ponds, eliminate the need to periodically relocate the intake pumping stations and to reverse the efficiency gains in the solar evaporation process. These effects have been evaluated using data and costs provided by Dead Sea Works and Arab Potash Company and applying standard engineering formulae. The project will also require some strengthening and modification to the retaining dykes around the solar evaporation ponds but the cost of this work has been included in the project cost estimates and so has not been included here as a cost to the chemical industry. The combination of all these effects leads to an overall positive benefit to the chemical industry and the net present value of this benefit has been determined to be US $0.25 billion.

Water Supply: The region is in a serious water deficit situation and this is project to get significantly worse in the event that no new sources of water are developed. It has been assumed for the purposes of this evaluation that this will always be the case in the event that a RSDSP does not go ahead. In these circumstances the benefit of the increased availability of water as a result of the project can be determined using the marginal value of water under these deficit conditions and the gradient of the demand curve. The marginal cost of water in Jordan is assumed to be the average cost people currently pay for tankered water in Amman (US $3.52 per m^3). The marginal cost of water in Israel and the Palestinian Authority is assumed to be the average incremental cost in supply which is thought to be US $1,24 per m^3. A value of -0.3 has been used for the gradient of the demand curve which is an average of values determined in other studies. On this basis a net present value for the benefit from the availability of additional water arising from the project has been evaluated as US $10.3 billion.

Power Market and Electricity Supply: Since the project infrastructure is located in Jordan and any negative energy balance will be drawn from the Jordanian national grid the long-run marginal cost of power generation in Jordan has been used to evaluate the benefit of hydroelectricity generated by the project. The long run marginal cost has been determined from data provided in the national power system expansion plan (NEPCO 2008) and the Master Strategy for the Energy Sector in Jordan for the Period 2007 – 2020. This gives a long-run marginal cost of US $0.068 per kWh in 2010 rising to US $0.072 in 2020 and then falling back to US $0.071 in 2030. The economic benefit of the hydro electricity generated by the project is then the total amount of hydroelectricity generated multiplied by the difference between the long-run marginal cost and the actual unit cost of producing hydroelectricity. The amount of hydro electricity produced varies significantly depending on the project configuration considered. Thus the net present value for this benefit also varies according to the project configuration considered within a range of US $0.8 billion to US $1.4 billion.

Infrastructure: The declining level of the Dead Sea leads to significant loss and damage to both public and private infrastructure including erosion and undermining of roads, damage to property from sinkholes, destruction of crops due to both sinkholes and falling water tables. The best available evaluation of this damage has been produced by the Jerusalem Institute for Israeli Studies but this only assess damage within Israel. Based on visual examination and a subjective assessment has been made that the combined damage in Jordan and the Palestinian Authority is equivalent to the damage sustained in Israel. This provides an annualised value of the damage of US $3 million per year. Assuming that, (1) in the event the project does not go ahead, damage will continue to occur at this rate indefinitely and that, (2) if the project does go ahead, the scale of damage will start to decrease soon after the Dead Sea level starts to rise and will cease entirely within a reasonable period after the Dead Sea has been stabilised at the project target level then the estimated net present value of the project in this respect would be US $ 0.01 billion.

Intangibles: A project specific contingent valuation survey was carried out in late 2010 to evaluate the intangible benefits of stabilising the Dead Sea. The survey process followed recognised good practice and followed an iteration of focus group interviews, pre-testing of the questionnaire, a pilot survey and a full survey. The full survey interviewed 9,047 respondees in 18 countries. The main thrust of the survey was to establish a “willingness to pay” to stabilise the level of the Dead Sea and prevent further environmental degradation and to build a symbol of peaceful co-operation in the Middle East. The results of the survey provide a net present value for the willingness to pay to save the Dead Sea of some US $30.6 billion and to build a symbol of peacefull co-operation in the Middle East of some US $11.1 billion.

28.3. In summary the economic evaluation shows a significant net positive benefit for the project with a substantial internal rate of return for all project configurations as shown in Table 28.3 below. However, it should be noted that this is very largely attributable to the value of the intangible benefits. A sensitivity analysis has been carried out to test the conclusions for all the major input parameters to the cost benefit analysis and the results confirm that even with wide variations in any single input parameter the conclusions do not alter substantially.

Table 28.3: Summary of Economic Costs and Benefits, Total NPV (2020)

	Without RSDSP	With RSDSP					
		Base Case Plus 00.1		Base Case Plus 220.1		Base Case Plus Pipeline	
Benefits		US$ Mn	%	US$ Mn	%	US$ Mn	%
Tourism	-2,635.7	3,475.0	6.15%	3,475.0	6.10%	3,475.0	6.09%
Chemical industry	-164.2	247.9	1.40%	247.9	0.43%	247.9	0.43%
Power generation	---	792.7	18.29%	1,284.3	2.25%	1,400.8	2.45%
Water supply	---	10,331.2	18.29%	10,331.2	18.13%	10,331.2	18.09%
Intangibles	---	41,644.4	73.71%	41,644.4	73.07%	41,644.4	72.92%
Infrastructure	-85.3	7.8	0.01%	7.8	0.01%	7.8	0.01%
Total benefits	-2,885.3	56,499.0	100%	56,990.6	100%	57,107.1	100%
Costs	0	16,279.0		17,417.6		17,377.0	
Benefit – costs	-2,885.3	40,220.0		39,573.1		39,730.1	
IRR	---	21.50%		21.19%		21.68%	

<u>Note</u> : In this table the costs are Total Net Present Costs, i.e.total capital and operating costs, discounted over a period of 50 years after project commissioning.

28.4. The project has a marginal negative benefit - cost if only the direct benefits are considered and the intangible benefits are ignored. However, even if only 10% of the value of the intangible benefits derived from the contingent valuation survey are adopted the project will have a positive benefit – cost evaluation and a healthy internal rate of return.

28.5. Determination of the unit cost of water desalinated has not yet been concluded and remains work in progress. The unit cost of desalinated water is being determined in two components (1) the bulk cost of desalinated water at the desalination plant outlet; (2) the additional unit cost of transmitting potable water from the desalination plant to demand centres within the territories of the Beneficiary Parties. Preliminary results so far suggest the unit cost of desalinated water will be within the following range:-

- Bulk desalination: US$ 1 to 1.5 per m^3
- Bulk transmission:
  - Jordan: US$ 0.7 to 1.2 per m^3
  - Israel and Palestinian Authority: US$ 0.2 to 0.35 per m^3
- Combined cost for delivered bulk desalinated water:
  - Jordan: US$ 1.7 to 2.7 per m^3
  - Israel and Palestinian Authority: US$ 1.2 to 1.85 per m^3

28.6. It is anticipated that although the majority of project expenditure during the construction phase will be spent outside of the region on procurement of plant equipment and materials and employment of international contractors, a significant proportion of the construction costs will be spent within the region. Since the most of construction work will be located in Jordan, Jordan will be the main beneficiary in this respect. It is projected that the Jordan economy will have grown by up to 10% more as a result of the project that in would do so without the project by the time of commissioning.

28.7. It is projected that the project will employee around 1,700 people during the peak years of construction. Whilst this is not a particularly large number it could have a perceptible impact on unemployment figures in Jordan and, provided that appropriate travel arrangements are permitted, in the Palestinian Authority as well.

29. Legal and Institutional Framework

29.1. If a decision is taken to proceed with the project it will be necessary to establish a legal and institutional framework to govern, develop, own, and operate the undertaking. Both the Red Sea and the Dead Sea are international water bodies and the Dead Sea will be significantly affected by the project. Thus, it is essential that the legal and institutional framework recognises the multi-national nature of the undertaking. Furthermore, as noted in Section 30 below, in order to attract international support and finance for the project it is essential that the legal and institutional framework is founded on internationally accepted law and good practice.

29.2. A wide ranging review has been carried out of legal and institutional arrangements for the governance of transboundary water resources and similar infrastructure in other parts of the world. This provides some guidance as to how effective a variety of different frameworks are in a varying circumstances and this is summarised in Table 29.2 below.

Agreement	Characteristics	Lessons
The Chad / Cameroon Pipeline	-Attempts to balance economic development with environmental and social needs. -No international leverage after construction complete.	The need for strong collaborative structures to bring together the participating parties from within, and from outside the region.
The Nile Process	-Inclusion of all interested riparians. -No mechanism for ensuring agreement.	Without willingness on the part of the |States in the advantaged position to make concessions or to resolve disputes the process will break down.
The Senegal Regime	-Extensive cooperative planning and research. -No collective decision making, resulting in unilateral decisions that exacerbate errors in collective planning.	Sharing information and discussing plans only goes so far.
The Mekong Commission	-A clear statement of the rights and duties of participating States as well as cooperative planning and research. -The lack of collective decision making is compounded by the inability to include the two uppermost riparians.	The scope and authority of any institutions must match the scope of the managerial need.
The international Joint Commission	-An independent decision making body compose of members appointed for fixed terms given wide authority to investigate and resolve problems affecting both States -Sometimes bypassed or even ignored by one or both States, a particular problem if one State would prefer the Commission to resolve an issue and the other refuses.	To remain effective, an international institution must have authority to initiate action and to implement its decisions.
The Port Authority of New York and New Jersey	-An independent decision making body coupled with financial independence. -Charged to build infrastructure to meet commercial needs, it has no authority to consider or invest in meeting social or environmental needs.	Institutions are more likely to be considered successful if their responsibilities are defined carefully and narrowly.
The Delaware River Basin Commission	-An institution with broad regulatory and operational authority that has enabled accomplishment of a great deal that could not have been accomplished by the States separately. -The lack of independent decision making forces decisions down to the lowest common denominator even when something more is necessary.	Independent decision making authority at the operational level is necessary if an institution is to be able to fulfill its responsibilities.

Table 29.2: Review of Representative Existing Legal and Institutional Frameworks

29.3. One particularly powerful lesson to be learnt from experience elsewhere is that neither self-regulation by the implementation and operational entity nor regulation by a politically motivated regulatory agency works well. Good governance requires a strong and autonomous regulatory authority.

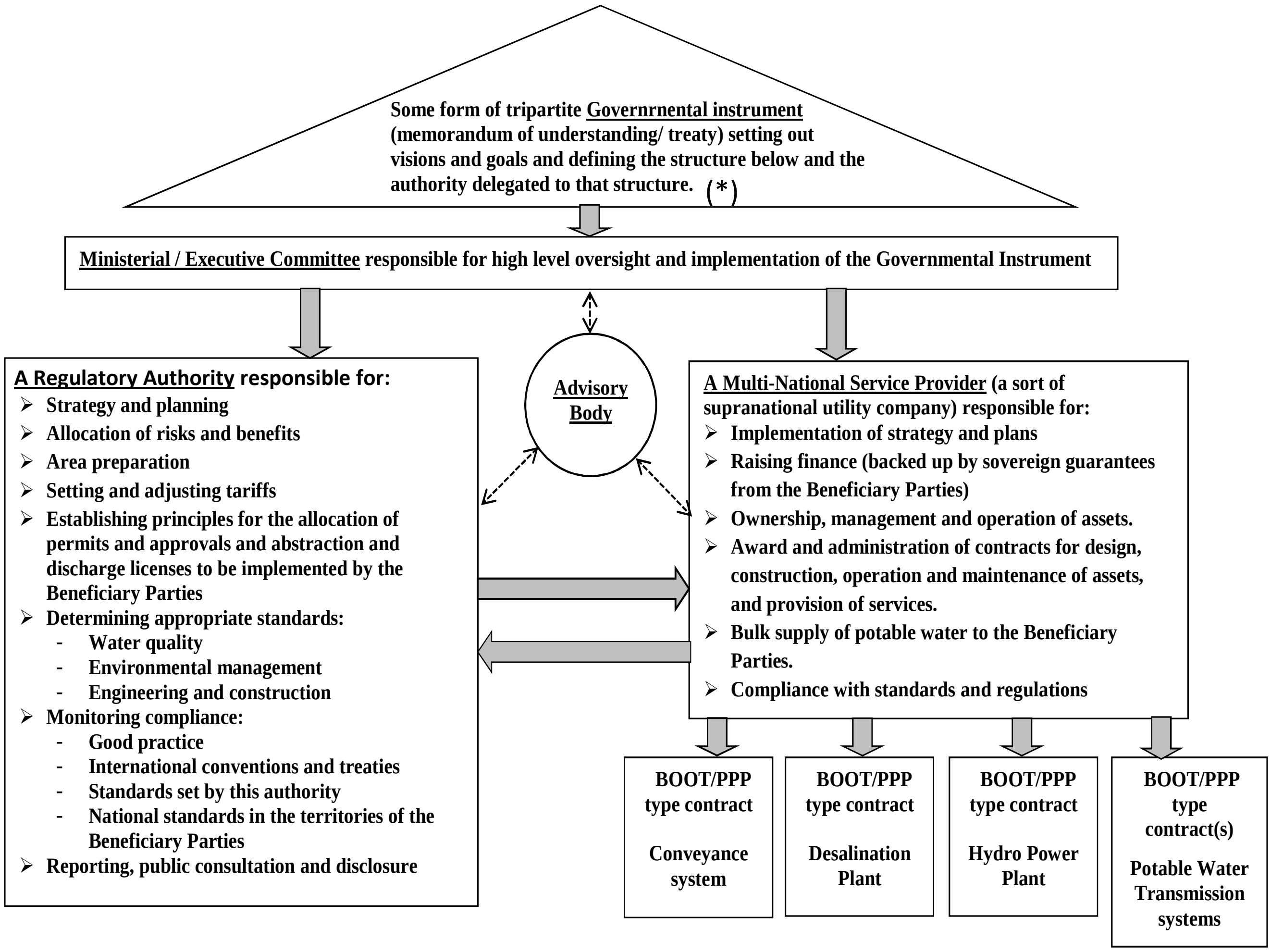
29.4. Two generic types of organisational framework have been considered for the Red Sea – Dead Sea Project each with its own merits and limitations as follows:-

<u>A National Project</u>: Since all of the main infrastructure will be located within Jordan, one option would be for Jordan to unilaterally develop, own and operate the infrastructure and

to enter into bilateral agreements to sell desalinated water (and possibly electricity) to Israel and the Palestinian Authority. This option has the merit of simplicity and it provides Jordan, as the main beneficiary, with total sovereignty of its water supply from the project. However, this approach will still have to recognise the international nature of both the Red Sea and the Dead Sea and will still require some form of co-operation and partnership with the co-riparians to the Dead Sea with respect to the changes brought about in the Dead Sea as a result of the project. Furthermore this solution would lead to asymmetrical control and authority over the project and would minimise the extent to which the project would build a symbol of peaceful co-operation in the region – a specific objective of the Terms of Reference for this study.

A Multi-National Project: The project could be developed with the three beneficiary parties jointly establishing, owning and operating the undertaking in full partnership and co-operation. This solution, whilst more complex to set up, has the merit of recognising the international nature of the project. It also better provides for transparent and equitable governance and equitable sharing of the benefits. In addition this type of structure also better meets the spirit of the Terms of Reference and is more likely to attract the international donations and grant aid necessary to make the project financially feasible (see section 30 below).

29.5. It is concluded that the most appropriate institutional framework would be a multi-national organisation structured along the following lines:-



Note : (*) The government instrument should be flexible enough to permit the eventual inclusion of other government.

Figure 29.5: Indicative Organisational Structure

29.6. Both the regulatory authority and the implementation authority / service provider would consist of a full time secretariat with their own permanent staff. Each would be governed by a part time board of directors appointed by the Beneficiary Governments. A key requirement for the success of the organisation will be the selection of these boards, the terms of reference given to the appointees and the duration of their appointments and also the voting arrangements and the mechanisms established for resolving disagreement and deadlock. It is essential that the appointments are made on the basis of merit, qualifications and experience and the appointees should be given the autonomy and the authority to make their decisions in the best interests of the stated objectives of the undertaking. A full check list of issues that must be considered in developing the outline organisational structure recommended is given in the main report.

29.7. The advisory body would provide an opportunity for non governmental stakeholders such as environmental agencies to participate in the decision making process and could usefully include at least one international body such as The World Bank to bring a broader range of experience and to provide assistance in managing any disagreement between the Beneficiary Parties. It is considered that the incorporation of a body of this nature into the organisation would greatly enhance transparency and equity and would facilitate improved public support for the project.

29.8. The institutional framework proposed above is also as a result of a comprehensive research into international law for similar projects, and reflects the best practice principles of good governance and a practical means for the resolution of disputes. This research also shows that, by following these guidelines, prospects for obtaining the required international financing for the project are substantially strengthened.

29.9. It has been noted during the Study Program that it is possible an application may be made to the UNESCO for recognition of the Dead Sea as a World Heritage Site. Such an application need not influence the development of a legal and institutional framework for the Red Sea – Dead Sea Project and could conceivable either precede it or follow on from it. It should however be recognised that any application will require to state exactly what it is about the Dead Sea that is being recognised and how it will be maintained and preserved. It is therefore essential that there is good co-ordination between the development of a Red Sea - Dead Sea Project and any application for recognition as a World Heritage site so that nothing in the one prejudices the aims and objectives of the other.

30. INDICATIVE FINANCING PLAN

30.1. The project has three distinct objectives but only one of these, the production of desalinated water and generation of hydroelectricity, produces any direct revenue to finance commercial borrowing. It is clear that if the total capital cost of the project were to be amortised through the tariffs for desalinated water and hydroelectricity the unit cost of water would be extremely high, and probably both unaffordable and politically unacceptable. In any case it would not be appropriate to allocate the entire project costs to only one of the multiple project objectives. It follows therefore that the capital costs and project financing should be distributed across all of the objectives of the project. However some of the individual components of infrastructure contribute to more than one project objective. This is demonstrated in Table 30.1 below.

Table 30.1: Relationship Between Project Objectives and Potential Financing Packages

Objective	Financing Packages					
	Sea Water Conv.	Desal.	Water to Jordan	Water to Israel	Water to P.A.	Hydro Power
To save the Dead Sea from environmental degradation.	In part	/	/	/	/	/
To desalinate water and/or generate hydro electricity at affordable prices for Jordan, Israel and the Palestinian Authority.	In Part	Yes	Yes	Yes	Yes	Yes
**To build a symbol of Peace and co-operation in the Middle East	Yes	Yes	/	/	/	/

***Assumes that the sea water conveyance, desalination plant and hydropower plant will all be developed and operated as part of a multi-national enterprise.*

30.2. Various methods of sub-dividing shared elements of project infrastructure between the respective project objectives have been examined. The method adopted divides the costs in accordance with the ratio of the relative net economic benefits arising from each of the project objectives. This provides a breakdown of the initial capital costs for the period up to initial commissioning of the project as shown in Table 30.2 below. It is reminded that at the initial commissioning of the project, the capacity of the desalination plant and of the water transmission line to Amman will be respectively around 45% and 60% of the final capacity

Table 30.2: Breakdown of the Initial Capital Costs of Project (US$ Million)

Item	Saving the Dead Sea	Provision of Potable Water	Generation of Hydropower	Total
Conveyance	3,856.2	959.1	128.5	4,943.9
Desalination Plant	0	1,104.7	0	1,104.7
Hydro Power Plant	0	0	241.4	241.4
Restitution canal	208.2	51.8	6.9	266.9
HV Connections to national grid	207.2	51.5	6.9	265.6
Project management and development of institutional structure	192.3	43.0	9.3	244.6
Sub-Total (excluding transmission of potable water)	4,463.9	2,210.1	393	7,067.1
Potable water transmission system to **Jordan**	0	1,663.1	0	1,663.1
HV connection to national grid	0	131.4	0	131.4
Project management	0	64.4	0	64.4
Sub-Total	0	1,858.9	0	1,858.9
Potable water transmission system to **Israel**	0	To be determined.	0	To be determined.
Project management				
Sub-Total				
Potable water transmission system to the **Palestinian Authority**	0	To be determined.	0	To be determined.
Project management				
Sub-Total				

**** Note that no interest during construction has been included in the above costs. This will be added when the appropriate financial interest rate is established.*

30.3. A wide range of types of finance and potential financing institutions have been considered. However as noted above only one objective, the production of desalinated water and generation of hydroelectricity, produces any direct revenue and can be financed through commercial borrowing. Thus other sources of finance have to be considered for the capital costs attributed to the other project objectives. This leads to a financing plan structured along he following lines:-

Table 30.3: Potential Sources of Initial Finance

Project Objective	Financing Package	Finance Required US $ billion	Potential Sources of Finance
Saving the Dead Sea	Conveyance	3.856	– Beneficiary government equity. – Grants. – Donations
	Dead Sea Restitution Canal	0.208	
	HV Power Connections	0.207	
	Institutional and Organisational Costs	0.192	
	Sub-Total	4.463	
Producing Potable water	Conveyance	0.959	– Government equity / Public funding – Private equity. – Soft loans and export credit. – Multilateral loans. – Contractor finance.
	Desalination	1.105	
	Dead Sea Restitution Canal	0.052	
	HV Power Connections	0.052	
	Institutional and Organisational Costs	0.043	
	Sub-Total	2.210	
Generating Hydropower	Conveyance	0.129	– Government equity / Public funding – Private equity. – Soft loans and export credit. – Multilateral loans. – Contractor finance.
	Hydropower plants	0.241	
	Restitution canal	0.007	
	HV Power Connections	0.007	
	Institutional and Organisational Costs	0.009	
	Sub-Total	0.393	
Sub-Total – Multinational Project		**7.066**	

Conveying Potable water to consumption centers	Potable water transmission to Jordan	1.859	Government equity / Public funding Private equity. Soft loans and export credit. Multi-lateral loans. Contractor finance. State subsidies ???
	Potable water transmission to Israel	To be determined	
	Potable water transmission to the Palestinian Authority	To be determined	

30.4. Saving the Dead Sea does not generate any revenue from tariffs and thus here is no revenue to finance operations and maintenance costs attributable to this component of the project. Clearly grant aid and donations cannot be sought on an annual basis to support all, or even part, of these costs. Thus the O&M costs attributable to saving the Dead Sea must be recovered through the tariffs for potable water and hydro-electricity. If the PPP/BOOT operator of the sea water conveyance is a separate contractor from those operating the desalination plant and the potable water transmission systems then the operator of the sea water conveyance will charge the operator of the desalination plant a tariff for the delivery of sea water to cover O&M costs of the sea water conveyance. This cost will then be recovered by the operator of the desalination plant in the tariff for potable water. A similar arrangement would also be applied with respect to sea water supplied to the hydropower plant.

30.5. Discussions are ongoing with a representative cross section of potential financing institutions to ascertain the appetite of the financial community to fund a project on this basis. An indicative financing plan cannot be finalised, and the financial feasibility of the project cannot be determined, until these consultations are completed. However, it is clear at this stage that financing of the project will not be easy and that the Beneficiary Parties will have to adopt a range of measures to attract funding if they wish to proceed with the project. There are three specific aspects that should be borne in mind:-

Conditions Precedent: It is almost inevitable that financial institutions will have some conditions precedent that must be satisfied before financing commitments are made, funds are obligated and thereafter, before funds can be drawndown. These will vary from one institution to another but may include some or all of the following:-

- Adoption of internationally recognised law and good practice in the legal and institutional framework adopted for the project.
- Institutional strengthening in the water sector in the territories of the Beneficiary Parties.
- Measures to reduce unaccounted for water.
- Measures to eliminate unsustainable exploitation of existing water resources, especially over abstraction from aquifers.
- Improved demand management in the water sector.
- Improved water use efficiency in the agricultural sector.
- Elimination of subsidies and full cost recovery in the water tariffs charged to consumers.
- Measures to implement at least partial restoration of the lower Jordan River.
- Specific commercial risk management measures (see below).

Commercial Risk Management: There are a range of political and commercial risks associated with the project that will be of concern to potential financing institutions. The institutions will expect to see certain measures put in place to mitigate the risk profile including some or all of the following:-

- Multi-national sovereign guarantees.
- National sovereign guarantees.
- Take or pay contracts to guarantee a minimum revenue to BOOT and/or private partnership contractors.
- Long term, fixed price power purchase agreements.
- Commercial insurance.
- Appropriate contract provisions for the impartial review, regulation and adjustment of tariffs.

Financial Feasibility: The financial feasibility of the project hinges on the following four factors:-

- The ability to raise some US$ 4.5 billion in grant aid and donations to finance the “non commercial” elements of the project. This will not be easy given the current global financial situation and the current political uncertainty throughout much of North Africa and the Middle East. However, as discussed in section 30 above the economic evaluation provides a substantial justification for this element of the funding.
- The ability to raise some US$ 2.6 billion in commercial funds to finance the multi-national “commercial elements” of the project. This would appear to be feasible, provided that the other financing components of the project prove feasible.
- The ability of the three Beneficiary governments to raise a further amount totaling in the order of US$ 2.5 billion to finance the individual transmission systems to deliver

potable water to the three territories (this amount includes an estimate of the cost of the transmission system to Israel and to the Palestinian Authority as provided in the note at the bottom of table 24.5).

- The resultant tariffs for the potable water delivered to the territories of the three Beneficiary Parties are affordable and politically acceptable.

31. THE PEACE DIVIDEND

31.1. One of the project objectives stated in the Terms of Reference is to "create a symbol of peaceful co-operation in the region" and the terms of reference anticipate that one of the intangible benefits arising from the project would be a so called peace dividend.

31.2. It is debateable whether, where a conflict situation exists, an outbreak of peace is a pre-requisite for co-operation or whether the benefits from some level of co-operation on less confrontational issues can act as a catalyst to engender an increasing level of peaceful co-operation on a broader front, ultimately leading to peace. There are proponents for both points of view and in the course of the study program there has been no clear consensus as to whether the project would have a peace dividend or not. However, there are two separate indications that there is a potential peace dividend associated with the project.

- Firstly, the study Program itself has involved dialogue and consensual agreement between the Beneficiary Parties on a range of matters without marginalising any one party. This process has continued even when the wider conflict has flared up in the background. It has also been widely noticed that this process has also led to dialogue between the participants on other contentious issues and it has led to some quality cross border dialogue, partnership and consensus building amongst scientific institutes, environmental groups and the like.

- Secondly, a peace process specialist (Eric Abitbol) carried out a peace and conflict effects study as part of the environmental and social assessment study component of the Study Program. As part of this work interviews were conducted with thirty two people representing a broad cross section of senior stakeholders in the peace process throughout the region. The conclusion was that whilst the project could not in itself bring peace it could, if structured appropriately and equitably, have a positive impact on the peace and conflict process.

31.3. Conflict is characterised by human suffering that cannot be monetarised. However, certain elements of the cost of conflict and the benefits of peace can be evaluated.

- The Strategic Foresight Group has recently undertaken an evaluation of the economic cost of conflict in the Middle East. The evaluation basically determines the economic value of peace in terms of increased economic growth, increased trade, improved opportunities and the reduction of damage and destruction less the cost of the peace process. The resultant evaluation suggests that the economic benefit of peace in Israel, Jordan and the Palestinian Authority would amount to some US $30 billion per year within a few years of achieving peaceful co-operation. This amount does obviously not correspond to the peace dividend generated by the project. It is just quoted here as a reference against which the estimated peace dividend provided below can be compared.

- A project specific contingent evaluation survey has been undertaken in which 9,047 respondees were interviewed across 18 different countries to determine a willingness to pay for such intangible benefits as "the existence value of the Dead Sea" and "the promotion of peace in the region". The survey demonstrates a willingness to pay value for the potential peace dividend from the Red Sea – Dead Sea Project of some $ 11 billion.

31.4. There are strong reasons to believe that there is a potential peace dividend from the project and it is clear that if it materialised 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. However, it is also clear from the studies that this peace dividend can only be achieved if the project is pursued and structured in a manner that specifically pursues this end. The recommended legal and institutional framework set out in Section 29 is based on this premise and in addition the following conditions would have to be met in implementing this framework:-

- The objectives of the project must be clearly articulated and must be achievable.
- The project must be owned, operated and governed in a manner which gives an equitable voice to all Beneficiary Parties in the decision making processes and for the mutual benefit of all the Beneficiary Parties.
- The governance structure and decision making processes must be founded on international law, and internationally recognised good practice without marginalising any of the Beneficiary Parties.
- All stakeholders must be involved in all phases of project development and operations.
- The project must not be seen to prejudice or undermine the negotiations of the Oslo Accord Final Status Agreement in any way.
- The project must make a significant contribution to relieving water stress throughout the territories of the Beneficiary Parties and must lead to the ending of unsustainable exploitation of transboundary water resources.
- The governance structure and decision making processes must incorporate a mutually accepted process for speedy resolution of disputes.
- Information and scientific data must be openly shared between the Beneficiary Parties in a spirit of co-operation and partnership.
- The benefits from the project must not come at the expense of an ecological catastrophe.

32. CONCLUSIONS AND RECOMMENDATIONS

32.1. Six potential project configurations have been considered based on three alternative conveyance systems. The salient points of each of these three conveyance systems are as follows:-

- Tunnel Option 00.1, has advantages based on considerations of operational energy saving and low environmental impacts. It is conceptually simple and the full lifecycle cost is the lowest of the three options. The operational energy requirements are extremely low as no pumping is required (with the additional benefit of no environmental impact from generating the energy required for pumping). However, it has a number of serious drawbacks: (1) it lacks the flexibility to adapt to future changes and to any unforeseen future needs; (2) it presents an extremely challenging piece of engineering and construction as it is situated in a tectonically disturbed region presenting some very difficult geomechanical conditions; (3) it would be one of the longest tunnels on earth and would be energy intensive during construction; (4) the risk of the project being delayed due to technical problems during construction is high; (5) the consequent risk of costs escalating significantly is also high; it would require a number of substantial construction sites in the confined space of the environmentally sensitive side wadis. It should be noted that this option has the lowest net energy demand averaging about 1,000 GWh per year less than the recommended configuration, albeit it produces significantly less hydropower, and generates on average 700,000 tonnes of CO_2 per year less than the recommended configuration.
- Tunnel-Canal Option 220.1 does not appear to offer many advantages over the gravity tunnel option. It lacks the conceptual advantage of being driven by gravity; it will require substantial energy input and the long canal sections give rise to serious social and environmental impacts. Moreover, its vulnerability to both natural and malicious contamination along the open canal sections make it unviable.
- The Pipeline Option offers some advantages when compared to the alternatives and is the least capital cost solution. However, it has higher operating costs and a marginally higher total NPV than alternative configurations. The engineering problems will be far less onerous; it would be flexible in its operation and changes in layout to meet future needs are feasible. Furthermore the construction of a pipeline will not require the provision of major construction sites with all the necessary ancillary works and energy supply systems within the environmentally sensitive side wadis. The pipeline results in a higher net energy demand and a larger carbon footprint than alternative configurations.

32.2. The estimated capital costs and whole lifecycle net present costs for all six basic configurations considered in detail lie within +/- 5% of the average, which means that cost is not necessarily the over-riding criteria in determining the optimum solution. However, a potential opportunity to further reduce the cost of the pipeline conveyance by some $ 0.5 billion has been identified but will need to be verified by a geotechnical detailed site investigation at the next stage of project development. Should this materialise the pipeline option would offer significant economic and financial advantages over the alternative solutions.

32.3. Based on the results of the Red Sea Modelling Study it is assessed that the intake can be designed to minimise impacts on the Red Sea environment to acceptable levels, both during construction and during operations of the system. The Final Report of the Red Sea

Modelling Study suggests a "Go" decision for a 2,000 MCM/year extraction rate of Red Sea water provided the intake is at the proposed eastern site and at a 140 -160 m depth.

32.4. Some potential impacts of mixing Red Sea water in the Dead Sea, in particular the future frequency and magnitude of both red algae blooms and whitening events due to precipitation of gypsum, have been examined. The Final Report of the Dead Sea Modelling Study concluded that although it is not possible to rule out the possibility of "whitening events" due to the introduction of Red Sea Water or rejected brine, this problem could be mitigated by adding Gypsum crystals at the discharge location allowing a faster sedimentation of the precipitated Gypsum. The Dead Sea Modelling Study recognised the potential for biological blooming provided stratification develops and if the upper mixed layer is diluted by at least 10%. However according to this study this phenomenon will be limited by the co-precipitation with gypsum of nutrients such as iron and phosphorus that will no longer be available for algae and bacteria growth. The Final Report of the Dead Sea Modelling Study also emphasizes the need for additional work to be carried out in order to clear some uncertainties that remain.

32.5. The onshore environmental and socio-economic assessment does not identify any prohibitive impacts. It suggests that the impacts of the pipeline conveyance will be wider spread but less severe than those for either the tunnel or tunnel and canal conveyance systems and that the impacts can be mitigated and managed to an acceptable level.

32.6. Based on a weighted multi-criteria assessment process, the pipeline conveyance combined with a high level desalination plant is the recommended optimum solution. This configuration has the lowest total installed cost but the whole lifecycle net present costs are some 3.5% higher than those for the low level gravity flow tunnel configuration. The multi criteria assessment process is based on subjective assessment of the relative weightings given to each criteria considered and also to the relative scoring given each option considered. The weightings and scoring given here represent the collective consensus of the Consultant's management team but it should be recognised that other parties may have other views. A summary of the pipeline combined with high level desalination plant configuration is given in Table 32.6 below. The layout and a schematic of the recommended project summarized in the Table 32.6 are shown in Figures 32.6a and 32.6b below.

Table 32.6: Summary Description of Recommended Optimum Configuration

Intake Works	
Location	Eastern intake site
Capacity	2,000 million m^3/year
Type	Offshore submerged discharge
Pump Station	
Location	On site of old thermal power station at eastern intake location
Discharge capacity	64.7 m^3/sec
Pumping head	273 m
Installed capacity	229 MW
Conveyance Tunnel	
Location	Around east and north perimeter of Aqaba
Length	25.5 km
Diameter	5.5 m
Lining	Welded steel
Pipeline - Pumping Section	
Location	From a tunnel portal 2km north of Aqaba airport to the Gharandal saddle in the Wadi Araba / Arava Valley
Length	66.5 km
Number of parallel pipelines	6 No.
Diameter	2.9 m
Wall thickness	14.5 mm
Gravity Pipeline – Sub-Section 1	
Location	From the Gharandal saddle to the high level desalination plant
Gross head	295 m
Length	50 km
Number of parallel pipelines	3 No.
Diameter	3.0 m
Wall thickness	15.0 mm
Desalination Plant	
Location	In wadi Araba / Arava Valley 50km north of Grarandal saddle and 40km south of the southern tip of the chemical industry evaporation ponds
Pre-Treatment	Multi-media filtration and dissolved air flotation
Desalination process	Sea water reverse osmosis (SWRO)
Post-treatment of potable water	Re-mineralisation with disinfection
Capacity	320 million m^3/year at start up increasing to 850 million m^3/year in 2060
Installed power capacity	247 MW (2020) – 556 MW (2060)
Average specific energy consumption	3.33 kWh/m^3 of potable water
Gravity Pipeline – Sub-Section 2	
Location	From the desalination plant to the hydropower plant
Gross head	255 m
Length	32 km
Number of parallel pipelines	3 No.
Diameter	2.9 m
Wall thickness	14.5 mm
Pipelines – Corrosion Protection	
Internal	Fusion bonded epoxy lining
External	Three layer polyethylene coating
Cathodic protection	Impressed current
Hydropower Plant No.1	
Location	Immediately upstream of high level desalination plant
Rated head	211m
Number of units	3 No.
Installed capacity	135 MW
Hydropower plant No.2	
Location	Close to Fifa village just south of chemical industry evaporation ponds.
Rated head	215m
Number of units	3 No.
Installed capacity	115.8 MW
System Energy Balance	
Total energy generated	2020: 1,817 GWh / 2060: 1,642 GW
Total energy consumed	2020: 4,347 GWh / 2060: 7,782 GWh
Net energy balance	2020: -2,530 GWh / 2060: -6,140 GWh
Dead Sea Restitution	
Discharge conveyance	New open canal northwards from the hydropower plant to the Truce Canal, along the Truce Canal and then eastward across the neck of the Lisan Peninsula.
Discharge works location and configuration	On the west shore of the bay to the east of the Lisan Peninsula.
Target Level for stabilisation of the Dead Sea	-416 m
Target Year for stabilisation of the Dead Sea	Circa 2054

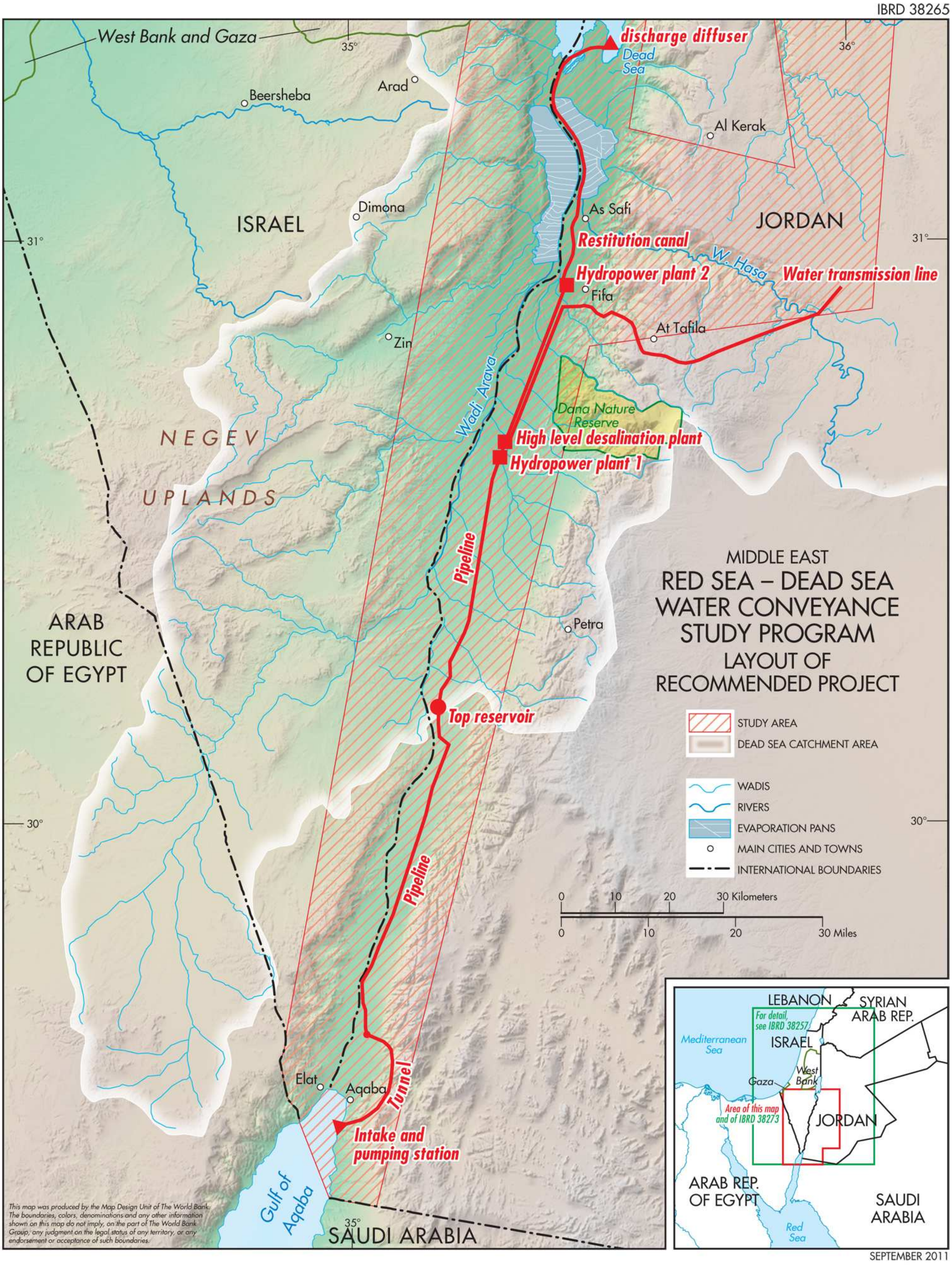


Figure 32.6a: General Layout of Recommended Project

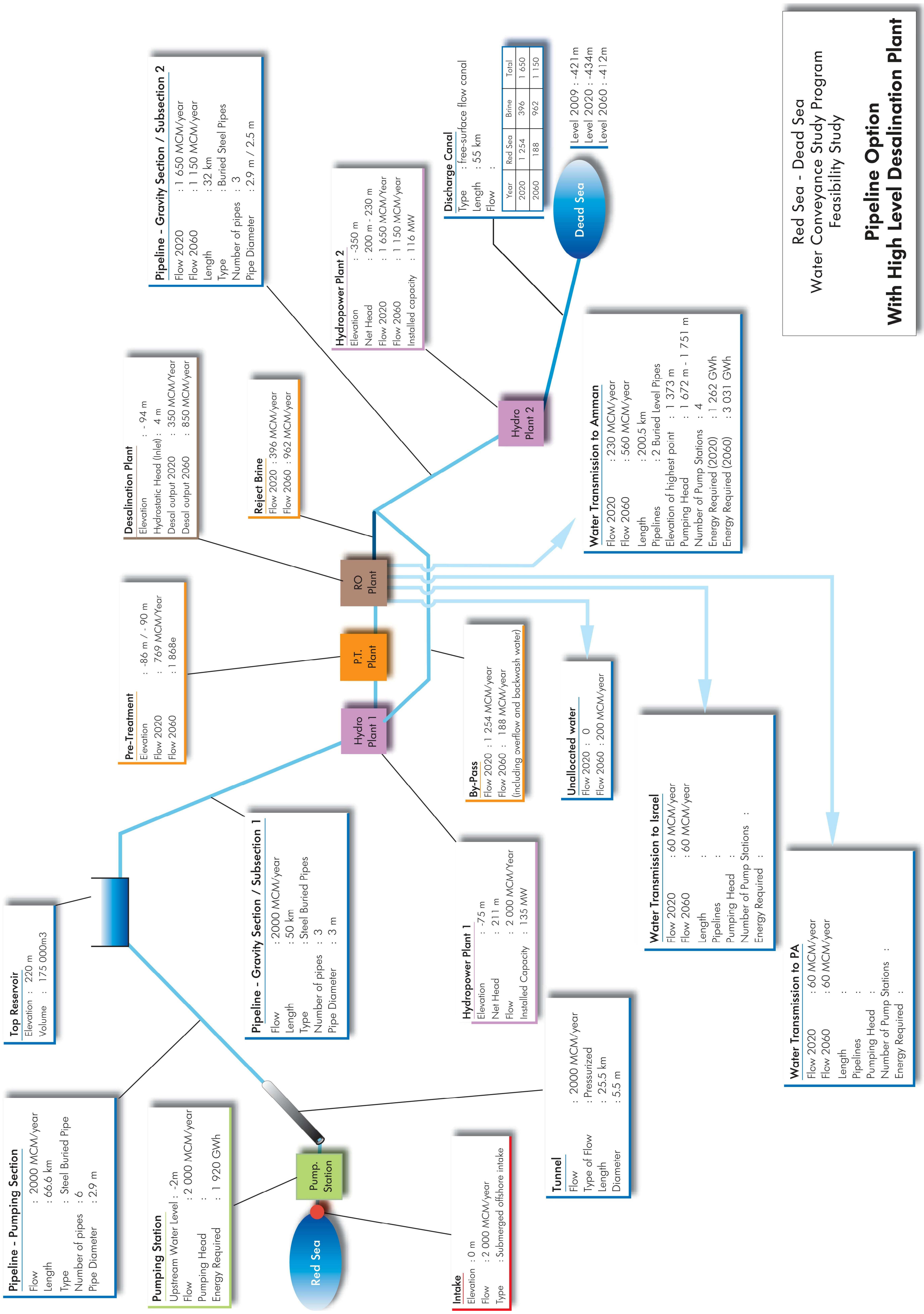


Figure 32.6b: Schematic of the Arrangement of the Recommended Project

32.7. The estimated full capital cost of the recommended project configuration is US $ 9.97 billion (excluding the potable water transmission system to Israel and to the Palestinian Authority). As noted several time previously in this report, a potential opportunity has been identified that could reduce the capital cost of the pipeline by some $500 million but this can only be verified through a detailed geotechnical site investigation program at the next phase of development. If this potential saving were to materialise the pipeline conveyance solution would not only represent the lowest capital cost by a significant margin but would also represent the lowest whole lifecycle discounted net present cost solution.

32.8. The greatest risk and cause for concern regarding the project as articulated by many stakeholders is the risk of leakage of sea water contaminating valuable groundwater resources. This is a very real risk and appropriate engineering solutions to minimise the risk have been incorporated into the designs and cost estimates for all conveyance systems considered. As a result it is considered that the risk as mitigated by the designs is as low as reasonably possible and is similar for all six configurations considered. The design measures are based on design to minimise the risk of leakage occurring, monitoring to any detect leakage, containment of leakage and shut down of the system in the event of major leakage. This design for leakage containment for the recommended pipeline conveyance system is shown on the Figure 15.9 in paragraph 15.9.

32.9. The project is economically feasible. The direct economic benefits of the recommended solution exceed the economic costs by some $ 1 billion compared to the No Project Scenario and this rises to over $ 42 billion when intangible economic benefits are included in the evaluation giving an internal rate of return of 22%.

32.10. A detailed review of existing organisations for the transboundary management of water resources and infrastructure from around the world and the track records of these organisations suggest that the institutional framework for a successful RSDSP should be based on the summarised structure shown in Figure 32.10 below and should be founded in internationally recognised water law and internationally recognised best practice.

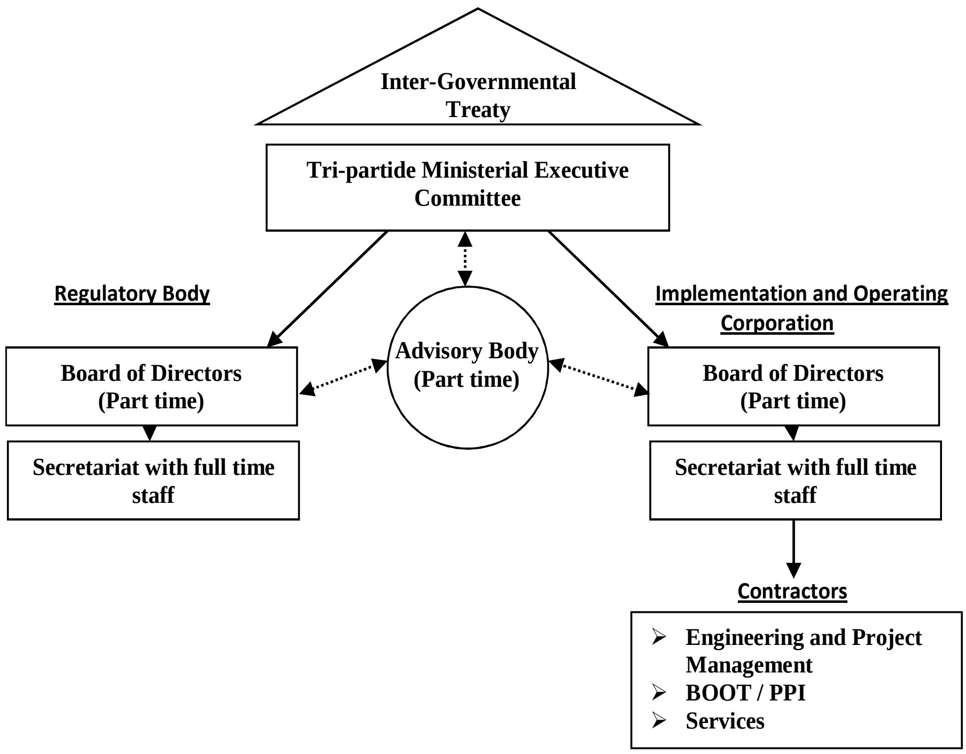


Figure 32.10: Recommended Organisational Structure

32.11. The only elements of the project that would generate direct revenue to finance borrowing are the production of desalinated water and the generation of hydroelectricity. However, if the entire capital cost of the project were to be amortised in the tariffs for the sale of water and electricity then the tariffs would be unaffordable and unacceptable. The solution proposed is to split the total capital costs between the various project objectives on the basis of the ratio of economic benefits from each objective. This will allow the portion of the initial infrastructure costs attributable to producing desalinated water and generating hydroelectricity ($ 2.6 billion) and transmission of potable water to the Beneficiary Parties (circa $ 2.5 billion) to be financed through borrowing and/or contractor finance which will result in financially feasible tariffs for water and electricity. However, it means that the portion of the initial capital costs attributable to stabilising the Dead Sea and creating a symbol of peaceful co-operation in the Middle East ($ 4.5 billion) must be financed through some combination of Beneficiary Party equity, international grant aid and donations.

32.12. Financing institutions may impose a range of conditions precedent prior to making funds available, these may include various measures to improve the management of water resources and water budgets in the region including more rigorous demand managements measures and implementation of measures to improve the quality of the lower Jordan River. It must also be recognised that given the political context of the project financial institutions will undoubtedly require a wide range of commercial sureties including the adoption international water law and good practice, provision of sovereign guarantees (both unilateral and trilateral), take or pay contracts and the adoption of binding internationally recognised provisions for the resolution of disputes.

32.13. The cost of conflict and hence the benefits of peace for the region are enormous. The project in itself cannot bring about peace but, if structured properly, could have some impact on the peace and conflict process.

32.14. All six project configurations studied in detail are technically and economically feasible. It is believed that the environmental and social impacts can be managed to an acceptable level. The financial feasibility of the project is dependent on the ability to raise in excess of $ 4 billion in donations and grant aid to fund the environmental component of the project – to stabilise the level of and prevent further environmental degradation of the Dead Sea.