

# **Red Sea - Dead Sea Water Conveyance Project Feasibility Study**

## **Interim Report for Sub-Studies**

**25<sup>th</sup> September 2008**

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# Red Sea - Dead Sea Water Conveyance Project Feasibility Study

## Interim Report for Sub-Studies

### 1. Introduction

This Interim Report for sub-Studies is issued in response to Sections 18.2.3 and 18.3.2 of the Terms of Reference for the Red Sea – Dead Sea Water Conveyance Study Programme. As directed in the Terms of Reference the report is presented in three parts as follows:-

- A review of existing and ongoing studies to date and an analysis of gaps in information.
- A proposal for studies to be undertaken in Phase 2.
- An annotated outline of the proposed Sub-Studies Report.

### 2. Review of Existing and Ongoing Studies to Date

#### 2.1. Progress

Progress has previously been presented in Progress Report No.1 submitted on 26<sup>th</sup> June 2008, Progress Report No.2 / Inception Report submitted on 20<sup>th</sup> July 2008 and Progress Report No.3 submitted on 30<sup>th</sup> August 2008. The next Progress Report is due for submission on 8th October 2008. We are awaiting the final consolidated comments on the Inception Report from the World Bank and TSC members.

#### 2.2. Data Collection

A major data collection exercise has been undertaken throughout the region during the first three months of the Study Programme. A data room has been established in the Consultant's office in Amman and hard copies of all data collected are stored here. A dedicated electronic ftp site has also been established with access provided to all the Consultant's team members as required. All electronic data received, working papers and reports generated are stored on this site. It is also intended that critical data received in hard copy will be scanned and downloaded to the site.

The completeness of the data collection varies across the beneficiary parties and remains ongoing. The current status of the data collection exercise is as follows:-

- Jordan – the process is well advanced.
- Palestinian Authority – some published papers and a limited amount of very basic and high level data on economic development, water resources, water supply, power supply and power transmission has been obtained to date. However we have not obtained any detailed master planning for either water or power.
- Israel – some data and a substantial number of relevant published papers have been collected to date. However, we have been unable to obtain either water or

power supply master planning details and have been unable to meet with either electrical power authorities or the Ministry of Tourism.

### 2.3. Project Overview / Regional Context

An internal Project Overview was prepared in July 2008. This sought to outline the key project issues based on the preferred project configuration set out in the Pre-Feasibility Study, and to update these in light of the latest data and information obtained. The Project Overview was updated on 30<sup>th</sup> August to reflect further data and information collected.

An internal Economic Analysis Methodology Note and an internal paper on The Project Economic context have both been prepared.

A table of the comparative advantages and disadvantages of the main project configuration options has been prepared. A table setting out the boundary limits of the main project variables has also been prepared.

### 2.4. Appointment of Regional Experts and Specialised Institutions

Scopes of work have been agreed and contracts are being concluded with local engineering partners in Jordan, Israel and the Palestine Authority.

The main issues for which the Consultant requires the benefit of the knowledge and expertise of local and regional Specialised Institutions (SI's) are as follows:-

- Establishing the oceanographic physical and environmental baseline conditions in the Gulf of Aqaba / Eilat and determining the impact of large scale water abstractions on these baseline conditions.
- Establishing the baseline conditions for the seismology, hydrogeology, environment and socio economic conditions for the Wadi Araba / Arava Valley (including Aqaba, Eilat and the Dead Sea areas).
- Determining the impact of discharging Red Sea water into the Dead Sea on the physical, chemical and micro biological conditions of the Dead Sea water and determining the effects of mixing the two waters.
- Determining the impact of stabilising the Dead Sea level on the adjacent groundwater regime and the development of sink holes.

It has been established that the following are the three main SI's best placed to assist with these issues:-

- A consortium of the Israeli Oceanographic and Limnological Research institute, the Inter-University Institute for Marine Science, the Marine Science Station and Stanford University (IOLR-IUI-MSS)
- The Geological Survey of Israel (GSI)
- The Dead Sea and Arava Centre (DSAC)

We have had extensive dialogue and communication with all of these SI's but to date we have been unable to agree a scope of works with any of them that can be achieved within the budget or time-frame of the Feasibility Study. We have already addressed this

situation in our letter “New Proposal for the Work of the SI’s, Revision 1” dated 16<sup>th</sup> August 2008 and as stated, we believe that Special conditions of Contract Section 5.3 apply to the situation. The main issue would appear to be that the Feasibility Study was contracted on the understanding there was sufficient basic research available to address the Sub-Studies with only further project specific analysis of the data required; whereas the SI’s believe that further basic research and the development of additional tools is necessary. The current situation is that we have issued letters during week ending 5<sup>th</sup> September 2008 to each of the SI’s with a set of “focused questions”. We have requested that the SI’s provide a revised commercial proposal together with a detailed breakdown of the tasks necessary to address these focussed questions and the time needed to undertake each task. We await responses to these requests.

A contract has been concluded with Professor Oroud at Mu’tah University in Karak for the development of a *preliminary* energy mass balance model to predict evaporation rates in the Dead Sea. This subject is discussed in more detail below, under Section 2.7 – Dead Sea.

Discussions have taken place with a number of other regional experts in Jordan, Israel and the Palestinian Authority. Discussions and reviews are ongoing with a number of experts but these will not be concluded until the way forward is determined with, or without, the three main SI’s discussed above.

## 2.5. Expert Missions

A number of missions to the region by experts in the Consultant’s team have been undertaken as follows:-

- Public Consultation and Environmental Expert
- Hydrogeologist / Geologist
- Hydrologist
- Oceanographic Expert
- Water Mixing Expert
- Hydraulic Engineer
- Economic Strategist / Regional Economist
- Natural Resources Economist
- Environmental Economist

The purpose of these visits was to review available data, progress the data collection process, develop a better understanding of the project and develop plans for execution of the Options Screening and Sub-Studies. In each case the visiting experts have made extensive field trips throughout the region and Mission Reports have been prepared covering each of the visits.

In addition to the above referenced visits by technical experts both the Deputy Team Leader and the Engineering Section Team Leader have undertaken two missions to the region to review the available data and to progress the programme and engineering management of the Sub-Studies. The Team Leader has been resident in the region from the start of the Study Program.

## 2.6. Mapping

Digital topographical information has been prepared for the project area from the Gulf of Aqaba / Eilat to the Dead Sea area. Maps at a scale of 1/25,000 have been obtained (or 1/50,000 where 1/25,000 coverage is not available) and these have been scanned and geo-referenced. Fifty metre contour lines have been digitised from these maps from an elevation of +350m down to – 400m and incorporated into a ACAD file. This topographical information will now be used in the Options Screening and Evaluation process to define the possible options for the project layout and to assess these options.

## 2.7. Sub-Study A – Gulf of Aqaba / Eilat

The area has been visited and the alternative intake sites have been reconnoitred by the Study Team management and relevant experts. Meetings have been held with Aqaba Special Economic Zone Authority, Aqaba Development Corporation and Ayla company.

An internal Working Paper setting out the main issues, options, variables and methodology for Sub-Study A has been developed.

The options screening and evaluation process has commenced based on the currently available data and the activities described in sections 2.2 to 2.6 above. Alternative volumes of abstraction, intake locations, intake types and configurations, pumping station locations, pumping heads and pump station configurations are currently being evaluated.

Work has commenced on assessing the socio economic baseline and impacts in the Aqaba and Eilat area.

The oceanographic aspects of Sub-Study A cannot be progressed much further without recourse to a hydro-dynamic oceanographic model and the knowledge held by IOLR-IUI-MSS. Options are currently being explored for alternative sources of hydro-dynamic modelling.

## 2.8. Sub-Study B – Water Conveyance

The area has been visited and the potential alignment of the water conveyance has been reconnoitred by the Study Team management and relevant experts.

An internal Working Paper setting out the main issues, options, variables and methodology for Sub-Study B is under preparation.

The options screening and evaluation process has commenced based on the currently available data and the activities described in sections 2.2 to 2.5 above. Alternative horizontal alignments and vertical profiles together with different configurations of tunnel, pipeline and canal for a range of flow capacities are currently under review.

It is expected that Sub-Study B can progress to completion of the options screening and evaluation process without input from the SI's except for the final selection of intake and discharge locations on the Red Sea and Dead Sea respectively. However it will not

be possible to complete this Sub-Study without input from regional experts on the hydrology (particularly flash flood characteristics) and seismology along the water conveyance alignment and an assessment of the environmental and socio economic baselines for the region.

## 2.9. Sub-Study C – Dead Sea

The area surrounding the Dead Sea on both sides has been reconnoitred by the Study Team management and relevant experts. The chemical abstraction industry works have been visited and a workshop has been held with the chemical companies to explore both the impact of the industry on the decline of the Dead Sea and the impact to the industry of stabilising the Dead Sea at various levels.

An internal Working Paper setting out the main issues, options, variables and methodology for Sub-Study C has been developed.

A review of current literature and knowledge of the evaporation in the Dead Sea has been carried out. The subject of evaporation has also been extensively discussed during meetings and the workshop with the chemical abstraction companies and their advisor on this subject, Dr Kauffman of IMI TAMI Institute for Research and Development Ltd.

The available data covering the inflows and outflows of the Dead Sea has been reviewed. A *preliminary* water mass balance model has been developed for the "No Project Case" and is being calibrated by comparing predicted levels for historic years with actual recorded levels. A table of predicted levels, areas and volumes through to year 2050 for the "No project" scenario is currently under preparation.

Professor Oroud at Mu'tah University has been contracted to develop an energy mass balance sub-programme to predict evaporation and to integrate this with the *preliminary* water mass balance model to allow the model to be used for the project Base Case and Base Case Plus scenarios. The integrated preliminary model is expected to be available in the second half of October. However this model will not be able to analyse or predict the impacts of mixing Red Sea and Dead Sea water on the physical and chemical properties of the Dead Sea water or the impact of this mixing on stratification, stability and micro-biological effects in the Dead sea. A more sophisticated hydro-dynamic / chemical, two (or even three) dimensional model will be required for the analysis of these effects.

The options screening and evaluation process has commenced based on the currently available data and the activities described in sections 2.2 to 2.6 above. Alternative inflow volumes, alternative locations for the discharge point including distances from the shore and depths below the surface and types of discharge configuration are currently under consideration. Work will commence shortly on a review of potential target years and target levels using the *preliminary* water mass balance and energy mass balance models discussed above.

Qualitative assessment of the impact on the chemical industry has been assessed for a range of scenarios but this needs to be quantified.

Currently available information and research on the formation of sink holes has been reviewed.

Work has commenced on assessing the socio economic baseline and impacts for the Dead Sea and the immediately surrounding area.

It will not be possible to progress many aspects of Sub-Study C much further without recourse to previous work on developing a hydro dynamic model covering the physical, chemical and micro-biological parameters of the Dead Sea. GSI have advised that they have spent four years working on a one dimensional model but it is not complete and they will not complete it or make it available unless they are paid for it. Furthermore, it is still not clear whether a one dimensional model will be adequate to provide a robust answer to all of the tasks set out in the Terms of Reference.

#### 2.10. Sub-Study D – Hydro Power Facilities and Desalination Plant

The area has been visited and the potential alternative locations for a desalination plant and hydro power facility have been reconnoitred by the Study Team management and relevant experts.

An internal Working Paper setting out the main issues, options, variables and methodology for Sub-Study D is under preparation.

Brief internal discussion papers have also been developed setting out the basis for projecting the Jordanian water demands through to 2050 and for how return flows and increased waste water flows arising from increased supply will be dealt with in these projections.

The options screening and evaluation process has commenced based on the currently available data and the activities described in sections 2.2 to 2.6 above. Alternative elevations for a desalination plant are under consideration. The optimum utilisation of available head for both the desalination plant and hydro generation is currently under review based on:-

- comparative gross energy balance.
- comparative investment requirements.

In the absence of any detailed water master planning data for either Israel or the Palestinian Authority, neither the ultimate capacity of the desalination plant nor the development of the fresh water transmission designs can be progressed, unless these Beneficiary Parties give some formal indication of what volumes of fresh water they require from the project.

Work has commenced on a review of the options for an alternative “within Jordan” water supply project to meet future water demands in Amman which must be

developed for economic comparison with the study Base Case Plus. This will be a desalination plant at Aqaba with pumping and a pipeline to Amman.

### 2.11. Issues and Gaps in Information

In summary the issues and lack of information currently affecting the sub-studies are as follows:-

- Lack of detailed water resource, water supply, power generation and power transmission master planning data for Israel.
- Lack of detailed water resource, water supply, power generation and power transmission master planning data from the Palestine Authority.
- The need for formal confirmation of advice received informally that Israel will only take a small volume of water from the project to serve demand centres in the Dead Sea area and Arava Valley.
- Lack of information and data on the tourist industry relating to the Israeli section of the Dead Sea.
- The delay in appointing the principal Specialised Institutions and the disparity between the expectations of the Institutions and the budget and time-frame set for the Study Programme.
- The apparent need for further data collection and field work before hydro-dynamic models of either the Gulf of Aqaba / Eilat or the Dead Sea can be developed (it was expected at the bid stage of the Feasibility Study that models were either in existence or could readily be finalised on the basis of existing knowledge and research).

## 3. **Proposal for Studies to Be Undertaken in Phase 2**

### 3.1. Expert Missions

The following expert missions are planned for the remainder of 2008:-

<u>Position</u>	<u>Name</u>	<u>From</u>	<u>To</u>
Environmental Economist	Ramon Ortiz	31-Aug-08	25-Sep-08
Water Economist	Malcolm Summerfield	01-Oct-08	26-Oct-08
Geologist / Hydrogeologist	Jacques Schittekat	20-Oct-08	31-Oct-08
Tunnel Expert	Alain Van Cotthem	20-Oct-08	29-Oct-08
Environmental Co-ordinator	Jean-Luc Pigeon		T.B.A.
Desalination Expert	John Tonner		T.B.A.

### 3.2. Specialised Institutions

Work will continue with Mu'tah University and possibly also JUST to develop and refine the preliminary water and energy mass balance models for the Dead Sea as discussed above under Section 2.8 - Sub-Study C.

Efforts to reach agreement with the principle Specialised Institutions identified above will continue. Subject to reaching agreement with these institutions they will commence work on the full list of focused questions we have addressed to them. This will include but is not limited to:-

- The establishment of the environmental and socio economic baseline conditions across the project area including the Gulf of Aqaba / Eilat and the Dead Sea.
- The completion of development of hydro-dynamic models to assess the impacts of a range of water transfer volumes on the physical, chemical and aquatic biology of the of both the Gulf of Aqaba / Eilat and the Dead Sea.
- The assessment of any adverse chemical or physical effects on the Dead Sea caused by mixing Red Sea and Dead Sea water
- The assessment of the environmental impacts of the potential range of water transfers on the project area including the Gulf of Aqaba / Eilat and the Dead Sea.

### 3.3. Consultants Core Team and Experts

The complete study of the “No Project” case will be completed during 2008.

The preliminary water balance model will be used to develop preliminary projections of year on year water levels in the Dead Sea for various volumes of discharge and this will be used to assess a realistic range of possible target years and target levels.

An initial projection of water demands in the Jordan, Israel and Palestine Authority and how much these demands may potentially be met from the project will be made during October. This initial assessment will be used in the Options Screening process and the figures will be further developed and refined during the course of the sub-studies.

In the short term the focus of the Consultant’s core team will be on the options screening and evaluation process. This will address all of the options and variables discussed under the various sub-studies in Section 2 of this report. It will involve more detailed reconnoitring of the short listed locations and alignments and the development of technical and economic comparisons of the variables and options. The outcome of this process will be a limited short list of options, variables and configurations to be carried forward for detailed analysis in the sub-studies. A final Screening and Evaluation Report will be issued in December 2008. A schedule of tasks with nominated responsible parties and timelines has been prepared for the Options Screening and Evaluation process.

A scope of works for dedicated site specific survey, mapping, satellite imagery and geotechnical site investigations will be developed for the preferred options which emerge from the options screening and evaluation process and contracts will be let for this work. It is critical to the schedule of the overall Study Program that these contracts are awarded early in 2009.

Following completion of the options screening and evaluation process a set of design criteria will be developed for the key components of the project prior to commencement of the design integration, preliminary engineering design and costing.

Also following completion of the options screening and evaluation process a detailed comparison of the relative environmental impacts, the positive and negative attributes

and the relative investment requirements of each of the remaining options and variables will be undertaken.

#### **4. Annotated Table of Contents for the Sub-Study Report**

An annotated table of contents for the sub-study Report has been developed and is included with this report. The principle authors and an indicative length for each section are given in the table as required by the Terms of Reference.

Although it is not a Sub-Study per se we have included a section in the annotated table of contents on the “No Project Case”. This is because the “No Project Case” sets the baseline for a number of issues addressed in the sub-studies and as such its inclusions helps the story line.

It should be noted that the annotated table of contents has been drawn up on the basis that a speedy resolution is obtained to all of the issues and gaps in information discussed above and in particular that a speedy resolution is found to the issue of the appointment of Specialised Institutions.

It should also be noted that the annotated table of contents for the Sub-Study report is a live document and will inevitably evolve as the options screening and evaluation process and the sub-studies develop.

It is anticipated that the overall length of the Final Report on Sub-Studies will be in the order of 250 – 300 pages plus appendices.

# Red Sea - Dead Sea Water Conveyance Study Program

## Feasibility Study

### Sub-Studies Report

#### Annotated Table of Contents

Table of Content		Commentary	Author	Pages
<b>Executive Summary</b>		Summarise the studies and give a complete overview of the conclusions.	David Meehan	4 - 6
<b>1.0 Introduction</b>				
1.1	Background to The Sub-Studies	State objectives of this report and describe the sub-studies in the context of Pre-Feasibility Study, the Feasibility Study, other studies and Terms of Reference.	David Meehan	0.5 - 1
1.2	Regional Context	High level summary of regional context in terms of demographics and economics relevant to the sub-studies with particular reference to water economics.	Jeremy Berkhoff	1 - 2
1.3	Methodology	Summary of phasing and methodology adopted in the sub-studies.	David Meehan	1
1.4	Contents of Report	Description of the contents of the report.	David Meehan	0.5
<b>2.0 No Project Case</b>				
2.1	History	Discuss the decline in the River Jordan and the historic fall in level of the Dead Sea	David Meehan	0.5 - 1
2.2	Meteorology	Review present historic data for Dead Sea weather parameters. Quantify the contribution of direct surface precipitation to the water balance of the Dead Sea. Discuss the micro climate(s) of the dead Sea and how these may change as the sea level changes and with the effects of global climate change. Make projections for future weather parameters with particular emphasis on those affecting precipitation and evaporation.	Henri Garros	1 - 3

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2.3	Hydrology	Identify all sources of river flow and surface run off into the Dead Sea and review the available data. Assess the contribution of irrigation and waste water return flows to this. Identify the impact of dams and water abstraction schemes on run off and river flows reaching the Dead Sea. Review available data and discuss the current situation, historic trends and future projections. Quantify the current, historic and future contribution of surface run off and river flows to the Dead Sea water mass balance. Review frequency and intensity of flash floods. Identify the impact of falling Dead Sea levels on volume and intensity of runoff and the erosion so caused.	Henri Garros	2 – 4
2.4	Hydrogeology	Identify the limits of aquifers affected by the Dead Sea water levels. Describe the current aquifer parameters, describe how these have responded to the historic falls in the Dead Sea water level and project how they will continue to react in the No Project Case in the future. Identify current abstractions from the affected aquifers, review the available data and discuss the quality and quantity of abstracted water. Review how abstractions might change in the future in light of changed demand / usage of water and falling aquifer levels. Discuss the aquifer water levels and the fresh / saline interface and project how this will react to a continuing fall in the Dead Sea water level in the No Project Case. Discuss and quantify the contribution of groundwater depletion to the Dead Sea water mass balance and how this will develop as the dead Sea water level continues to fall in the No Project Case. Reference Sections 2.7 below. Quantify the volume of groundwater depletion and continued lowering of the groundwater level as the Dead Sea continues to decline in level as described in Section 2.8 below.	Jaques Schittekat	3 - 6
2.5	Chemical Industry	Review the historical development of the chemical industries and their contribution to the regional economies. Identify the changes in operating practices adopted by the Chemical industries to accommodate the historic falls in Dead Sea level. Review the future development plans of the chemical industry. Quantify the historic abstractions and return flows of the chemical industry and project future patterns. Discuss the impact of this on the contribution of the chemical industries to the fall in level of the Dead Sea.	David Meehan	2 – 3
2.6	Evaporation Research and Modelling	Discuss the complexities of determining evaporation in hyper saline waters and the application of this to the determination of evaporation of the Dead Sea. Review past literature and research on evaporation of the Dead Sea. Present and explain both the preliminary energy mass balance model produced by Professor Oroud and the more sophisticated dynamic model prepared by (GSI) for determination of evaporation. Quantify current evaporation based on the model and compare this with the results of	Yousef Soudani	3 – 5

Table of Content		Commentary	Author	Pages
		previous research. Discuss the accuracy and limitations of the modelling.		
2.7	Dead Sea Water Mass Balance for the No project Scenario	Summarise and discuss all of the inflow and outflow components of the Dead Sea water mass balance with reference to sections 2.1 to 2.6 above. Discuss the complex interaction between groundwater depletion and evaporation. Refer to the evaporation modelling discussed in Section 2.6. Describe the nature of the water mass balance model and the integration of the evaporation modelling into the water mass balance model. Discuss the final model inputs / outputs.	Yousef Soudani	5-8
2.8	Dead Sea Water Levels	Present the output of the Dead Sea water mass balance model and the best predictions for the continuing decline in the Dead Sea through to year 2050. Present year on year water level, area and volume through to year 2050. Discuss the range of uncertainty in these predictions and the impact of climate change within that range of uncertainty. Discuss the potential for the Dead Sea to stabilise at some future reduced level due to increased salinity and the impact of the chemical industry may have on this.	Yousef Soudani	2 – 3
2.9	Evolution of Sink Holes	Describe the historic development of sink holes. Review and discuss the geological / soil matrix context and available data on the mechanism for the development of sink holes. Draw conclusions and make projections on the future development of sink holes as the Dead Sea continues to decline in the No project Case.	Jaques Schittekat	2 – 3
2.10	Baseline Conditions	Describe the current baseline climatological, physical, chemical and micro-biological condition of the Dead Sea with reference to past studies and the current modelling.	Jean-Luc Pigeon	4 - 6
2.11	Environmental Impacts	Review the environmental impacts of the continuing fall in the Dead Sea in the No Project Case:- in terms of Dead sea water level, quality, chemistry and micro-biology; in terms of the exposed foreshore and visual impacts; in terms of the ground water levels and regimes; in terms of the impact on flora and fauna in the immediate vicinity of the Dead Sea.	Jean-Luc Pigeon	2 – 3
2.12	Socio Economic Impacts	Review the socio economic impacts of the continuing fall in the Dead Sea water levels in the No Project Case:- in terms of the impact on local residents and local agriculture and business, in terms of the impact on the tourism industry; in terms of the impact on the chemical industry. Discuss the net effects of all these impacts on the economies of each of the beneficiary parties.	Ramon Ortiz	3 – 4
2.13	Preliminary Conclusions – No Project Case	Summarise projected future evolution of the Dead Sea in the No Project case and draw conclusions on the overall impact of this.	David Meehan	3 - 4

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<b>3.0 Conclusions from the Project Options Screening and Evaluation Report</b> <b>(***Note:- This section will present a <u>summary</u> of the findings of the earlier Options Screening and Evaluation Report)</b>				
3.1	Screening Process	Set out the initial options framing and discuss the generic screening process.	David Meehan	1
3.2	Rates of Abstraction from the Red Sea.	Will be three rates. Possibly 30, 45 and 60 m <sup>3</sup> /sec (1.0, 1.5 and 2.0 billion m <sup>3</sup> /year)	David Meehan	0.5 - 1
3.3	Location of Intake works	Will probably be two intake locations with a provisional view of which is the optimum.	David Meehan	0.5 - 1
3.4	Pump Station Location	Will probably be one pump station location for each of the two intake locations.	David Meehan	0.5 - 1
3.5	Water Conveyance Capacity	Same as 3.1 above.	David Meehan	0.5
3.6	Water Conveyance Level and Alignment	A single outline conveyance level and alignment between the provisional optimum intake location on the Gulf of Aqaba and the provisional optimum discharge location on the Dead Sea.	David Meehan	0.5 - 1
3.7	Rate of Discharge to the Dead Sea	For the Base Case this will be the same as 3.2 and 3.5 above. For the Base Case Plus this will be the volumes determined in 3.2 and 3.5 above less the volume of desalinated fresh water produced as determined in 3.11 below (i.e. up to a maximum possible nine variants but it is expected this will be reduced to between four and six variants).	David Meehan	0.5 - 1
3.8	Location of Discharge to Dead Sea	Will probably be two locations with one at the southern end of the Dead Sea to minimise conveyance length and hence cost and one further north on the Dead Sea to reduce risk and exposure to the chemical abstraction industry.	David Meehan	0.5 - 1
3.9	Location and Configuration of Desalination Plant and Hydro Power Facility	A single outline combined configuration for the desalination plant and hydro power facility based on a gross energy analysis and a comparison of the total investment cost for each option considered.	Etienne Frossard	1 - 2
3.10	Capacity of the Desalination Plant	Probably either two or three capacities depending on 3.11 below. Could possibly be 12.7, 19.0 and 25.4 m <sup>3</sup> /sec (400 million, 600 million and 800 million m <sup>3</sup> /year).	David Meehan	1 – 2
3.11	Potable Water Demand	Probably either two or three capacities. The values will depend on the latest water demand projections for Jordan and confirmation of likely quantities to be supplied to Israel and Palestine. Could possibly be 12.7, 19.0 and 25.4 m <sup>3</sup> /sec (400 million, 600	David Meehan	1 – 2

Table of Content		Commentary	Author	Pages
		million and 800 million m <sup>3</sup> /year).		
3.12	Fresh Water Transmission	Identification of the demand centres to be supplied. An outline routing from the desalination plant to the demand centres to be supplied.	Yousef Soudani	2 - 3
3.13	Target Year and Target Level	A range of potential target years and target levels based on the range of possible rates of abstraction from the Red Sea (3.1 above) and possible capacities for the desalination plant and potable water demand projections (3.10 and 3.11 above).	David Meehan	1- 2
<b>4.0 Sub-Study A – Gulf of Aqaba / Eilat</b>				
4.1	Objectives of Sub-Study A	Briefly set out the objectives of Sub-Study A	David Meehan	0.5
4.2	Data and Methodology	Review relevant current data and knowledge and identify any deficiencies. Discuss the additional studies carried out by Specialised Institutions and how this addresses the deficiencies. Provide an overview of the methodologies used in Sub-Study A.	David Meehan	1 - 2
4.3	Baseline Conditions	Review and establish the baseline physical, chemical, biological and pollution conditions of the Gulf of Aqaba / Eilat. Project how these baseline conditions will develop with time if there is no project. Provide an overview of the current state of health of the Gulf of Aqaba / Eilat. Determine which of the baseline conditions will be sensitive to the type, location and volume of the water abstraction.	Michael Krom	4 – 6
4.4	Impact of Abstraction on the Red Sea Environment	Introduce and discuss the need for, and work carried out on, oceanographic modelling. Use the oceanographic model to review the impact of abstracting the volumes identified in Section 3.2 from the Gulf of Aqaba / Eilat at each location as identified in Section 3.3 above. Particular attention will be given to impacts on sea temperature, currents upwelling and downwelling, movement of coral larvae and general impact on the marine eco-system. Explore the sensitivity of the prevailing environment to both distance from the shoreline and depth below the water surface for the abstraction point at each location. Highlight any environmental constraints on abstraction volumes, distances from the shoreline and depths below the surface for each location. Establish the ranking of each site in terms of impact on the Red Sea environment.	Michael Krom	4 – 6
4.5	Location of Intake Works	Review the positive and negative attributes of the potential sites identified in Section 3.3 in terms of compatibility with adjacent land use and land use planning, visual impact, topography, physical constraints, accessibility, geotechnical conditions, hydrology and flood risk, pollution risk and environmental impact. Review the relative impact of the two sites on the overall system costs. Identify the preferred location.	Etienne Frossard	2 – 3
4.6	Types of Intake Works	Identify the range of generic design types for the intake works. Discuss the positive and	Andre	3 - 4

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		negative attributes of each type of intake design. With references to Sections 4.4 and 4.5, identify the constraints (environmental, physical , aesthetic, navigational etc) on the choice of intake type at each location. Review the appropriateness of each type of design for each of the locations with reference to the findings of Section 4.4 and 4.5. Recommend the single most appropriate intake type for each location.	Lejeune	
4.7	Ancillary Intake works	Consider the need for, and the solutions to, fish screens, trash racks, de-sanding, sediment settlement, filtration, pre-treatment and controls at the intake works.	Andre Lejeune	2 - 3
4.8	Pump Station Location	Review the positive and negative attributes of the potential sites identified in Section 3.4 in terms of compatibility with adjacent land use and land use planning, visual impact, topography, physical constraints, accessibility, geotechnical conditions, hydrology and flood risk, pollution risk and impact on the overall water transfer system configuration. Review the environmental impact of a pump station at each site with particular reference to impacts on noise, visual intrusion and impact on surrounding land use and activities. Develop a comparative ranking of the options.	Etienne Frossard	2 - 3
4.9	Pumping Configuration and Riser Mains	Establish the potential pumping heads required based on the conclusions in 3.6 above. Develop general layouts with key dimensions and main characteristics for the pump station and pumping configuration to meet the pumping heads indicated in Section 3.6 for each of the flow rates identified in Section 3.2 above.	Daniel Fayolle	2 - 3
4.10	Intake Canal	Review options and determine the most appropriate type (pipeline, canal, box culvert etc) and configuration for the inlet channel to connect the inlet works to the pump station for each of the flow rates identified in Section 3.2 above at each location. Develop general arrangements with key dimensions for each configuration. Review the groundwater regime and quality and determine its sensitivity to leakage of sea water and the need for any special mitigation measures such as leakage containment.	Andre Lejeune	1 – 2
4.11	Optimisation and Design of Intake and Pump Station Configuration	Summarise the options for intake works and pumping configuration discussed in Sections 4.5 to 4.10 above. Determine the optimum configuration of intake and pumping facilities for each of the three possible abstraction rates indicated in Section 3.2 above. Provide a general layout of the optimum configurations with key dimensions. Determine the specific requirements for protection of the main electrical and mechanical equipment from corrosion caused by the salty water. Discuss the operating logistics including manning levels, spare parts requirements, support facilities required and type and volume of industrial waste that will be generated. Provide a schematic layout for the required permanent supporting infrastructure	Etienne Frossard	3 - 5

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		(access roads, workshops, warehouses, offices accommodation, power supply, water supply sewerage etc.). Discuss the operating logistics including manning levels, spare parts requirements, support facilities required and type and volume of industrial waste that will be generated.		
4.12	Power Supply and Transmission	Review the availability of power generation capacity and the options for power transmission routings to the optimum pump station and pumping configuration indicated in Section 4.11. Provide a schematic layout of the proposed transmission arrangement. Review the impact on air quality as a result of the increased power generation required. Review the impacts of the transmission line routing.	Peter Vaessen	1 – 2
4.13	Environmental Impacts	Drawing on Sections 4.1 to 4.12 review the type and magnitude of environmental impacts (both oceanographic and terrestrial) for the optimum intake and pumping arrangement described in Section 4.11.	Jean-Luc Pigeon	2 - 4
4.14	Socio Economic Impacts	Drawing on Sections 4.1 to 4.13 review the nature and magnitude of socio economic impacts for the optimum intake and pumping arrangement described in Section 4.11. Particular attention will be given to impacts on the regional economy, navigation, recreation, fishing and transport systems both during construction and operation. Review potential mitigation measures.	Ramon Ortiz	2 - 3
4.15	Costs of Intake Works and Pumping Station	Develop construction, operation and maintenance costs and a life cycle net present value for the intake and pumping configuration described in Section 4.11.	Francois Halgand	2 - 3
4.16	Conclusions – Sub-Study A	Summarise the state of health of Gulf of Aqaba / Eilat. Summarise the optimum intake and pumping arrangement. Summarise the oceanographic and terrestrial impacts both during construction and during operation of the optimum intake and pumping arrangement. Summarise the construction, operation and maintenance costs.	David Meehan	4 - 6
<b>5.0 Sub-Study B – Water Conveyance</b>				
5.1	Objectives of Sub-Study B	Briefly set out the objectives of Sub-Study B	David Meehan	0.5
5.2	Data and Methodology	Review relevant current data and knowledge and identify any deficiencies. Discuss the additional studies carried out by Specialised Institutions and how this addresses the deficiencies. Provide an overview of the methodologies used in Sub-Study B. Discuss the validity of optimising the conveyance system configuration for the median potential flow volume and the applicability of the results for higher and lower flow volumes.	David Meehan	1 – 2
5.3	Geotechnical Setting	Provide a broad overview of the topographical, geological and seismological conditions	Jacques	3 - 4

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		of the Wadi Araba / Arava Valley, and the significance to the project.	Schittikat	
5.4	Hydrological Setting	Provide a broad overview of the climate and hydrology of the Wadi Araba / Arava Valley with particular reference to severe flood frequency, magnitude and routing, and the significance to the project.	Henri Garros	3 - 4
5.5	Hydrogeological Baseline	Review the general groundwater regime of the Wadi Araba / Arava Valley. Describe the aquifers, their extent and interconnectivity and quantify current water quality, water levels, usage and abstraction.	Jacques Schittikat	4 - 6
5.6	Environmental Baseline	Establish the environmental baseline of the Wadi Araba / Arava Valley in terms of land use, flora, fauna, culture, heritage and the like. Identify those aspects of the environment that are likely to be most sensitive to construction and operation of the project.	Jean-Luc Pigeon	4 - 6
5.7	Conveyance Types	Introduce the range of possible water conveyance types (pipeline, tunnel, canal, box culvert etc.) and discuss the positive and negative attributes of each. Develop approximate dimensions for each of these types for the transfer flow volumes established in Section 3.4. Develop principles of hydraulic regulation and control for stability with regard to transients.	Andre Lejeune	4 - 6
5.8	Conveyance Level and Alignment	Review the trade off between conveyance costs for different levels of conveyance (which will largely be driven by the length of tunnel inherent in each) and the cost of pumping up to different levels. Review and refine the broad conveyance alignment and level proposed for the provisional optimum conveyance configuration identified in Section 3.6 with particular reference to Sections 5.3 and 5.4. Consider any variations in optimum solution between the Base Case and Base Case Plus scenarios.	Eric Waeffelaert	4 - 6
5.9	Conveyance Design	Quantify and dimension the lengths of tunnel, canal and pipeline in the conveyance system for the conveyance configuration identified in Section 5.8 and for each of the flow rates identified in Section 3.5. Consider any variations in optimum solution between the Base Case and Base Case Plus scenarios. Provide an alignment plan, a level profile and a general arrangement with key dimensions for the optimum configuration(s) for each of the transfer flow rates identified in Section 3.5 above. Outline the likely number and location of construction camps, tunnel access portals/shafts and work faces needed for construction. Provide a schematic layout for the required permanent supporting infrastructure (access roads, workshops, warehouses, offices accommodation, power supply, water supply sewerage etc.).	Francois Halgand	4 - 6

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5.10	Groundwater Protection	With reference to Section 5.5 review the groundwater regime along optimum conveyance alignment. Identify the aquifers that will be sensitive to both drainage during tunnel construction and leakage of sea water from the conveyance during operations. Assess possible design solutions to limit risks of leakage.	Jacques Schittikat	2 – 3
5.11	Environmental Impacts	Drawing on Sections 5.1 to 5.10 review the type and magnitude of environmental impacts for the provisional optimum conveyance configurations identified in Sections 5.8 and 5.9.	Jean-Luc Pigeon	3 - 4
5.12	Socio Economic Impacts	Drawing on Sections 5.1 to 5.11 review the nature and magnitude of socio economic impacts for the provisional optimum conveyance configurations identified in Sections 5.8 and 5.9.	Ramon Ortiz	2 - 3
5.13	Costs	Develop construction operation and maintenance costs and a life cycle net present value for the optimum conveyance configuration for each of the flow volumes identified in Section 3.6.	Francois Halgand	3 - 4
5.14	Conclusions – Sub-Study B	Summarise the state of the environmental health of the Wadi Araba / Arava Valley along the alignment of the provisional optimum conveyance route. Summarise the optimum conveyance configuration for both the Base Case and Base Case Plus. Summarise the environmental and socio economic impacts of the optimum conveyance configuration both during construction and during operations. Summarise the construction, operations and maintenance costs.	David Meehan	4 - 6
<b>6.0 Sub-Study C – Dead Sea</b>				
6.1	Objectives of Sub-Study B	Briefly set out the objectives of Sub-Study C	David Meehan	0.5
6.2	Data and Methodology	Review relevant current data and knowledge and identify any deficiencies. Discuss the additional studies carried out by Specialised Institutions and how this addresses the deficiencies. Provide an overview of the methodologies used in Sub-Study C	David Meehan	1 – 2
6.3	Baseline Conditions	Describe the current baseline climatological, physical, chemical and micro-biological condition of the Dead Sea with reference to past studies and the current modelling.	Jean-Luc Pigeon	4 - 6
6.4	Mixing of Red Sea and Dead Sea Water	Review the potential issues with regard to mixing of the waters (physical changes, chemical changes, stratification, potential for instability and turn over, potential for chemical precipitation, potential for micro biological blooms, potential to influence changes in micro climate etc) that could have an impact on the baseline conditions established in Section 6.3 above. Describe the hydro-dynamic modelling undertaken to analyse these potential impacts. Model the mixing and impacts of Red Sea and Dead	Tal Ezer	6 - 10

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		Sea water for the range of discharge flows established in Section 3.7 above. Discuss the hydro-dynamic model inputs and outputs. Quantify the likely risks and extent of the impacts. Use the model to test the sensitivity of the risks and impacts to a variety of depths and distances from the shore line for the discharge point. Model the plume of Red Sea water that will develop for each of the possible inflow volumes identified in Section 3.7 and determine the maximum extent of the mixing front from the discharge point. Review the nature and extent of any plume of chemical (gypsum ?) precipitation that might occur. Consider various alternative discharge configurations including diffusers, mechanical mixing, multiple discharge points and etc. to improve the efficiency of mixing. Establish whether the mixing process places an upper limit on the rate of discharge to the Dead Sea below 2 billion m <sup>3</sup> /year.		
6.5	Location and Configuration of Discharge to the Dead Sea	Based on Section 6.4 review the optimum configuration for a southern discharge point in the Dead Sea with particular reference to distance from the shoreline and depth below the surface. Review whether there is any difference in the impact to the chemical industry between discharging through the Truce Canal, as proposed in the Pre-Feasibility study, or discharging into the bay on the eastern side of the Lissan peninsula. Select a preferred southern discharge location. Again with reference to Section 6.4 review the risks and exposure to the chemical industry of the southern discharge location and review how any risk and exposure to the chemical industry would be reduced if the discharge point is moved northwards away from the chemical industry intakes.	Tal Ezer	4 - 6
6.6	Design of Discharge Works	Determine a general arrangement for a discharge works at the southern end of the Dead Sea based on the optimum depth below the surface and distance from the shoreline, as determined in section 6.6 above. Consider the residual energy and review the need for energy dissipation and / or scour protection at the discharge point. With reference to Section 6.5 establish a location for a discharge point sufficiently far north of the chemical industry abstraction points to minimise impact to the industry. Provide a general layout with key dimensions for the discharge works covering the range of discharge flows identified in Section 3.7. Provide a schematic layout for the required permanent supporting infrastructure (access roads, workshops, warehouses, offices accommodation, power supply, water supply sewerage etc.).	Andre Lejeune	3 - 4
6.7	Dead Sea Water Mass Balance	Review the impacts of the mixing of Red Sea and Dead sea water on the factors influencing evaporation. Discuss how these are addressed and dealt with in the water mass balance model discussed in Section 2.6. Review all of the water mass balance	Yousef Soudani	5 – 8

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		inputs and outputs discussed in Section 2.6 and evaluate how these will differ for the Base Case and Base Case Plus scenarios. Review model inputs and outputs for the range of potential flows identified in Section 3.7 through to the year 2050.		
6.8	Target Levels and Target Years	Using the Dead Sea water mass balance model discussed in Section 2.7 and 6.7 above establish year on year water levels for the Dead Sea through to 2050 for each of the possible volumes of discharge to the Dead Sea established in Section 3.7 above. Establish the years and levels at which the Dead Sea will stabilise for each of the possible volumes of discharge to the Dead Sea established in Section 3.7 above.	David Meehan	2 – 3
6.9	Groundwater Impacts	Discuss how the hydrogeology established in Section 2.4 above will be affected by the changing Dead Sea levels as established in Section 6.8 above with particular emphasis on effects on ground water table levels, ground water quality and saline intrusion.	Jacques Schittikat	3 - 4
6.10	Sink Holes	Reference section 2.9. Describe how the development of sink holes will be influenced by the range of possible levels in the Dead Sea in the Base Case and Base Case Plus scenarios and the eventual stabilisation of the Dead Sea level. Draw conclusions and make projections on the future development in terms of extent and time of sink holes for the range of inflows, target levels and target years.	Jacques Schittikat	3 - 4
6.11	Environmental Impact	Drawing on Sections 6.1 to 6.10 review the type and magnitude of environmental impacts on the Dead Sea and immediately surrounding land for the range of possible inflows identified in Section 3.7 and the range of target years and target levels identified in Section 6.8. Review potential mitigation measures.	Jean-Luc Pigeon	4 - 5
6.12	Socio Economic Impacts	Drawing on Sections 6.1 to 6.11 review the nature and magnitude of socio economic impacts of stabilising the Dead Sea at the range of target years and target levels identified in Section 6.8. Particular attention will be given to impacts on the regional economy, tourism and the chemical industry. Review potential mitigation measures.	Ramon Ortiz	2 - 3
6.13	Cost of Discharge works	Develop construction operation and maintenance costs and a life cycle net present value for southern discharge point for the range of possible inflow volumes identified in Section 3.7. Establish the cost to the chemical works arising from a discharge point at the southern location. Establish the differential cost including (increased conveyance costs) to move the intake location to the northern discharge location established in Section 6.6 and compare this to the savings to the chemical industry as a result.	Francois Halgand	2 - 3
6.14	Conclusion of Sub-Study C	Summarise the chemical, physical and micro-biological impacts of adding Red Sea Water to the Dead Sea. Summarise the options for stabilising the Dead Sea at different target levels and target years. Summarise the cost of the discharge works at the	David Meehan	4 – 6

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	southern end of the Dead Sea. Summarise the cost of moving the discharge point to the northern discharge point and review the cost / benefits of this. Recommend the optimum an discharge location.		
<b>7.0 Sub-Study D – Hydro Power facilities and Desalination Plant</b>			
7.1 Objectives of Sub-Study B	Briefly set out the objectives of Sub-Study D	David Meehan	0.5
7.2 Data and Methodology	Review relevant current data and knowledge and identify any deficiencies. Discuss the additional studies carried out by Specialised Institutions and how this addresses the deficiencies. Provide an overview of the methodologies used in Sub-Study D	David Meehan	1 – 2
7.3 Water Demands	Review the water master planning and water demand projections of each of the Beneficiary Parties. Assess the likely impact of increased supply on waste water and return flows on the overall water demand and supply situation. Assess likely demands for fresh water from the project at the demand centres identified in Section 3.12 through to 2050.	Malcolm Summerfield	6 - 10
7.4 Combined Configuration of Desalination Plant and Hydro Power Facility	Determine the ultimate capacity of the desalination plant. Review the options and relative merits of sizing the hydro power facilities for the early available rates of flow (maximum) versus the long term (and reduced) steady state flow after the design fresh water demand capacity has been reached. Determine the capacity of the hydro facility to be built. Compare options for different penstock configurations. Refine the combined configuration of the desalination plant and hydro power facility outlined in the options and screening process.	Francois Halgand	4 - 6
7.5 Design of Desalination Plant	Review available desalination technologies and select the preferred technology. Review requirements for pre-treatment. Review the arrangements for energy recovery. Review source, frequency of replacement and cost of membranes. Review water demand growth and recommend an appropriate phased development. Provide a general arrangement of the recommended pre-treatment and desalination facilities with key dimensions. This general arrangement will include return of the reject brine to the water conveyance to the Dead Sea. Discuss the operating logistics including manning levels, spare parts and chemicals requirements, support facilities required and type and volume of industrial waste that will be generated.	John Tonner	6 - 10
7.6 Cost of Desalination Plant	Develop construction, operation and maintenance costs and a life cycle net present value for the desalination plant described in Section 7.5.	John Tonner	2 - 3

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7.7	Design of Hydro Power Facility	Determine the number and types of turbines to be adopted. Determine the final penstock configuration. Determine the characteristics of the main electrical and mechanical equipment required. Determine the specific requirements for protection of the main electrical and mechanical equipment from corrosion caused by the salty water. Provide a general arrangement of the recommended hydro facilities with key dimensions. Discuss the operating logistics including manning levels, spare parts requirements, support facilities required and type and volume of industrial waste that will be generated.	Daniel Fayolle	6 - 10
7.8	Cost of Hydro Facilities	Develop construction, operation and maintenance costs and a life cycle net present value for the hydro facilities described in Section 7.7.	Daniel Fayolle	2 - 3
7.9	Potable Water Transmission Alignment and Pumping Configuration	Refine and optimise the outline alignment and pumping configuration determined in the options screening and evaluation process. Establish need for, and capacity of, balancing storage / service reservoirs. Develop preliminary designs for the potable water pumping and transmission system(s).	Yousef Soudani	4 - 6
7.10	Cost of Potable Water Pumping and Transmission System.	Develop construction, operation and maintenance costs and a life cycle net present value for the potable water pumping and transmission facilities described in Section 7.9.	Francois Halgand	2 - 3
7.11	Control and Communication Systems	Determine the control and communication requirements, establish a control and communication philosophy and develop an outline design for a SCADA system. This will embrace the facilities considered under Sub-Studies A, B and C as well as Sub-Study D	Daniel Fayolle	2 - 3
7.12	Cost of Control and communication System	Develop construction, operation and maintenance costs and a life cycle net present value for the hydro facilities described in Section 7.7.	Daniel Fayolle	1 - 2
7.13	Power Transmission	Review the capacity of the power grid to both provide the net power requirements of the project and receive power from the hydro facility. Review the overall power balance of the desalination plant, hydro facility and potable water pumping and transmission system. Develop schematic layouts and main characteristics for the power transmission linking the desalination plant, hydro facilities and potable water pumping and transmission systems to the grid.	Peter Vaessen	2 - 3
7.14	Cost of Power Transmission	Develop construction, operation and maintenance costs and a life cycle net present value for the transmission system and net energy requirements of the desalination plant, hydro facilities and potable water pumping and transmission systems.	Peter Vaessen	1 - 2
7.15	Environmental Baseline	Establish the environmental baseline covering the location of the desalination plant, the location of the hydro power facilities and the route of the potable water	Jean-Luc Pigeon	2 - 4

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		transmission system in terms of land use, flora, fauna, culture, heritage and the like. Identify those aspects of the environment that are likely to be most sensitive to construction and operation of the project.		
7.16	Environmental Impacts	Drawing on Sections 7.1 to 7.15 review the type and magnitude of environmental impacts for the desalination plant, hydro power system and potable water pumping and transmission system.	Jean-Luc Pigeon	3 - 6
7.17	Socio Economic Impacts	Drawing on Sections 7.1 to 7.16 review the nature and magnitude of socio economic impacts for the desalination plant, hydro power system and potable water pumping and transmission system.	Ramon Ortiz	2 - 4
7.18	Conclusion of Sub-Study D	Summarise water demand projections. Summarise the overall configuration for the desalination plant, hydro facilities and potable water pumping and transmission. Summarise the environmental and socio economic impacts of the desalination plant, hydro facilities and potable water pumping and transmission. Summarise the costs.	David Meehan	4 - 6
<b>8. General</b>				
8.1	Schedule	Discuss construction methodologies and develop an overall project construction schedule	Etienne Frossard	2 - 4
8.2	Construction Logistics	Review and quantify construction logistics. Review capacity of existing infrastructure to support construction. Establish any potential bottlenecks in the supply chain. Discuss waste that will be generated during construction and appropriate waste management practices to be adopted.	David Meehan	2 - 4
8.3	Operational Logistics	Review and quantify operational logistics. Review capacity of existing infrastructure to support operations. Establish any potential bottlenecks in the supply chain. Discuss waste that will be generated during operations and appropriate waste management practices to be adopted.		

**Overall editing – David Meehan**

**Overall length – circa 250 pages**