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Final

December 2014 EAPC Pipeline Spill: Report of the Professional Consultant to the Mediator

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December 2014 Evrona Oil Spill: Report of the Professional Consultant to the Mediator

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Acronyms and Abbreviations

AEGL-1	EPA Acute Exposure Guideline Level 1 values
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
ALOHA	Areal Locations of Hazardous Atmospheres
API	American Petroleum Industry
CERCLA	Comprehensive Environmental Response, Compensation, and Liability
CSM	conceptual site model
DOI	U.S. Department of the Interior
DOJ	U.S. Department of Justice
dSTY	discounted service tree-years
DWHOS	Deepwater Horizon Oil Spill
EAPC	Eilat-Ashkelon Pipeline Company
EPA	U.S. Environmental Protection Agency
EU-/JRC	European Union-/Joint Research Center
HaMaarag	National Ecosystem Assessment Program
HEA	habitat equivalency analysis
INPA	Israel Nature and Parks Authority
LDD	LDD Advanced Technologies Ltd
MoEP	Ministry of Environmental Protection
MRL	Minimal Risk Level
NASA	National Aeronautics and Space Administration
NIOSH	U.S. National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRD	Natural Resource Damages
NRDA	Natural Resource Damage Assessment
OPA	Oil Pollution Act of 1990 Act
PCM	Professional Consultant of the Mediator
REA	resource equivalency analysis
TPH	total petroleum hydrocarbons
UNEP	United Nations Environment Programme
USDA	U.S. Department of Agriculture

Limitations

This report summarizes work performed to date and presents the findings resulting from that work. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available through ongoing discovery or through any additional work or review of additional work performed by others.

Executive Summary

The December 2014 release of 5,000 m^3 of crude oil from the Eilat-Ashkelon Pipeline Company (EAPC) pipeline near the Be'er Ora intersection with Route 90 resulted in the worst oil spill in Israel's history. The released oil caused complaints of nausea and unease from some local Be'er Ora citizens and from individuals 15–20 km away in Eilat. The released oil traveled south along the west side of Route 90 and ultimately crossed the road and entered a large wadi system traversing the length of the Evrona Nature Reserve.

The spill has resulted in multiple class action suits, a civil action, and government actions, and the parties have entered into a mediation process in an attempt to resolve their differences. My role in this mediation is as Professional Consultant of the Mediator (PCM) with the scope of my analysis focused on addressing a series of questions agreed to and provided by the parties (see Appendix B) and in assisting the mediators (Adv. Gabrieli and Adv. Wiesengrun) in addressing other issues in dispute set forth by the parties.

Based on my experience with oil spill injury assessment, on my meetings with the plaintiffs and the defendants, on discussions with the mediator, and on the review of information from the open literature and provided by the parties, the following opinions/answers are provided regarding the change questions presented by the parties:

1. *Was damage caused and ecological environmental hazards following the event, including to the ecological system and to biodiversity, damage to quality of life, convenience and wellbeing and the perception of the quality of life and if yes – what is this damage and hazards (whether they can be rehabilitated or no* [sic] *including damage which has not yet been finally formed including the cost of monitoring and the cost of rehabilitation as a result of the event and the cost as a function of the rehabilitation time to the extent it is possible to rehabilitate). All while referring to actions performed and that are being performed on the ground today, and referring to the chapters of damage in the pleadings filed by the Applicants/the Plaintiffs and the answers to these claims in the pleadings filed by the Respondents/the Defendants.*

As noted in my report, to ensure clarity in what is being discussed, I have defined "impacts" to the environment/ecology as injury to those resources and will reserve the term "damages" for the costs associated with restoring or rehabilitating the injury. In reviewing the pertinent information associated with the spill, the response, and the short- and long-term impacts from the spill, I find the following:

1.1. The release of oil from the EAPC pipeline on December 3, 2014 did result in ecological injury. Specifically, this injury occurred in the Evrona Nature Reserve because of the soil penetration and saturation of oil that flowed through active stream channels in the nature reserve. Golan et al. (2016) pointed out that most vegetation in hyper-arid zones, like the Arava Valley, is directly linked to rainfall and water redistribution through active stream channels. This explains the increased acacia density in the nature reserve associated with the active stream channels. Because the acacia trees are the keystone species in this ecosystem, the fate of the ecosystem is closely related to the fate of the acacia trees. Information from studies that evaluated the demographics (age/size) of the trees in the 1975 oiled-soil area indicated a near total absence of trees younger than about 40 years. Studies conducted as part of the ongoing monitoring efforts have demonstrated that germination failure caused primarily by the hydrophobicity of the oiled soils mechanistically explains the age distribution of acacia trees in the 1975 oiled-soils area. The data do not yet allow us to know whether or when there will be a time when the oiled-soils once again support germination. This negative recruitment impact on the keystone species implies that as a result of the 2014 oil spill, the existing Evrona ecosystem will slowly change over the next 40-100 years until few acacias trees are left in the areas of active stream channels that were impacted by the oil. The lack of recruitment of acacia trees in this area will also affect other elements of the ecosystem—the presence of the Dorcas gazelles and other flora and fauna—that rely on the acacia trees.

1.2. In terms of "damage to quality of life, convenience and wellbeing and the perception of the quality of life," I have noted (Section 1.2) that it is possible to quantitatively asses the injury to the Evrona Nature Reserve and to identify damages for the loss of recreational use of the public land. This is an explicit element of the U.S. Natural

Resource Damages (NRD) model. Leaving aside the question of legal authority, on December 10, 2014, the Ministry of Environmental Protection (MoEP) officially closed the nature reserve to the public, and it remained closed until the MoEP re-opened it on April 2, 2015. Thus, it is clear that the public lost access to the recreational use of the nature reserve during this time. However, aside from anecdotal accounts that during the early days of the spill, as many as 200 individuals were turned away from birding in the nature reserve because of the oil spill, there is no quantitative information in the case file with the type of information (e.g., daily visitor counts) that could be useful in understanding to what degree the public was unable to use the resources at the Evrona Nature Reserve.

2. *To the extent that such damage and hazards were caused as mentioned above, what is the proven damage (whether it has been formed or whether it has not yet been fully formed) incurred as a result of the event* [sic].

2.1. Ecological Damages: As noted above and further discussed in Sections 5 and 6, data from field and laboratory studies conducted within the areas of the 1975 and 2014 oil spill sites, indicates a long-term impact to acacia tree recruitment. Unfortunately, the data are unclear as to exactly how long the oil-impacted soils in these areas will negatively impact germination of acacia seedlings. Date from the 1975 spill indicate that the underlying causes will last for a minimum of 40 years. While, there is some indication that the site may be close to beginning recovery (e.g., no apparent recruitment concerns for shrubs in the 1975 area), the current depth of knowledge make it impossible to predict exactly when successful acacia tree recruitment will begin. Consequently, (and as discussed in Section 7), ecological injuries (in terms of ecological services losses) have been quantified for recovery times of 40, 60, 80, or 100 years.

As noted in Section 8, the damages associated with the ecological injuries would be those costs associated with restoration option(s) that replaces the injuries. The same range of recovery times were used to provide a range for the restoration required to offset the ecological injuries caused by the 2014 oil spill. In this case, one proposed restoration option would be planning and implementing the diversion of Wadi Raham water into the central part of the Evrona Nature Reserve; with the costs associated with this restoration option being the ecological damages. Additionally, damages would include the costs for long-term monitoring of the effectiveness of this restoration option. Finally, the damages could include the costs of setting up and funding a facility where acacia trees can be germinated before being transplanted to clean areas being serviced by the new flow of water through the nature reserve.

2.2. As noted above, the Evrona Nature Reserve was closed to the public and thus, the public was unable to use the nature reserve for recreational activities, but also as noted above, the data to quantify this as an injury and determine a damage was not part of the case file.

3. *Was a risk caused as a result of the event to the population living in the area and especially to the residents of Beer Ora* [sic] *and Eilat, as well as to passersby on Route 90. If yes – furthermore, are there longstanding implications to the exposure of contaminants of this type* [sic].

3.1. While there is always a desire for more information following events such as oil spills, particularly in support of a more in-depth understanding of exposure, as discussed in Section 3 (based upon a review of the available data, the body of literature pertaining to these types of exposures, the comments from the various experts, and on our own internal assessment of the data), the information collected during the Evrona oil spill does not support a conclusion for increased human health risk above acceptable regulatory levels.

4. Does any impact exist of prior oil leaks, to the extent existing, in the relevant area and does any impact exist on building an international airport in this area and if yes- what is its impact on the disputes being examined?

4.1. While I have not been presented with any evidence that prior oil spills occurred in the area of the 2014 oil spill (within or outside of the nature reserve), the impact of the 1975 EAPC pipeline crude oil spill seen farther to the south of the 2014 spill location has been noted. Both field and laboratory studies associated with this 40 year-old spill provide clear evidence of potentially catastrophic long-term injury to the ecosystem from acacia recruitment failure due to the hydrophobicity of oiled soils.

4.2. At a qualitative level, the presence of the new international airport severely enhances the fragmentation of the ecosystems in the Arava Valley. Despite a narrow corridor to the east, the placement of the international airport, coupled with the presence of Route 90 immediately west of the airport, severely minimizes the migration route of animals throughout the Arava Valley, an issue that, if not resolved, will potentially compromise the abundance of gazelles in the Arava Valley.

5. *Did the actions taken by EAPC and/or that EAPC undertook to perform lead to and/or will lead to a solution or remedy or improvement of the damage mentioned above, to the extent existing* [sic].

5.1. In my review of the case file, and based on over 25 years of dealing with oil spills, it is my opinion that, once the release occurred, much of the effort undertaken by EAPC, either by itself or in coordination with other agencies, resulted in minimizing what could have been a much larger environmental disaster. The ability to contain the oil as quickly as was done, to minimize further migration into the salt flats, to ensure that winter rains did not move the oil farther towards Eilat and Aqaba and ultimately into the Red Sea, and to ensure that penetrating oil did not reach an aquifer are all examples of how the response work performed by or on behalf of EAPC helped resolve a bad situation and, more importantly, prevented a bad situation from evolving into a much larger environmental disaster.

5.2. That said, the rehabilitation work that EAPC has conducted at the Evrona Nature Reserve (based upon my reading of the information provided to me through July 2018) will not lead to a solution or remedy of the most significant ecological injury—the inability of the acacia trees to germinate in the oiled soils found associated with the water pathways where the acacia trees prefer to grow.

1. Retention

1.1. Qualifications

I am currently a principal scientist and group vice president at Exponent, Inc. (Exponent), a scientific and engineering consulting firm headquartered in Menlo Park, California. I have been at Exponent since 2016. My billing rate is $425 per hour. Details of my experience, credentials, project experience, and publication record are presented in my resume (Appendix A). A list of my prior testimony in the last four years in included in Appendix B. Billing information related to this matter (total fees billed, billing rates of staff, and total hours charged) is included in Appendix C.

Before joining Exponent, I was Chief of the Assessment and Restoration Division in the National Oceanic and Atmospheric Administration's (NOAA's) Office of Response and Restoration/National Ocean Service (2007–2016). During this time, I was responsible for co-leading NOAA's national Natural Resource Damage Assessment (NRDA) Program, along with the Chief of the Restoration Center in NOAA's Office of Habitat and the Chief of NOAA's General Counsel's Natural Resources Section. In this capacity, I worked closely with staff and political appointees from the U.S. Environmental Protection Agency (EPA), the U.S. Department of the Interior (DOI), and the U.S. Department of Justice (DOJ). I also interacted extensively with other federal and state government resource agencies, members of various states' offices of the attorney general, and managed a group of about 50 scientists and economists working on NRDA cases throughout the United States and U.S. territories.

Beginning with the April 2010 Macondo Well blowout and extending until I left NOAA in 2016, I led NOAA's assessment of natural resource injuries for the Deepwater Horizon Oil Spill (DWHOS) and co-led the DWHOS NRDA on behalf of the U.S. Government. In this capacity, I helped develop and implement case science and science strategy, and I was responsible for technical oversight for all the assessment work conducted by NOAA. On behalf of NOAA, I oversaw an approximately $100M/year environmental investigation program, employing hundreds of scientists and economists. As one of NOAA's lead NRDA scientists, I interacted with colleagues from across NOAA, EPA, the U.S. Department of Agriculture (USDA), DOI, the President's Office of Science and Technology Policy, the U.S. Government's Joint Subcommittee on Ocean Science and Technology, and academia to help create a more transparent damage assessment process. I also worked closely with colleagues from NOAA, DOJ, DOI, USDA, EPA, and state representatives from Texas, Louisiana, Mississippi, Alabama, and Florida to conduct the DWHOS NRDA. In 2011, I was appointed as the lead NOAA agency scientist in charge of oversight for NOAA's science efforts conducted in support of the incident, external to the work conducted under the Oil Pollution Act of 1990 (OPA) during either the response actions or the NRDA.

Before working for NOAA, I was president and senior scientist at Applied Geochemical Strategies, Inc. (2002–2007), an environmental consulting company. I have held senior technical and management positions at ZymaX Forensics (2005–2007), Arcadis JSA (1999–2002), ENTRIX (1995–1999), and Unocal (1990–1995). During my time with Unocal, I served as the technical lead NRDAs for the corporation. In total, between 1990 and 2007, I participated in nearly a dozen natural resource damages (NRD) cases, under both OPA and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), for various responsible parties. My education is in the fields of geology, geochemistry, chemistry, and oceanography. I was a post-doctoral fellow at the Carnegie Institute, Stanford University, and a National Research Council fellow at National Aeronautics and Space Administration (NASA)-Ames Research Center (1988–1989). I received a Ph.D. in Chemical Oceanography from the University of North Carolina, Chapel Hill, in 1989 and a B.S. in Geology from the University of California, Los Angeles, in 1975. Additionally, I have held academic appointments as a guest investigator at the Woods Hole Oceanographic Institution (1986) and as an adjunct faculty member in the Physics Department at California Polytechnic State University, San Luis Obispo (2001–2007).

In total, I have nearly 30 years of consulting experience centered on providing advice to and conducting studies for industrial, legal, and governmental clients on scientific aspects of the NRDA process, investigation of contaminated sediment and soil sites, oil and gas geochemistry, environmental monitoring and exposure assessment, and the use of forensic methods to apportion environmental liabilities associated with oil spills and industrial waste site cases. I have published and been retained as a testifying expert and witness on cases involving NRDA, environmental forensics, transport and fate, pollutant source identification, chemical fingerprinting, and source apportionment related to crude oil, refined products, and other organic pollutants.

1.2. Scope of Analysis

Based on information provided by the parties in Attachment 1[1]of Exponent's February 14, 2018 retention letter (Appendix B), I have been identified as a Professional Consultant of the Mediator (PCM) with the scope of my analysis focused on assisting the mediators (Adv. Gabrieli and Adv. Wiesengrun) in addressing a series of issues in dispute set forth by the parties that are directly related to or allegedly caused by the December 3, 2014 Eilat-Ashkelon Pipeline Company (EAPC) Pipeline release near the Be'er Ora Junction with Route 90 in the southern Arava Valley, Israel.

As PCM, I have been asked to review and assess the following:

- Literature and presentations regarding the baseline ecology and hydrodynamics of the Arava Valley in the vicinity of Be'er Ora, the area towards the north and east of Be'er Ora, and the area encompassing the Evrona Nature Reserve;
- Literature and presentations regarding the nature of the oil released from the EAPC pipeline, the extent to which the oil spread throughout the environment (over land, into the soil, and through the atmosphere);
- Literature and presentations describing the response to the oil spill and actions taken for mitigation or remediation purposes as part of that response;
- Literature and presentations describing ecological results and analyses from studies conducted in the study area immediately following the oil spill and as part of larger monitoring programs that have been ongoing for much of the past 4 years since the oil release occurred; and

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1 "The Translation of the Procedural Arrangement in the Framework of a Mediation Proceeding (Secret and Confidential)."

- Information pertaining to hydrodynamic changes in the study area as a result of building the Ilan and Assaf Ramon International Airport, immediately northeast of Be'er Ora.

Based on this review, on discussions with the parties, and on my years of experience assessing human health and ecological impacts associated with oil spills, I have been requested to provide the mediator with my responses to the following issues of dispute:

1. *Was damage caused and ecological environmental hazards following the event, including to the ecological system and to biodiversity, damage to quality of life, convenience and wellbeing and the perception of the quality of life and if yes – what is this damage and hazards (whether they can be rehabilitated or no* [sic] *including damage which has not yet been finally formed including the cost of monitoring and the cost of rehabilitation as a result of the event and the cost as a function of the rehabilitation time to the extent it is possible to rehabilitate). All while referring to actions performed and that are being performed on the ground today, and referring to the chapters of damage in the pleadings filed by the Applicants/the Plaintiffs and the answers to these claims in the pleadings filed by the Respondents/the Defendants.*

2. *To the extent that such damage and hazards were caused as mentioned above, what is the proven damage (whether it has been formed or whether it has not yet been fully formed) incurred as a result of the event* [sic].

3. *Was a risk caused as a result of the event to the population living in the area and especially to the residents of Beer* [sic] *Ora and Eilat, as well as to passersby on Route 90. If yes – furthermore, are there longstanding implications to the exposure of contaminants of this type* [sic].

4. *Does any impact exist of prior oil leaks, to the extent existing, in the relevant area and does any impact exist on building an international airport in this area and if yes- what is its impact on the disputes being examined?*

5. *Did the actions taken by EAPC and/or that EAPC undertook to perform lead to and/or will lead to a solution or remedy or improvement of the damage mentioned above, to the extent existing* [sic].

To address the issues raised by the charge questions, I have modeled my approach and analyses on those developed and promulgated by DOI (43 C.F.R. 11 *et seq.*) and NOAA (15 C.F.R. 990 *et seq.*) for conducting NRDAs. In my opinion, this model provides a logical framework within which to quantify the impacts to natural resources arising from an oil spill and to quantify the damages[2] associated with those impacts. I have also relied on human health risk assessment approaches to evaluate the likelihood of any short- or long-term health impacts to people exposed to the spill.

Reviewing the five charge questions and simplifying based on the approaches presented above results in the following query:

Did the 2014 Evrona oil spill cause injury to human health and/or the environment? To answer this, a conceptual site model (CSM) was developed as a framework for the event. Based on experience and prior knowledge, and on site-specific data collected before, during, and after the December 2014 release, the CSM describes what the site looked like before the oil release (baseline conditions), where the oil came from (oil source), where and how the oil moved once it was in the environment (oil pathways), how the oil changed as it moved through the environment (oil weathering), and the magnitude of exposure of humans and the ecosystem to various fractions of the oil (oil exposure). The probable injuries to human health and the environment caused by the oil exposure are then assessed based on the CSM framework.

Following this framework allows us to asses and answer the question of is there a causal linkage between the oil release event and the observed human health and/or ecological injuries. If a

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[2] In attempting to use clear language, I have adopted the language used in the United States in evaluating NRD. Specifically, I refer to "injury" as defining the impact to (immediate or long-term) to the resources that compose the ecosystem (e.g., dead animals, dead or dying trees, loss of ecological services that the resources provide [shade, subsistence, protection in the example of a dead tree]). Within the context of ecological injury, I define "primary rehabilitation" as the actions taken during the response that resulted in either minimizing the injury or completely resolving the injury. I refer to "damages" as the monetary costs associated with compensating for the injuries and define the term "baseline" as the condition of the ecosystem the day before the December 2014 release occurred.

causal link can be established, the next steps are to determine the damages caused by the oil spill (accounting for baseline conditions) and then to scale these injuries to restoration that will effectively offset the lost services. In terms of human health, a risk-based assessment will provide an understanding of the level of human health impacts, if any. While this may be unsatisfying to some, the goal is to use objective data and internationally accepted levels of safe exposures to ascertain the nature and magnitude of health risks associated with the level of human exposure to constituents from the oil. In terms of injuries to the environment and the ecological services it provides, the U.S. NRD Claim model emphasizes in-kind compensation for these loses through restoring, replacing, or acquiring the equivalent. Such compensation, if appropriately conducted, has the benefit of replacing all services that were injured. Consequently, we have identified possible restoration options that, if acceptable and achievable, would help restore/replace the ecological services injured by the release.

Charge question 1 also speaks to "damage to quality of life, convenience and wellbeing and the perception of the quality of life." How different individuals react to oil spills is very difficult to quantify. While there is little doubt in my mind that people were affected as they experienced the spill or viewed the aftermath of the oil in the Evrona Nature Reserve, quantifying the emotional effect is quite difficult and beyond my expertise. There are many studies from the DWHOS that focused on understanding how individuals felt about the spill and documented the associated challenges (e.g., Gill et al. 2014 and Graham et al. 2016), and this was for the largest marine oil spill in US history. These challenges increase with spills of lower public visibility. Outcomes from these studies suggest that how a person feels about the effects of an oil spill are often related to the person's experiences during the spill, what the person had heard about the spill, where that information came from, etc. For folks who listened and believed that the spill would destroy the Gulf of Mexico as they knew it, levels of anxiety and anger were very high. As the literature from the DWHOS indicates, determining how people felt about the spill, how they perceived and personally internalized the outcomes from the spill response, and how they ultimately considered the results from the spill years after the spill requires focused studies involving long-term interactions with the impacted population (questionnaires, interviews, public meetings, etc.). Even with this body of information, quantifying this emotional impact is challenging and, as noted above, beyond my technical expertise.

However, under the U.S. NRD Claim model, claims for loss of recreational use of the impacted area caused by the release of the oil are recognized based on a measure of the impact that the oil spill had on the recreational use of the land. In the case of the December 2014 Evrona oil spill, the Ministry of Environmental Protection (MoEP) published the following on their website:[3]

> ***Wednesday, December 10, 2014:*** *The public is being asked not to come to the area in Israel's southern Arava region, where crews are continuing the cleanup in the wake of last week's massive crude oil spill. The Evrona Nature Reserve has been closed, after air quality tests conducted over the past few days found high levels of benzene, a toxic and carcinogenic chemical. These levels could put pregnant women, young children, and the elderly at risk. It should be noted that the values are not considered dangerous for those working at the site. Tests found normal air quality values in Eilat and Be'er Ora.*

From information provided on the MoEP website and in the March 22, 2016 document titled "EAPC and the Officers Response to the Petition to Approve the Action as a Class," the MoEP reopened the Evrona Nature Reserve to the public on April 2, 2015.[4] Thus, it is appropriate to consider that the Evrona Nature Reserve, usually open to the public for their recreational pursuits, was officially closed to the public from December 12, 2014, through April 1, 2015. For the purposes of estimating the time that the public was initially excluded from using the Evrona Nature Reserve recreationally as a result of the Evrona oil spill, it is my opinion that the presence of the oil and the response activities that occurred in the Nature Reserve immediately following the release likely precluded recreational enjoyment by the public of the Evrona Nature Reserve starting on December 4, 2014. Consequently, the Nature Reserve was closed for public use for approximately 120 days, representing the number of days of lost use of the nature reserve by the public. To the degree that once opened to the public, areas of the nature reserve remained inaccessible to the public would represent additional injury (assuming the reason for closing these areas to the public resulted from the 2014 oil spill).

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[3] http://www.sviva.gov.il/English/ResourcesandServices/NewsAndEvents/NewsAndMessageDover/Pages/2015/04-April/Four-Months-After-Oil-Spill-Evrona-Nature-Reserve-to-be-Reopened.aspx. Accessed September 5, 2018.

[4] Class Action 49319-12-14, 37. EAPC and the Officers Response to the Petition to Approve the Action as a Class Action. March 22, 2016; see also http://www.sviva.gov.il/English/ResourcesandServices/NewsAndEvents/NewsAndMessageDover/Pages/2015/04-April/Four-Months-After-Oil-Spill-Evrona-Nature-Reserve-to-be-Reopened.aspx. Accessed September 5, 2018.

This aspect of the damages was not explicitly called out in charge question 1 and I am uncertain if Israel's legal framework allows for recovery of this type of damage. That noted, the specific information required to assess the damages of the lost recreational use does not appear to have been gathered or presented for evaluation. Specifically, the damage calculation requires several parameters to be known. First, the average number of daily trips is required (i.e., how many individuals from the public would have been expected to visit the nature reserve during these 120 days). Second, some estimate of the value of each individual's trip is required. Usually, the value information is derived either from de novo economic studies (e.g., revealed preference method) or by using a benefit transfer method. The absence of this type of information as well as information that would allow an assessment as to how or if closure of specific areas of the nature reserve (subsequent to MoEP opening the entire reserve in April 2015) impacted the public's recreational use prevents the incorporation of an assessment of the lost recreational use damages in this report. If this type of information can be obtained, the damages associated with the loss of access to the Evrona Nature Reserve by the public could be determined.

2. Background and Description of Incident

The Arava Valley is located between the Dead Sea and the Gulf of Eilat (Amit et al. 1999; Figure 1). Within the Arava Valley, and of significance in this case, are the village of Be'er Ora and the Evrona Nature Reserve. Be'er Ora is approximately 1 km west of Route 90,[5] whereas the nature reserve is approximately 15 km north of Eilat (Gordon et al. 2018; Gruner et al. 2015) and east of Route 90 (Gruner et al. 2015). The nature reserve, a hyper-arid environment, lies between Route 90, a border fence with Jordan, the Be'er Ora settlement, agricultural areas, and the newly constructed airport (Gruner et al. 2015) in a 10-km-long by 0.5–2-km-wide basin within the Arava Valley (Amit et al. 1999). The nature reserve is 40 km^2 in size[6] and includes the Evrona salt flat, which is approximately 20 km^2 in size (Shanas and Olek 2014) and represents a drainage basin for water flowing from the Eilat Mountains to the west and from the Edom Mountains in the east (Gruner et al. 2015). Besides containing a unique desert environment, this area also contains archaeological sites[7] and the last fully preserved salt marsh in the Arava Valley (Golan et al. 2016).

On December 3, 2014, actions associated with moving a pipeline owned by EAPC resulted in the release of approximately 5,000 m^3 of petroleum into the environment[8] (Gruner et al. 2015; Israel Environment Bulletin 2015). The oil spill occurred in the southern Arava Valley adjacent

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5 The Village of Be'er Ora extends from approximately 0.75 to 1.5 km west of Route 90 and from 0.3 to 0.5 km north of the Be'er Ora Village (Ora Street).

6 https://www.jpost.com/Israel-News/Head-Evrona-Nature-Reserve-reopens-to-public-4-months-after-oil-spill-395939 Accessed May 22, 2018.

7 https://www.jpost.com/Israel-News/Head-Evrona-Nature-Reserve-reopens-to-public-4-months-after-oil-spill-395939. Accessed May 22, 2018.

8 Based on a density of 0.8710 kg/m^3, the oil released from the EAPC pipeline had an American Petroleum Industry (API) gravity of approx. 31.0° (Flikstein 2015, Appendix 2). The 5,000 m^3 of oil released is equal to approximately 1.32 million U.S. gallons or 31,500 barrels of oil. This volume of oil makes the Evrona oil spill larger than any on-shore oil spill in the United States within the past decade and classifies it internationally as a large oil spill (see http://www.itopf.org/knowledge-resources/data-statistics/statistics/ [accessed September 5, 2018]).

Class Action 49319-12-14, 84. EAPC and the Officers Response to the Petition to Approve the Action as a Class Action. March 22, 2016 to the Be'er Ora intersection on Route 90 and approximately 650–700 m east-southeast of the nearest dwelling in Be'er Ora.

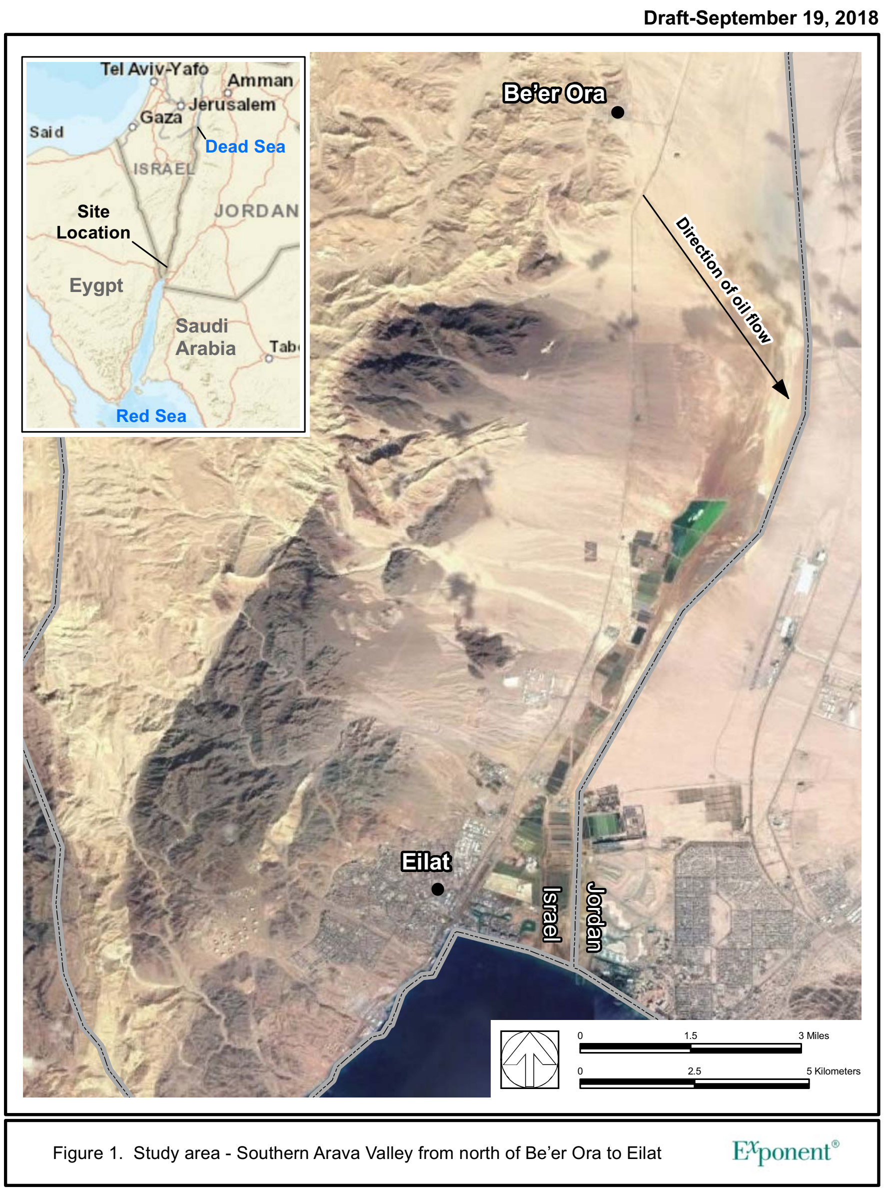

Figure 1. Study area – Southern Arava Valley from north of Be'er Ora to Eilat

It is estimated that the oil flow out of the pipeline lasted for about 8 minutes before the valve was closed (Gruner et al. 2015). As a result, both volatile and non-volatile components of the oil were released into the environment. Based on the analytical results from the analysis of oil samples submitted by EAPC on November 24, 2014, and believed to be similar to what was released from the pipeline, the gasoline range organic fraction (the volatile fraction of the crude oil) accounted for 27.7% of the total petroleum hydrocarbons (TPH), the diesel range organic fraction accounted for 50.1% of the TPH, and the oil range organic fraction accounted for >20% of the TPH.[9]

The release of volatile components during the spill is further evidenced by observations of individuals who were in the Be'er Ora area during the release, were in Eilat after the release, and newspaper articles reporting that petroleum odors were experienced in the Aqaba area.[10] Air monitoring, initiated approximately 15 hours after the release, was conducted in potentially affected areas following the release, on December 4–25, 2014. This was followed by more focused air sampling in Be'er Ora, Evrona, and Nimra in January and February of 2015 (Ramboll Environ 2016; Moshel 2015). Section 3 of this report provides a focused review of these data and information in terms of assessing the degree of human health risks, if any, resulting from the EAPC pipeline oil release.

Non-volatile components of the oil flowed from the release site southward approximately 1.8 km along the west side of Route 90. At this location, the oil flowed through Wadi Ora[11] and crossed Route 90 towards the east. The oil continued flowing through the Wadi Ora drainage for approximately 4.5–5 km in a southeasterly direction through the Evrona Nature Reserve. The oil was stopped approximately 200 m from the Jordanian border[12] (EAPC response to class action 2016). Within the streambeds flowing through the nature reserve, oil flowed through sub-channels that were found to be from 50 cm to up to 5 m in width and 30 cm in depth (Golan et al. 2016; Figure 2).

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9 See Flikstein 2015, Appendix 2.

10 See Class Action 49319-12-14, 1-5. Motion to Certify a Class Action. Undated.

11 July 16, 2018 email between Hada Waisler and Tal Wiesengrun.

12 Class Action 49319-12-14, 96. EAPC and the Officers Response to the Petition to Approve the Action as a Class Action. March 22, 2016

Figure 2. Flow of oil through the wadi system following the 2014 EAPC spill (from Shapira 2018)

Immediately following the release, "a causeway for damming the flow at a number of points west and east of Route 90 and within the Nature Reserve area" (Mandelbaum 2016) was established. The day after the release (December 4, 2014), oil was collected from four excavated pool locations along this causeway; the pool locations had been selected based on proximity to the Jordanian border and the progression rate of the oil in order to intercept the greatest amount of oil (Gruner et al. 2015). Collected oil was then pumped into containers using sewage suction vehicles. According to EAPC, the pumping resulted in the recovery of approximately 2,000 m^3 of oil.[13,14] Once pumping was complete, the entire layer of oiled soil was removed using

[13] Class Action 49319-12-14, 96. EAPC and the Officers Response [sic] to the Petition to Approve the Action as a Class Action. March 22, 2016

[14] Note that while none of the documents Exponent has reviewed contests the amount of oil claimed by EAPC to have been either originally released from the pipeline or recovered during the response actions, no independent assessment of these amounts has been provided. This may be due to the fact that immediately following the

pumping equipment, manual pumps and adsorbent materials[15] (Gruner et al. 2015). Oil-covered acacia pods were also removed. Following rain on December 9, 2014, oil/water liquid in the pools was once again pumped out and the surface layer of oiled soil removed.

On December 5, 2014, pursuant to the instructions and close supervision of the MoEP, EAPC was allowed to temporarily store excavated oily soil at the Nimra waste disposal site, located approximately 4.2 km north of Be'er Ora. By December 11, 2014, 31,878 tons of oiled soil had been taken to Nimra. As noted below, atmospheric monitoring for volatile hydrocarbons was conducted at the Nimra site while the contaminated soils were stored there. Following the cessation of emergency response actions, oiled soil was taken to one of two landfill sites permitted for biological handling of polluted waste; from December 15, 2014, through February 12, 2015, 19,753 tons of oiled soil was transferred to Neot Hovev, and later (April 15 and 16, 2015) 2,341 tons of oiled soil was transferred to the Efah landfill.[16]

During the response actions, precautions were taken to not contaminate groundwater sources in the immediate area, including the construction of dams and cessation of drilling in Mekorot (Gruner et al. 2015). Additional precautions for rain events included establishing dirt dams and using adsorbents to prevent oil movement (Gruner et al. 2015). Oiled soil found west of Route 90 was completely removed and sent to the Nimra waste site; oiled soil adjacent to the east side of Route 90 and outside of the nature reserve border was also removed.[17] As detailed above, approximately 35,000 tons of soil was removed (Gruner et al. 2015). Within a week, more than 90% of the oil was removed via pumping or manual removal (Anonymous 2015). On December 9, 2014, a rain event occurred, but crude oil was not observed to flow outside of the impacted area (Anonymous 2015). In addition, following the above response actions, an air survey was

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release, a command group initially lead by Mr. Guy Samet (MoEP) and including EAPC representatives, LDD Advanced Technologies Ltd (LDD) representatives, relevant environmental protection entities, the Israeli Nature and Parks Authority (INPA), regional residents (e.g., Eilat Strip Regional Council), MDA, Firefighting Service, Ministry of Health, and the Drainage Authority was set up and these actions were all coordinated and agreed to through this group. Class Action 49319-12-14, 92. EAPC and the Officers Response to the Petition to Approve the Action as a Class Action. March 22, 2016

15 Pumping of excavated pools was finished by December 7, 2014. Removal of most of the oil contaminated soils from these pools finished by December 8, 2014 (see footnote 6).

16 Mandelbaum 2016, 4

17 Complete removal of oiled soil was confirmed using soil hydrocarbon analyses.

conducted to assess the distribution of oil and samples were collected for analysis (Gruner et al. 2015).

Based on a review of meeting minutes provided by the parties, it appears that interaction, communication, and coordination began almost immediately. The first evidence of a formal inter-agency/inter-group meeting are the meeting minutes dated December 5, 2014, which describe a meeting between the Israel Nature and Parks Authority (INPA), the MoEP (southern district), EAPC, and Eilat-Eilot Environmental unit that occurred during the first full day of the spill (December 4, 2014).[18] Reading through all of the meeting notes provided indicates that, by December 7, 2014, the coordination had expanded and meetings led by the MoEP were occurring twice daily. The forecast of substantial rainfall in the southern Arava Valley tested the ability of the command group to widen the protective planning while still responding to the spill. Having participated in many oil spills responses during my career, I have come to expect chaos during the initial 24 hours, as no matter where the spill occurs or the amount of preparation, an oil spill is simply a chaotic and unpredictable event. That such coordination could be attained so quickly is a testament to all of the individuals, groups, and agencies involved. Furthermore, that so much was accomplished in halting the oil flow through the Evrona Nature Reserve and then removing so much free oil in such a short time (70% from the nature reserve by the beginning of day 4) is also a testament to the groups leading and implementing the response actions. In any "after action" analysis of what went well and what went poorly, there are always things that could have been done better; there are always actions that, had they been taken, may have prevented the release or minimized the volume released; there are always preparations that, in hindsight, would have made for a more effective and/or efficient response. I do not have the information to opine on how ready EAPC was for such a spill. However, as a professional in the oil spill response field for almost 30 years, I can say that given the tools available, EAPC did a very good job cooperating with the various agencies and dealing with an unexpected, chaotic, and constantly evolving environmental disaster.

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[18] The Israel National Parks Authority, Dec. 5, 2014. Minutes of a coordination meeting held on December 4, 2014.

As a direct result of the oil flow into the Evrona Nature Reserve, both plant and wildlife exposures were reported after the 2014 oil spill. For the local Dorcas gazelle (*Gazella dorcas*) population, oil-stained pelage and behavior such as limping were observed following the spill (Gruner et al. 2015). Initially, gazelles avoided the spill area because of the people and machinery present during response efforts, but following the completion of oil removal, the gazelles and other species returned to the affected area (Gruner et al. 2015). Following the oil spill, it was observed that most birds disappeared from the area (Gruner et al. 2015); this may have resulted from human and machine activity during spill response. Plants with partial oil coverage were also observed. The 2014 oil spill contacted an estimated 84 acacias; oil was found at the trunks (Gruner et al. 2015). Another 205 trees were found near the spill with 158 of the 205 trees located less than one meter from oil.

After the spill, soil surface hydrophobicity increased, indicating water was not penetrating into the soil (Gruner et al. 2015). Increased hydrophobicity affects the water supply to plants, though potentially breaking the soil crust can increase water seepage into the soil (Gruner et al. 2015). Mechanical damage to soil crust may have adversely impacted microbiological activity and crust integrity. Sections 4–6 provide a focused review of these data and information in terms of assessing the degree of ecological injury, if any, resulting from the EAPC pipeline oil release.

3. Health Assessment of Potential Impacts from EAPC Pipeline Release

The health evaluation described in this section is based on review of analyses conducted by defense expert Ramboll Environ (2016) and plaintiff's expert Avi Moshel (2015), as well as subsequent opinions from Avi Moshel (2017), a summary of opinions from Dr. Elihu Richter and Mr. Moshel (undated), and responses to these reports from Ramboll Environ (2016, undated). Both the Ramboll Environ and Moshel analyses can be described as screening risk assessments with the general approach of comparing measured (or modeled) chemical concentrations associated with areas potentially impacted by the spill to health-protective guideline values to predict whether people may have been exposed to chemical concentrations higher than safe exposure levels. The opinions of plaintiff's experts Dr. Richter and Dr. Peter Honeyman and of Dr. Bernarda Flikstein were also considered, although these experts did not conduct a health risk assessment (Richter and Honeyman, undated; Flikstein 2015).

3.1. Conceptual Site Model

One of the first steps in assessing risks to human health from an environmental exposure such as the EAPC pipeline release is to develop a CSM describing potential pathways for human exposure. An exposure pathway is the course along which chemicals move from a source to an exposed person, including the point of release (source) and movement from the source (transport) to environmental media (air, soil, groundwater, etc.) where people (e.g., residents, highway passersby, response workers) could be exposed. Only those exposure pathways judged to be potentially complete are of concern for human exposure.

The source and transport were described in Section 2. The potential exposure pathways are discussed further below.

3.2. Affected Areas and Potential Exposure Pathways

Oil was recovered from the environment over the days following the spill, with 90% of the oil recovered within a week. Removal of soil contaminated with crude oil from the vicinity of the

Be'er Ora intersection, southwards along the western side of Route 90 and to a more limited degree from the Evrona Nature Reserve, was completed over the weeks and months following the release. Direct exposure by dermal contact or incidental ingestion of crude oil or contaminated soil would not have occurred because unauthorized individuals would not be allowed at the spill site and spill response workers would be using appropriate personal protective equipment, limiting the potential for exposure. Therefore, the only potentially complete direct exposure pathway would be inhalation of volatile chemical constituents that were released from the crude oil and migrated offsite to where people could be exposed. One exception is potential exposure to contaminated soil relocated to the Nimra landfill, as discussed below.

Another exposure pathway to consider is whether crude oil percolated down through soil to contaminate the groundwater below, resulting in indirect exposures to people using contaminated groundwater. However, groundwater sampling at the site conducted after the spill indicated groundwater was not impacted (Ramboll Environ 2016). Therefore, pathways involving indirect exposure to groundwater are considered incomplete.

The areas where exposure to chemicals associated with the release may have occurred include Route 90 near the spill site, oiled areas in the Evrona Nature Reserve, the Nimra landfill, the village of Be'er Ora, the towns of Eilat and Aqaba, and at the new Ilan and Assaf Ramon Airport site. The potential exposure at these locations are discussed in detail below.

3.2.1. Route 90 near spill site

Based on proximity to the crude oil release, the highest exposure levels would be expected in the area along the road closest to the spill. Potentially exposed groups include adults and children exposed by inhalation of volatile crude oil constituents while passing by on Route 90 during the release and cleanup period.

3.2.2. Evrona Nature Reserve

The direction of flow after the spill carried crude oil south along Route 90 and then east through the Evrona Nature Reserve. Although the nature reserve was closed to the public during the response and cleanup, it is possible that people may have entered the impacted areas of the nature reserve on occasion without permission and been exposed by inhalation of volatile crude oil constituents in the air. Potentially exposed individuals would most likely be adults or older children; small children would not likely be trespassing in a spill response area.

3.2.3. Nimra landfill

Contaminated soil from the spill site was transported and temporarily stored at the Nimra landfill, where workers may not be trained for work with hazardous wastes and may not have used appropriate personal protective equipment. Thus, landfill workers could potentially have been exposed by inhalation to volatile constituents emitted from the contaminated soil. In addition, they could have been exposed by direct contact (incidental ingestion, skin contact) with contaminated soil.

3.2.4. Be’er Ora

Be’er Ora is the closest residential community to the release location, located approximately 0.7 km northwest of the EAPC pipeline spill site. Depending on wind direction, volatile chemicals from the crude oil could have migrated offsite to the community of Be’er Ora, where adults and children living there could be exposed by inhalation. Ramboll Environ (2016) noted that the best sources of high-quality meteorological data for assessing wind direction and speed at the time of the spill are the stations at the King Hussein Airport in Aqaba, Jordan, approximately 11 km southeast of the spill site, and the Eilat International Airport, located approximately 17 km southwest of the spill site. Ramboll Environ analyzed these data and reported that that “winds blow predominantly from the northeast, both during the spill times and generally,” indicating that winds do not generally blow towards Be’er Ora from the spill site and did not at the time of the spill.

3.2.5. Eilat

Eilat is the closest city to the spill site, located approximately 15–20 km to the south. Based on the relatively long distance from the spill site, it is unlikely that chemicals released from the crude oil significantly impacted air quality in Eilat. Nevertheless, inhalation exposure to volatile chemicals in air for residents of Eilat was included in the health assessment as a potentially complete exposure pathway.

3.2.6. New Ilan and Assaf Ramon Airport site

A new airport is under construction just north of the spill site. Construction workers at the new Ilan and Assaf Ramon Airport site could potentially have been exposed by inhalation of volatile crude oil constituents in the air during the release. Potential exposure to volatile chemicals at the new airport site was included in the health assessment.

3.3. Exposure Concentration Data

Air monitoring was conducted in potentially affected areas following the spill, on December 4–25, 2014, followed by more focused sampling in Be'er Ora, Evrona, and Nimra in January and February of 2015 (Ramboll Environ2016; Moshel 2015). The sampling was conducted by multiple contractors using different methods, including very short-term (typically minutes, called "grab" samples) sampling of air at ground level (although some samples were collected at breathing level), 30- and 60-minute sampling at breathing level, and 24-hour sampling at breathing level. The 30-minute, 60-minute, and 24-hour samples at breathing level are most appropriate for comparing to short-term health guidance levels based on those time increments. Grab samples are not representative of exposure levels over longer periods. In addition, ground level samples, particularly near the released crude oil, are likely to overestimate exposure concentrations in the breathing zone, typically 1.5–2 m above ground level. Nevertheless, grab samples are useful in the immediate aftermath of an incident to quickly qualitatively evaluate the nature and extent of impacts.

Only limited sampling data were available to evaluate short-term exposures (1–24 hours). The few samples collected for these time increments (as compared to the grab samples) represent only a snapshot of conditions at the time and specific location of sampling. In addition, no data were available for assessing the potential for health effects from longer-term exposures (weeks to months). To provide a more comprehensive assessment of exposure, Ramboll Environ (2016) conducted emission and air dispersion modeling using established, validated models developed by EPA: the ALOHA (Areal Locations of Hazardous Atmospheres) model was used to evaluate very short-term exposures (10, 30, and 60 minutes) immediately after the release, and the AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory Model) dispersion model was used to evaluate short-term (1 hour) and medium-term (8-week average) exposures.

3.4. Comparison of Site Concentrations to Health-Based Guidance Values

In a screening risk assessment, site concentrations (measured or modeled) are compared to health guidance levels. Chemical concentrations less than a guidance level are considered safe. Chemical concentrations that exceed a guidance level do not necessarily indicate the presence of a hazard, particularly if the exceedances are small in magnitude and infrequent, but instead indicate the need for additional analysis and/or context. Both Ramboll Environ (2016) and Moshel (2015) conducted versions of screening risk assessment, although the Moshel assessment was limited in scope, encompassing only a few selected samples, focusing on specific grab samples with the highest concentrations. As previously noted, grab samples collected over a few minutes are not representative of the exposure concentrations for relevant health-based guidelines. In addition, these particular grab samples were collected at ground level and likely overestimate concentrations at breathing level. Consequently, the Moshel (2015) analysis is not representative of conditions to which people would have been exposed. The Ramboll Environ analysis included all available data, supplemented with modeled concentrations using well-established, validated emission and dispersion modeling.

In the screening risk assessment for the spill site, measured and modeled concentrations were compared to short- and medium-term health-based guidance values for crude oil chemicals. The chemicals assessed were the primary volatile and semi-volatile aromatic hydrocarbons associated with crude oil releases: benzene, toluene, ethylbenzene, xylenes, trimethylbenzenes, cumene, n-hexane, benzo[a]pyrene, and naphthalene. As discussed in the expert reports in this case (Ramboll Environ 2016; Moshel 2015, 2017; Richter and Honeyman, undated), some of these chemicals are considered human carcinogens (benzene and benzo[a]pyrene) or possible human carcinogens (naphthalene and ethylbenzene) by the World Health Organization

International Agency for Research on Cancer.[19] However, cancer risk assessment evaluates increased risk of developing cancer over a lifetime, typically from long-term exposures. Regulatory policy assumes there is no threshold below which exposure to a carcinogen will not increase the risk of cancer. Instead, regulations are based on an acceptable risk level, usually a 1 in 100,000 or 1 in 1,000,000 *increase* in risk of developing cancer. For short-term exposures, risks would rarely, if ever, exceed this acceptable risk level. Instead, health limits for short-term exposures are based on protection from noncancer health effects that may occur with high levels of exposure for short periods (hours, days, or weeks).

For this site, exposures would have been limited to short timeframes ranging from minutes to months during the response and cleanup. Site measure concentrations were compared to MoEP 24-hour Air Quality Values and EPA Acute Exposure Guideline Level 1 values (AEGL-1)[20] for 30 minutes and 8 hours. Modeled concentrations were compared to AEGL-1 for 60 minutes, U.S. Agency for Toxic Substances and Disease Registry intermediate Minimal Risk Levels (MRLs), MoEP ambient air values, and MoEP reference levels. See Ramboll Environ (2016) for more detailed discussion of the various health guidance values.

3.4.1. Results

With a single exception, all measured and modeled concentrations for exposures during the response were lower than applicable health guidance value[21] (i.e., compared to guidance values with the closest exposure timeframe). This includes concentrations measured and/or modeled for Be'er Ora, Eilat, Evrona, Nimra, and the new airport site. Because individual sample concentrations, including those in close proximity to the release, were lower than health-based guidance values, exposures farther away and longer after the spill would also be less than levels of concern. The single exception was a 24-hour benzene sample collected at ground level at the

[19] https://monographs.iarc.fr/list-of-classifications-volumes/

[20] An AEGL-1 is defined as an air concentration "above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."

[21] See Ramboll Environ (2016) for a discussion of sample locations, sample collection, data quality, and detailed discussion of the model used and model results.

Nimra landfill directly over contaminated soil. The benzene concentration for this sample was 0.0016 ppm, which slightly exceeded the MoEP 24-hour target value of 0.0012 ppm. Taken in context, this sample does not indicate an elevated risk because ground level samples over a source are likely to overestimate breathing zone concentrations, the magnitude of exceedance is very small, and the other 24-hour sample at Nimra was far below (0.0002 ppm) the guidance value.

Potential health risks were evaluated in this health assessment by comparing concentrations of individual chemicals to protective guidance levels for each chemical. Chemicals that act through a similar mode of action to induce similar toxicological effects may have additive or synergist (i.e., greater than suggested by the sum of the individual exposures) effects (EC 2012). Alternatively, some chemicals may act antagonistically, resulting in lower toxicity than expected from the sum of the individual exposures. Standard practice, recently affirmed by the expert panel convened by the European Commission, is to assume additivity unless sufficient scientific evidence indicates otherwise (EC 2012). Consistent with this concept, the health assessment used a screening approach by which potential additivity could be assessed. Concern for additive effects is considered low because measured concentrations for exposures during the response were lower than applicable health guidance values, and modeled concentrations, which are more likely to represent typical exposure over a longer period (though still relatively short duration), were far below applicable health guidance values.

3.5. Sensitive Subpopulations

A health assessment, whether a screening risk assessment such as conducted by Ramboll Environ (2016) or a detailed assessment, should address the potential for harm to sensitive subpopulations, such as children, the elderly, people with pre-existing health conditions (e.g., asthmatics), pregnant women, and fetuses. This health assessment addressed sensitive subpopulations by incorporating a number of health-protective assumptions that tend to overestimate exposure and the potential impacts of chemicals. Toxicological values that are incorporated in health guidance values and used in risk assessment include variables that either directly (i.e., through use of toxicological data from sensitive subgroups) or indirectly (i.e., through use of safety factors) provide an adequate level of protection even for sensitive subgroups. Likewise, exposure assessment typically includes assumptions that overestimate exposure and, thus, add another level of protection for all people, including more sensitive subgroups. In this assessment, all measured concentrations, even the highest concentrations, were compared to guidance values. In reality, concentrations of chemicals in air are variable and a person would not likely be exposed to the highest concentration for very long. Instead, exposure would be equivalent to an average of concentrations over space and time.

3.6. Evaluation of Odors

Odors have been identified by plaintiffs' experts as *a priori* evidence of exposure and health effects (Moshel 2015, 2017; Richter and Honeyman, undated). While the presence of odors may provide qualitative evidence of the presence of chemicals, odor detection is not a quantitative measure of exposure and therefore cannot be used to evaluate risk. Some chemicals have good "warning properties"[22] based on having a detectable odor at concentrations well below the threshold for toxicity, whereas other chemicals have poor "warning properties" with the threshold for toxicity near or lower than the odor detection threshold (Ader et al. 2005; NIOSH 1975). Some chemicals have odors that can induce short-term, transient effects such as nausea and headache that desist when exposure ceases. There is also a great deal of variability in odor detection, with some individuals able to detect odors at concentrations far below other individuals (Ruth 1986), but it must be stressed that this variability in odor detection is not correlated with variability in toxicity. Even if specific chemicals could be identified by odor, it is difficult to attribute them to a specific source. The value of odor detection is that it may qualitatively alert us to the presence of a source of exposure, which can then be quantitatively evaluated. In this case, potential exposure to chemicals associated with the spill have been quantitatively evaluated in the health assessment conducted by Ramboll Environ (2016).

[22] A warning property is a characteristic of a hazardous substance that alerts a person to its presence. Warning properties may include odors, visible particles or fumes, and physical responses such as eye, skin, or throat irritation.

3.7. Assessment of the Need for Medical Monitoring

Plaintiffs' expert Richter and Honeyman (undated) have claimed a need for medical monitoring to assess the occurrence of future health effects. Medical monitoring is typically only indicated when there has been a significant (large) exposure, usually over a longer period, to chemicals with specific health effects (e.g., asbestos and mesothelioma). There is little or no benefit of medical monitoring when exposures were short-term and low, particularly for health effects that are not expected following this type and magnitude of exposure (ATSDR 1995). In addition, the health assessment based on both measured and modeled air concentrations of chemicals associated with the spill indicates exposures did not exceed safe exposure levels associated with the health guidance levels.

3.8. Human Health Conclusions and Damage Implications

Response to the EAPC oil release was initiated within several minutes and proceeded relatively quickly over a period of weeks and months. The relative speed of the response, the distance from populations centers, and meteorological conditions served to limit the potential for human exposure. A health assessment using internationally accepted scientific methodologies of risk assessment was conducted to evaluate potential risks associated with exposures to volatile chemicals released from crude oil during the spill, response, and cleanup. The evaluation used a screening risk assessment approach to compare measured and modeled concentrations to health guidance levels.

The results of the health assessment showed that in all but one instance all measured and modeled concentrations were below applicable health guidance levels with the appropriate exposure timeframe. The only exception was a single 24-hour benzene sample measured at 0.0016 ppm at the Nimra landfill that slightly exceeded the health guidance level of 0.0012 ppm. This sample was taken at ground level, likely overestimating the concentration in the breathing zone. The other 24-hour sample from Nimra was measured at 0.0002 ppm, well below the health guidance level. Thus, the health assessment indicates a lack of impacts on human health. Because of these results in the screening risk assessment, a detailed human health risk assessment, which would use more realistic, site-specific exposure assumptions and therefore predict lower health risks than the screening assessment, is not warranted.

The information provided in the pleadings suggests that people were exposed to odors from the released oil. However, as noted above, while the presence of odors may provide qualitative evidence of the presence of chemicals, odor detection is not a quantitative measure of the magnitude of exposure and therefore cannot be used to evaluate risk. While there is always a desire for more information following events such as oil spills, particularly in support of a more in-depth understanding of exposure, as discussed above, the information collected during the Evrona oil spill does not support a conclusion for increased human health risk above acceptable regulatory levels.

4. Ecological Setting of the Evrona Nature Reserve

4.1. Overview

The Evrona Nature Reserve, characterized as a hyper-arid desert with alluvial fans and salt playas as its two main habitats (Tsoar 2018a), episodically receives water from multiple wadis (ephemeral streams), including wadis Raham, Ora, and Evrona, and encompasses multiple drainages that stretch toward the Red Sea at the Gulf of Eilat (Amit et al. 1999). The salt playas extend east toward Jordan and act as a drainage basin for the Eilat and Edom Mountains found to the west and east, respectively (Gruner et al. 2015). The nature reserve is characterized by alluvial soils, including pebbles and gravel, with sand and clay becoming more common downstream (Gruner et al. 2015). A number of geological faults are located in the general vicinity of the oil spill, with the southern portion of the Arava Valley having a 2-km-wide fault zone in the Arava playa region (Amit et al. 1999). There are two distinct geohydrological areas in this area. To the west of Route 90 is a deep phreatic aquifer, at a depth of approximately 50–60 m near the Be'er Ora Junction, which flows in the general direction toward the Gulf of Eilat. Another, shallower aquifer is located east of Route 90 within the nature reserve (Gruner et al. 2015). This shallow aquifer was artesian in the past, but according to Gruner el al. (2015), years of extraction from this aquifer have increased the depth of this aquifer down to 10–17 m.

The climate in the southern Arava Valley is hyper-arid,[23] with mean annual precipitation of 30 mm and a diel soil temperature range of 30–50°C (Amit et al. 1999). Water and salinity are the main limiting factors in this environment, with rainfall being highly variable (Tsoar 2018a). The area has no stable water supply, despite floods occurring in the winter months (Gruner et al. 2015). Biomass and biodiversity are likely correlated with water runoff, which is found more concentrated in shallow creeks in the alluvial fan habitat (Tsoar 2018a). The region has partial

[23] Based on the aridity index adopted by the European Union-Joint Research Center/United Nations Environment Programme (EU-JRC/UNEP) (Cherlet et al. 2018) and data from Evenari et al. (1982), the climate of the Evrona Nature Reserve is classified as hyper-arid.

vegetative coverage, mainly consisting of halophytes, with remaining soil being barren (Amit et al. 1999).

The Evrona Nature Reserve, specifically along the salt flat, has some of the highest biological diversity found in the region. In particular, the salt flats in the nature reserve represent rich habitat compared to the surrounding area (Gruner et al. 2015), and within these salt flats, streambeds with nearby acacia trees support the highest diversity of wildlife (Shanas and Olek 2014). Important flora in the nature reserve include two species of acacia tree (*Acacia raddiana* and *A. tortilis*), and three salt-tolerant, fruit-producing bushes: *Nitraria retusa (Forssk.) Asch*.,[24] *Zygophyllum album*,[25] and *Alhagi graecorum Boiss*[26] (Gruner et al. 2015). Mammals that reside in the nature reserve include the Dorcas gazelle, striped hyena (*Hyaena hyaena*), Arabian small gerbil *(Gerbillus nanus arabium*), Cairo spiny mouse (*Aconys cahirinus*), and other rodents (Gruner et al. 2015). Birds such as blackstart (*Cercomela melanura*) and greater hoopoe-lark (*Alaemon alaudipes*) are found at the nature reserve and are considered territorial (Gruner et al. 2015). A number of reptiles, such as Middle Eastern short-fingered gecko (*Stenodactylus doriae*), and Bosc's fringe-toes lizard (*Acanthodactylus boskianus*) are also found in nature reserve habitats (Gruner et al. 2015).

Acacia trees are considered keystone species in the Evrona Nature Reserve because of how they structure the surrounding habitats: plant species diversity and soil nutrient content are significantly higher under acacia canopy (Munzbergova and Ward 2002), and these trees provide habitat for a number of wildlife species (Gruner et al. 2015). As pointed out by Golan et al. (2016), "in arid environments, plants act as ecosystem engineers and play a significant role in the function of the ecosystem by serving as landscape modulators and shaping landscape patchiness. Changes in plant density due to lack of germination or restricted survival affect vegetation richness and composition (Boeken 2008)." In the Evrona Nature Reserve, acacias are found at densities of up to 200 trees/km^2 (Golan et al. 2016). The root system of adult trees may spread up to 3 m in diameter (Gruner et al. 2015), and young trees, in particular, are noted to produce a deep

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24 http://www.flowersinisrael.com/Nitrariaretusa_page.htm. Accessed May 15, 2018.

25 https://phys.org/news/2018-02-characterization-zygophyllum-album-monofloral-honey.html. Accessed May 15, 2018.

26 http://www.flowersinisrael.com/Alhagigraecorum_page.htm. Accessed May 15, 2018.

peripheral root system that is important to obtaining sufficient water during the first years of growth (Shanas and Olek 2014). Acacia yield various resources such as leaves, seeds, flowers, nectar, and resin, serving both diurnal and nocturnal wildlife species (Gruner et al. 2015). These trees influence both biotic and abiotic conditions by controlling the water balance, improving survival of nearby vegetation, and attracting animals that fertilize the surrounding soils, including the largest free gazelle pack in the southern Arava Valley (Gruner et al. 2015; Shanas and Olek 2014; Munzbergova and Ward 2002). The Dorcas gazelle is dependent on habitat provided by acacia trees to maintain its population in the region (Tsoar 2018a) and relies on the acacia tree as a refuge from heat in the summer (Shanas and Olek 2014). In turn, the Dorcas gazelle ingests acacia leaves and seed pods and disseminates seeds in its stool (Gruner et al. 2015). The digestion process also encourages acacia seed sprouting and helps prevent parasite infection of the seeds (Shanas and Olek 2014). In July 2014, the gazelle population in the nature reserve consisted of 242 individuals (Gruner et al. 2015).

The Arabian small gerbil is considered a habitat specialist and prefers sandy habitats, though it can also be found in solidified sand flats (Sinai et al. 2003). The gerbil's density is related to annual precipitation, with decreased density associated with low precipitation (Sinai et al. 2003). The home range of the gerbil is site and sex dependent and ranges between 5,500 and 19,000 m^2 (Sinai et al. 2003). A number of birds are known to transit through the area (Gruner et al. 2015). *S. doriae* is a nocturnal gecko that spends days within burrows to avoid predators and high temperatures (Zaady and Bouskila 2002); this gecko has multiple burrows it uses within its home range (Bogin 1999, as cited in Zaady and Bouskila 2002). Diurnal lizard species such as *A. boskianus* and *A. opheodurus* remain concealed in burrows except for a few hours of above ground activity (Zaady and Bouskila 2002). Insects such as antlions, ants, grasshoppers, and desert mantises are also found in the nature reserve (Gruner et al. 2015). In the Arava Valley, up to 13 insectivorous bats species were found near acacia trees and had higher activity compared to bats in other habitat types in the Arava Valley (Hackett et al. 2013). Bat activity was also correlated with arthropod abundance, with green acacia trees having consistent arthropod abundance during a midsummer study (Hackett et al. 2013).

The two most prominent shrubs at the nature reserve are *Salsola cyclophylla* and *Hammada salicornia* (Gruner et al. 2015). At the site, these two species constitute up to 93% of the shrub population. The genus *Salsola* is recognized for its tolerance for highly saline conditions (Abdel-Hamid 2016), and *S. cyclophylla* is found in extreme desert environments and fruits from October to November.[27] Another perennial shrub, *Nitraria retusa (Forssk.) Asch,* grows in salt marshes where it forms saline mounds and saline sand bars along channels of wadis (Shaltou et al. 2013; Suleiman et al. 2008).

4.2. Stressors impacting the Evrona Nature Reserve

4.2.1. Fragmented Habitat

A number of anthropogenic stressors currently impact the Evrona Nature Reserve. First, the area is fragmented and narrowly constrained by Route 90 to the west and the border fence with Jordan to the east. To the north, the Be'er Ora settlement bounds the nature reserve, while lands to the south are characterized by agricultural uses and salt production; in addition, the Ilan and Assaf Ramon Airport[28] is currently under construction north of the nature reserve adjacent to Be'er Ora (Gruner et al. 2015; Figure 3). The airport is 19 km north of Eilat and will immediately replace the Eilat and Ovda airport traffic of up to 70 flights/day.[29] It is anticipated to serve about 1.9 million domestic and international passengers a year[30] with capabilities for expansion of up to 4.2 million passengers a year through 2030.[31] The new airport sits on 5.5 km^2 of land with a terminal that will have an area of 50,000 m^2.[32] Figure 3 illustrates the spatial relationship between the spill site in the Evrona Nature Reserve and the new airport. Development of the airport and associated infrastructure has greatly restricted habitat continuity to the north, leaving the Nature Reserve area more isolated and the movement of high dispersing animals, like the Dorcas gazelle more restricted (Gruner et al. 2015).

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27 http://www.eol.org/pages/2904266/details. Accessed May 22, 2018.

28 http://www.iaa.gov.il/en-US/rashot/projects/Pages/TimnaAirport.aspx. Accessed May 21, 2018.

29 http://www.ramon-airport.com/flights-to-ramon-airport/. Accessed May 21, 2018.

30 http://www.iaa.gov.il/en-US/rashot/projects/Pages/TimnaAirport.aspx. Accessed May 21, 2018.

31 http://www.ramon-airport.com/. Accessed May 21, 2018.

32 https://www.inn.co.il/News/News.aspx/46168. Accessed May 21, 2018 (in Hebrew).

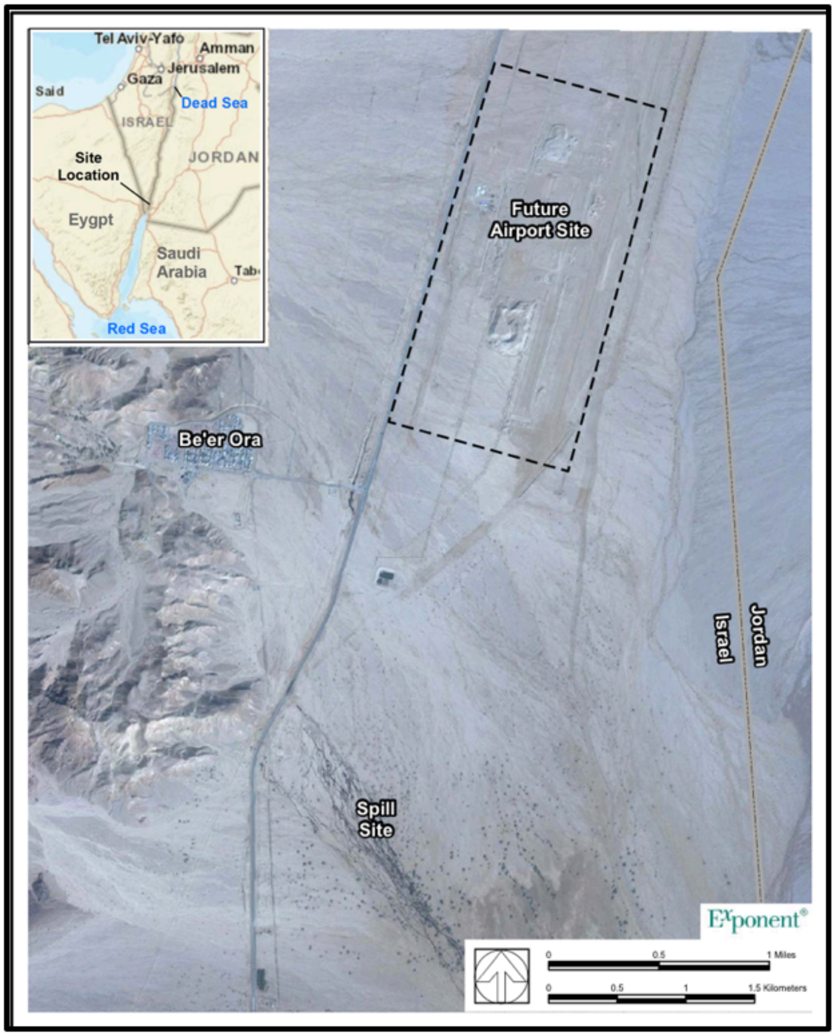

Figure 3. Location of Ilan and Assaf Ramon International Airport relative to the Evrona Nature Reserve 2014 oil spill area

4.2.2. Climate Change

The climate of the Arava Valley is naturally extreme in temperature, relative humidity, and rainfall. In general, conditions become more arid to the south, with annual rainfall dropping from an estimated 50 mm per year in the north to approximately 30 mm per year in the southern Arava (Goldreich and Karni 2001). Arava rainfall is characterized by high intensities over localized areas, resulting in highly variable annual and monthly rainfall measurements. Furthermore, the evaporation rate in the Arava exceeds the annual precipitation amount, also contributing to extreme conditions (Evenari et al. 1982; Goldreich and Karni 2001).

Despite the fact that acacia trees are adapted to live under such extreme climate conditions, recent observed declines in the already low rainfall rates have had a negative impact on acacia survival, indicating that climate change is a significant stressor in the region. For instance, Stavi et al. (2014) reported a significant negative correlation between latitude and mortality, indicating that trees in the more arid south were less likely to survive. In fact, between 1951 and 2008, annual precipitation in Eilat has decreased 58% (Figure 4) which has reduced the frequency of floods and decreased water available to acacia trees, causing increased tree mortality (Stavi et al. 2014). Ward and Rohner (1997) documented acacia mortality following road construction in which available water was channeled away from wadis, providing further evidence that acacia survival is limited by water availability. However, while the effects of road construction on Acacia survival can be ameliorated via construction of culverts, the effects of climate change on acacia survival is not easily addressed. Thus, it is expected that reductions of precipitation resulting from the changing climate will continue to act as a stressor on acacias and the wildlife that rely on these trees.

Decadal mean of cumulative yearly precipitation rates in several locations along the Arava Valley between 1951 and 2008.

Decade	Hatzeva[a]	Paran[b]	Yotvata[c]	Eilat
1951–1960	NA	NA	NA	28.7 (4.1)
1961–1970	NA	NA	NA	34.3 (2.5)
1971–1980	NA	NA	24.9 (2.9)	29.3 (1.9)
1981–1990	39.6 (3.7)	NA	32.3 (2.5)	27.4 (1.8)
1991–2000	37.0 (1.9)	28.1 (1.7)	28.1 (2.1)	24.3 (1.8)
2001–2008	38.8 (3.9)	23.2 (1.7)	13.4 (0.9)	12.1 (0.8)

Notes: NA — not available; numbers within parentheses are standard error of the means.
[a] Data are available since 1987.
[b] Data are available since 1993.
[c] Data are available since 1977.

Figure 4. Reported yearly precipitation rates within the Arava valley since 1951 (from Stavi et al. 2014)

4.2.3. The 1975 Oil Release

Nearly 40 years before the 2014 spill, on July 10, 1975, an oil release from the Eilat-Ashkelon pipeline caused oil to flow across Route 90 about 400 m south of where the 2014 release crossed the road (Figure 5). Oil from the 1975 release flowed along the western side of the Evrona salt flat, east of Route 90 (Gruner and Segev 2015; Nothers et al. 2017). The 1975 release was caused by a malfunction in the pipeline protection system and occurred between 3:00 and 4:00 am local time (Israel Institute of Petroleum and Energy 1975). During this event, an estimated 8,000–10,000 m^3 of oil was released and settled in low topographic areas, penetrating up to 40 cm downwards into the soil (Gruner and Segev 2015). The oil flowed in natural drainage paths (wadis unimpacted by the later 2014 oil flow) in a general east to southeast direction toward the Jordanian border and the Red Sea (1975 spill report; Nothers et al. 2017). Up to 150 dunams (approximately 37 acres) of the nature reserve east of Route 90 may have been impacted; however, in contrast to the 2014 spill trajectory through the nature reserve, the 1975 spill affected less sensitive areas in the nature reserve (Gruner and Segev 2015). Stream channels make up approximately 40% of the impacted area, with the width of the impacted channels ranging between 0.5 and 5 m and the channel's depth between 10 and 40 cm (1975 spill report).

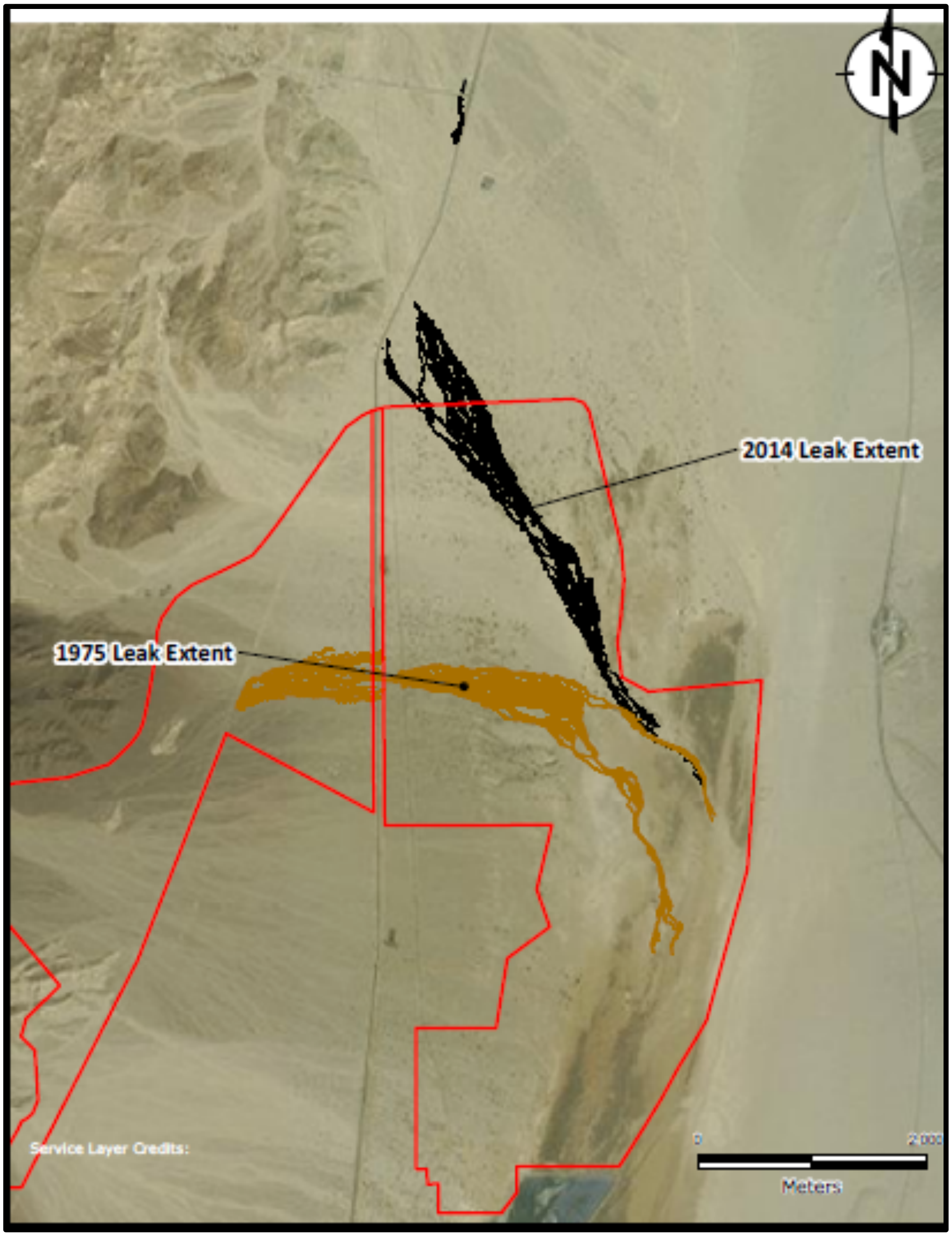

Figure 5. Locations of releases from the EAPC pipeline (east of Route 90 only): in 1975 (yellow) and 2014 (black). Red line denotes boundary of Evrona Nature Reserve (from Ramboll Environ 2018).

Cleanup of the 1975 spill consisted of using bulldozers to dig pits for oil storage followed by manually pumping the oil into tankers (1975 spill report). No information is available on the amount of oil pumped at the site during cleanup. Ash piles were used to block oil flow in other locations, and two weeks after the spill, pits were dug around the spill site to determine oil depth. Oil penetrated up to 40 cm downwards into the soil in the 1975 spill (Gruner and Segev 2015). Recommendations were provided in 1975 for additional surveys of the areas to better understand oil penetration into the ground (1975 spill report), but it is unknown if these surveys were completed.

Although the 1975 spill is in approximately the same location as the 2014 spill (about 4.5 km to the south), high summer temperatures during the 1975 spill (up to 40°C) likely caused rapid evaporation of volatile oil constituents, eventually turning the oil into a hardened asphalt-like material (Gruner and Segev 2015; Gordon et al. 2018). No documentation of any ecological damages that may have occurred due to the 1975 spill has been made available, and currently the natural rehabilitation of the area in not fully understood (Gruner and Segev 2015; Nothers et al. 2017). No active remediation has been implemented at the 1975 spill site (Gruner and Segev 2015). Current conditions at the 1975 spill site indicate that existing acacia trees are healthy, with no significant difference in adult acacia growth observed between impacted and non-impacted areas (Gruner and Segev 2015). However, with no long-term monitoring at the site, exact conditions can only be estimated.

A plot survey of the 1975 oil spill areas was conducted in 2015 to assess acacia tree size, distribution and longevity, perennial flora diversity, and ground moisture (Gruner and Segev 2015). Moisture content in the oil-impacted soil was found to be lower by nearly half when compared to the control area, and it was also found that rainfall was more likely to pool, rather than infiltrate, in oil-impacted areas (Gruner and Segev 2015). In addition, field observations indicated that flora soil penetration and animal burrowing were less likely to occur in oil-impacted areas (Gruner and Segev 2015). Acacia recruitment in the 1975 impacted area was 74% less than the control area, as small trees were not found in the impacted area, indicating that germination had not occurred since the spill (Nothers et al. 2017). Consequently, acacia trees in the impacted area were on average larger than those in control areas; however, this was a result of the decreased recruitment in the impacted area from the oil (Gruner and Segev 2015; Nothers et al. 2017). On-the-ground observations also indicated only two acacia trees to be less than 10–20 years old in the oil-impacted areas and aerial photography confirmed this lack of new acacia trees (Gruner and Segev 2015). Nothers et al. (2017) surmised that these young trees may have actually been established seedlings at the time of the spill and exhibited stunted growth in the subsequent decades, making aging of these trees difficult.

Perennial composition showed no significant difference between the impacted and control areas, indicating either that no effect occurred or that the community has recovered in the past 40 years (Nothers et al. 2017). Shrub density was similar in the impacted area and the control area, though shrubs appear to have selected "clean islands" in which to grow within the impacted area (Gruner and Segev 2015). The perennial shrub *Hammada salicornia* displayed larger sizes in the impacted areas compared to the control (Nothers et al. 2017). Overall, biological diversity for the perennial shrubs was not statistically different between the impacted and control areas (Gruner and Segev 2015).

5. Documented Effects to Ecological Receptors in the Evrona Nature Reserve from Exposure to the 2014 Oil Spill

Following the 2014 spill, the INPA, in conjunction with National Ecosystem Assessment Program (“HaMaarag”), initiated a five-year ecological monitoring program to characterize the potential effects of the spill on resident species and ecological processes (Shapira 2018). Researchers have assessed resident populations of birds, reptiles, insects, shrubs, small mammals, and soil microorganisms, along with specific studies to quantify spill impacts to adult acacia fitness and acacia germination. Although these studies are still underway, available post-spill data have been used to assess the level of ecological injury potentially resulting from oil exposure.

As described previously, CSMs provide a logical construct between the release of oil and exposure of the oil to ecological resources. Based on our understanding of the 2014 oil release, potential routes of exposure of wildlife in the Evrona Nature Reserve include ingestion, inhalation, direct contact, and indirect effects through modifications of habitat and/or food sources. Based on available data, it is not expected that Dorcas gazelles experienced any direct adverse effects from oil exposure, given that this species largely avoided the spill area once response activities commenced (Gruner et al. 2015). Additionally, the likelihood of risk to omnivorous and herbivorous mammals and avian insectivores through diet or inhalation is expected to be low. The potential for direct oiling of wildlife is greatest for organisms with limited ability to move out of the path of flowing or pooling oil, particularly those that live in the bed or banks of the wadis. These may include small reptiles and burrowing mammals, as well as ground-dwelling arthropods. In addition, both oiling and response activities have the potential to disrupt the soil microbial crust, which may have additional effects on soil moisture content.

5.1. Soil microbial communities

Microbiotic crusts, composed of cyanobacteria and mosses, serve an important ecological role in desert ecosystems by fixing nitrogen and carbon and stabilizing the shifting surface soils. Both the 2014 spill and the subsequent response activities may have disrupted the continuity of the microbiotic crust within the area. Following manual disruption of microbiotic crusts in the western Negev, recovery of cyanobacterial activity was observed within approximately 10 years, while moss communities required up to two decades to re-establish (Kidron et al. 2008). Presumably, re-establishment of crusts would be slowed by the presence of oil, but as observed by Gordon et al. (2018), deposition of clean soils occurs in oiled areas, which would likely promote crust regrowth. There is little available data to quantify the ecological impact of such a disruption in the 2014 spill area, and the likely rate of recovery. However, data collected as part of the HaMaarag surveys examined both microbial community structure and activity in 2014 spill-contaminated soils. The population structure of the soil microbial community (bacteria, archaebacteria, and fungi) was assessed in areas affected by the 2014 and 1975 spills, as well as control areas, and significant population differences were determined (Angel 2018). Furthermore, cultivated contaminated soils did not support communities that were notably different from those observed in uncultivated spill-affected soils. Similarly, an analysis of the microbial activity in these areas indicated that respiration rates were lowered in oiled soils (Halberstadt 2017). However, it should be noted that for both of these studies, authors reported that more research is needed to fully assess the effects on the soil microbial community and function, as current data rely on a relatively small sample size (Angel 2018; Halberstadt 2017). As such, it is currently unclear what long-term effects on soil function may result from altered microbial communities and respiration or how this might impact crust regrowth.

5.2. Acacia

Keystone acacia trees are expected to experience adverse effects from oiling by either direct loss of established adult trees or prevention of future seedling establishment and growth. There is evidence of both in the 2014 spill area. A five-year monitoring program published data for the initial two years between 2016–2018 (Nelvitsky and Winters 2018). Data consists of sampling acacia in the 2014 spill area, the 1975 spill area, and control areas (Nelvitsky and Winters 2018;

Shapira 2018). All trees were marked and mapped in these study areas for a total of 389 trees (including salt cedars, palm trees, etc.), of which 276 were identified as *Acacia tortilis* and 106 were identified as *A. raddiana* (Nelvitsky and Winters 2018). The remaining five trees found in this specific area were not acacias (Nelvitsky and Winters 2018). The general condition of the tree and distance to the oil was recorded (Nelvitsky and Winters 2018). Acacia trees found within 2 m of oil and considered in "good condition" were used for further monitoring, including water conditions near the tree, tree greenness, vitality, grazing line, bottom leaf height, leaf protein content, and seedling monitoring occurred (Nelvitsky and Winters 2018).

Overall, mature acacia trees were not affected (Shapira 2018) by the release. Based on results from the survey data, three acacia trees within the spill area have shown indications of oil stress. These results agree with the findings reported by Ramboll Environ (2015) that approximately 10 acacia trees appeared stressed or dying following the 2014 spill.

While mature acacia trees appear to be largely unaffected by exposure to oil, acacia seedlings appear to be much more sensitive. Laboratory studies conducted with oiled soils from both the 1975 and 2014 spill areas have demonstrated that acacia germination rates, seedling success, and plant vigor are all reduced compared to non-oiled soils (Golan et al. 2016; Tran et al. 2018). Golan et al. (2016) reported significantly slower germination rates in oiled soils from both the 1975 and 2014 event areas compared to control soils. Furthermore, seedlings grown in oiled soils were shorter and produced fewer leaves than those grown in non-oiled soils. Most critically however, seedlings grown in oiled soils demonstrated a higher rate of post-germination mortality, 45% for seedlings in 1975 oiled soils and 90% for 2014 oiled soils (Golan et al. 2016). Similarly, Tran et al. (2018) conducted a series of studies to examine the effects of field-collected oiled soils on germination, growth, and fitness of the two species of acacia found in the Arava. As with the previous study, adverse effects on seedling germination rates and growth, including reduced stem diameter, leaf production, and height, were observed in soils from the 1975 spill area. For soils impacted by the more recent oil spill, a serial dilution was performed to create test soil mixtures reflecting 30, 70, and 100% of field contamination rates, and acacia germination and growth were significantly suppressed in all concentrations of 2014 oiled soils versus controls. In addition, Tran et al. (2018) also observed increased superoxide dismutase and ascorbate peroxidase activities in the root tissue of seedlings grown in oiled soils, indicating that oil toxicity, as well as oil-mediated soil hydrophobicity, might be the cause of repressed germination and growth.

Observed adverse effects on seedlings grown in oiled soils may be a result of 1) toxic effects of oil constituents; 2) increased hydrophobicity of oiled soils; or 3) a combination of both. In a 2018 study on the hydrophobicity of soils impacted during the 1975 and 2014 spills, Gordon et al. (2018) found that the hydrophobicity of 1975 oiled soils was very similar to that of soils oiled in 2014, despite significantly lower TPH concentrations.

Nothers et al. (2017) concluded that, for acacia, trees under 40 years old were significantly underrepresented in the spill area and the fact that "small trees (height <1 m and canopy <2 m) were completely absent from the contaminated area … means that still no germination has occurred [since the spill]." Therefore, the results of this investigation (Nothers et al. 2017) concur with laboratory findings of Golan et al. (2016) and Tran et al. (2018) that oil exposure can suppress acacia germination under field conditions.

HaMaarag has also conducted field surveys of acacia sprouting, sprout condition, and adult tree vigor within the area affected by the 2014 oil spill (Nelvitsky and Winters 2018). Out of the 160 plots searched, 18 plots were determined to contain acacia sprouts. In the control area, the majority of identified sprouts (27 out of 30) were newly established within the previous year. However, in the plots impacted by oiling, there were no sprouts of less than 2 years of age. Because of the high number of newly sprouted seedlings found in the control areas, the abundance of acacia seedlings was more than 5 times higher than that found in the oil-impacted areas (Nelvitsky et al. 2018). Within the oil-impacted areas, researchers determined that observed seedlings had likely sprouted before the December 2014 spill, indicating that although established seedlings might be able to survive soil oiling, the oil prevents the establishment of new seedlings. Conversely, mature tree condition was overall unaffected by the presence of oiled soil, although three stressed acacias (all *A. tortilis*) were identified within the 2014 spill area (Shapira 2018).

In conclusion, while there is evidence that the effects of oil on mature, established acacia trees are likely negligible, there is significant evidence that oil exposure significantly suppresses seedling germination and survival.

5.3. Shrubs

Assessment of the population-level effects to smaller bush and plant species in the Evrona following oil spills has been studied in both the 1975 and 2014 spill areas. The biodiversity and health of plants within the 1975 spill area were surveyed by researchers in March 2015 and compared to nearby communities unaffected by the oil (Nothers et al. 2017). Overall, only small and temporary effects have been noted. Nothers et al. (2017) examined the bush communities within the 1975 spill area and found a few trends. One bush species, *Salsola cyclophylla*, was determined to be significantly smaller within the spill-affected area compared to individuals in the control area, while individuals of another species, *Hammada salicornia*, were on average larger in the spill area than in the control area. The observed increase in *H. salicornia* size in the spill area was a result of missing or reduced smaller size classes, likely due to decreased recruitment following oil exposure (Nothers et al. 2017). Although *H. salicornia* recruitment appeared to have been repressed following the spill, high abundances of small plants observed by researchers indicated that recruitment has recovered.

In addition, the HaMaarag monitoring program conducted between 2016 and 2018 sampled shrubs and undergrowth in the 2014 spill area, the 1975 spill area, and control locations (Shapira 2018; Berger-Tal et al. 2018). In the 1975 area, *Plicosepalus acaciae, Salsola cyclophylla*, and *Haloxylon salicornicum* were monitored. In the 2014 area, *P. acaciae, Nitraria retusa, Traganum nudatum Delile* and *Anabasis articulata* were monitored (Berger-Tal et al. 2018).[33] Measurements, some of which were species-specific, included relative water content, chlorophyll and carotene content, carbon-nitrogen ratios, plant size, photosynthetic activity, and spectral index (Berger-Tal et al. 2018).

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[33] Researchers reported that the two sites generally differed in terms of plant diversity and that these differences resulted from habitat differences and not exposure to oil.

Overall, no significant community-level effects on shrubs were found in either the 1975 or the 2014 oiled locations (Nothers et al. 2017; Shapira 2018), although some species-specific differences were noted (Berger-Tal et al. 2018). Based on the available survey data, however, effects on shrubs are expected to be minor, and recovery is expected to occur well before acacia community recovery.

5.4. Small mammals, reptiles, and arthropods

The number and diversity of small mammals and reptiles lost to direct oiling is difficult to quantify from documents provided, although some individuals were undoubtedly smothered by oil. Frumkin (2015) provides photographic evidence of an oiled snake carcass observed 2.5 months after the spill and recounts an observation from Roi Talabi (INPA ecologist in the Eilat Region) of dozens of dead mammals, birds, reptiles, and invertebrates.

Shanas and Olek (2014) surveyed species abundance in the oiled area. Although their survey methods are not detailed, they estimated that habitat of about 300 rodents was affected, primarily greater Egyptian gerbils (*Gerbillus pyramidum*) and Cairo spiny mice (*Acomys cahirinus*). Additionally, they estimated approximately 1,040 reptiles to be affected, including Bosc's fringe-toed lizard (*Acanthodactylus boskianus*), Arava gecko (*Stenodactylus doriae*), Snake-eyed skink (*Ablepharus sp.*), wedge-snouted skink (*Sphenops sepsoides*), and short-fingered gecko (*Stenodactylus sthenodactylus*). These estimates represent the population size that may be indirectly impacted by loss of habitat, although a subset of these individuals may also have been lost to direct oiling if they were unable to flee from the areas with flowing or pooled oil. However, the number of direct losses cannot be quantified based on data collected in the immediate aftermath of the release.

The HaMaarag sampling program conducted in 2016 and 2017 collected reptiles in the 2014 spill area, the 1975 spill area, and control areas (Buskila and Zalca 2017; Shapira 2018). Monitoring was concentrated within 48-hour sessions occurring in both the day and night, four times a year, for roughly 12 surveying work days/year (Buskila and Zalca 2017). Photographs, footprint tracing, and an overall species inventory were collected (Buskila and Zalca 2017). Overall, data from the two spill areas do not indicate an adverse effect on the variety or abundance of the reptile species from oil exposure; abundance was the same between control and oil locations (Shapira 2018). The 2014 oil area had more diversity than the 2014 control area, while the opposite trend was noted for the 1975 areas (Buskila and Zalca 2017).

Some behavioral differences were noted for select reptile species. Abundance and activity times of diurnal lizards and nocturnal geckos were affected (Shapira 2018). For example, in the 2014 oil locations, the soil temperature was 3°C higher than control soil. Lizard activity occurred earlier in the day within oiled locations compared to other sample locations, though the oil did not significantly alter the number of individuals observed throughout the day (Shapira 2018). The same temperature effect was not observed in the 1975 areas (Buskila and Zalca 2017). In most cases, geckos were observed more frequently in the control plots (Buskila and Zalca 2017); however, it is unclear whether these observations indicate a loss of geckos or simply a change in distribution. As such, it was concluded that, although the oil spill may have affected "the abundance and activity times of active daytime lizards and active night time geckos," overall species richness and general abundances of these reptiles were not affected (Shapira 2018).

The same monitoring program sampled arthropods in the 2014 spill area, the 1975 spill area, and control areas (Segev et al. 2017; Shapira 2018). Terrestrial arthropods were monitored using pitfall traps placed next to acacia trees, where possible (Segev et al. 2017). Antlion funnels were monitored in 10 plotted locations in the oil spill and control areas (Segev et al. 2017). Soil mesofauna and flying and tiny arthropods were sampled in oiled and control areas (Segev et al. 2017). Overall, no consistent effect was observed across species sampled; in general, effects were limited to a few species and a general trend showed more effects found in soil- and ground-dwelling arthropod species, rather than those found in trees (Segev et al. 2017). For example, the abundance of soil mesofaunal arthropods was significantly reduced in oiled soils (Segev et al. 2017). More ants were found in control areas, although the aggregating tendencies of this social insect complicated density calculations (Shapira 2018). The most common beetle species, *Mesostena* spp, was significantly less likely to be collected from oiled locations, and the number of antlion funnels was reduced in 2014 oiled soils versus control areas (Segev et al. 2017). However, antlion densities were similar in 1975 oiled and control locations (Shapira

2018). When the 1975 and 2014 oiled areas were compared, more arthropods were found near acacia trees in the 1975 oil location compared to the more recent oil spill area (Shapira 2018).

For arachnid monitoring, pitfall traps, tree-trunk traps, and foliage vacuuming were used at approximately 30 acacia trees in 2014 oiled, 1975 oiled, and control areas (Gavish-Regev and Lubin, undated). For other species such as scorpions, wolf spiders, and *Sahastata* species, additional methods of monitoring with UV flashlights, headlamps, and crevice sampling were used (Gavish-Regev and Lubin, undated). For arachnids, no significant effect was noted for species living in acacia trees or on the soil surface between the oil locations and the control locations (Gavish-Regev and Lubin, undated; Shapira 2018). For those species living at least part of their life cycle within the soil, abundance was higher in the control plots (Shapira 2018).

Overall, it was concluded that reductions in the abundances of certain species (such as tenebrionid beetle species) in oiled areas accounted for much of the differences in arthropod community composition (Shapira 2018). Moreover, the abundances of soil-dwelling arthropods such as ant lions and soil mesofaunal invertebrates were significantly reduced in oiled areas. Similarly, the abundances of tree-associated arachnids were unaffected by either the 1975 or 2014 spill; however, soil-associated arachnids (such as scorpions and burrowing spiders) were decreased in spill areas (Shapira 2018).

5.5. Birds and Bats

Korin (2018) states that sixteen subspecies of microbats and one species of fruit bat inhabit the Arava and that acacia are preferred hunting zones for foraging on insects or other food sources. Similarly, Frumkin (2015) speculated that the loss of acacia reduced habitat availability for migratory birds that stopover in the region during spring and autumn migration. Therefore, loss of acacia may result in a diminished habitat and/or food source for bat and bird species. Preliminary surveys conducted by Korin (2018) suggest a possible minor effect on bats since activity (number of vocalizations) was significantly higher in a control area compared to the 2014 oiled area during summer months; however, this effect was not observed during fall and spring sampling, indicating that, overall, populations of bats were not likely to be significantly impacted by the spill itself.

Micro bats were also monitored in the HaMaarag survey program (Korin 2018; Shapira 2018). Monitoring occurred in spring, summer, and fall via use of ultrasonic sound recordings (Korin 2018). After the first sampling year in 2016, some study design modifications were made: increase in plots, sampling only during new moons, changes in sampling locations, and the use of light traps to sample nocturnal arthropods (Korin 2018). Few negative effects associated with the oil were noted (Korin 2018, Shapira 2018). Nocturnal activity and insect-eating bat richness was higher in the control locations during the summer season compared to the oil spill locations, and insect activity was also higher during this sampling period (Korin 2018, Shapira 2018). However, this effect was not observed in either spring or fall surveys.

A monitoring program was developed by HaMaarag to survey both birds and bats in the 1975 and 2014 spill areas (Shapira 2018). Bird abundance data were collected every month for a year via a series of point count surveys, and species were identified visually or by call. A survey specifically for rare species with a similar study design was performed four times a year (Weiz et al. 2018). Some preliminary findings were reported, including a decline of seed-eating birds in the 1975 and the 2014 oil spill locations and a decrease in the carrying capacity of the Evrona area compared to a control location (Weiz et al. 2018; Shapira 2018).

5.6. Dorcas Gazelle

There is little evidence of any direct effects from the spill on Dorcas gazelles. Annual surveys of gazelle abundance have been conducted since 1999. Total count in 2017 was 246 individuals, the second highest abundance since censusing began. Although there was an apparent slight decline in abundance in the immediate years following the spill (2015–2016), the number of gazelles observed in both years was within range for pre-spill years (2011–2014; Figure 6). The ephemeral decline in abundance may reflect temporary displacement of gazelles from the reserve in response to the spill and subsequent remedial actions.

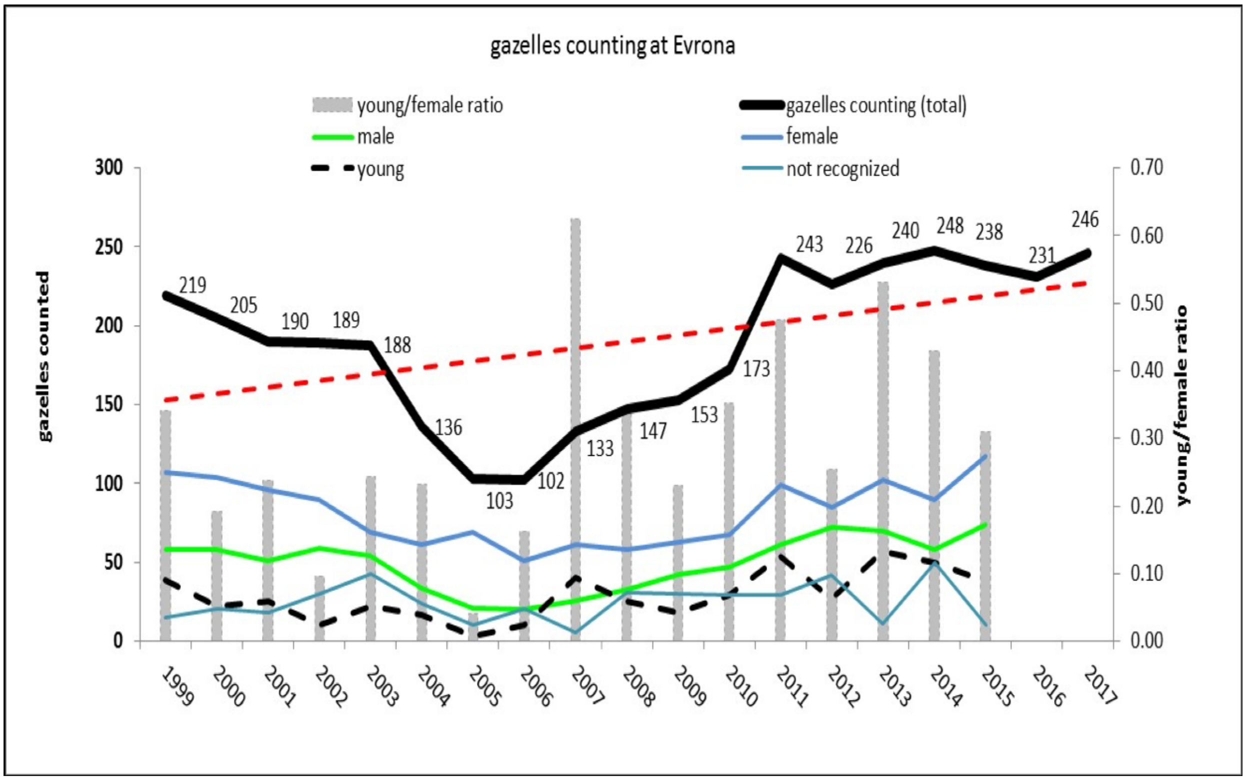

Figure 6. Gazelle counts at the Evrona Nature Reserve (from Ramboll Environ, 2018)

Dorcas gazelles rely on acacias as a food source, eating the foliage and seeds; they also use the trees as shelter from the desert heat. In turn, gazelles benefit trees since passage of seed pods through the gazelle's gastrointestinal tract improves germination rates and protects the seeds from predation by bruchid beetles (Or and Ward 2003). Services that acacia provide to gazelles may be altered in several ways by the spill. First, direct tree mortality removes a subset of trees from the local population. Surviving trees may exhibit reduced growth or seed production, which reduces the abundance and quality of the gazelle's food supply, though this was not demonstrated during acacia surveys conducted post-spill. Finally, reductions in germination and recruitment of new acacia trees caused by residual petroleum in soil will reduce food sources that may contribute to future population-level effects to gazelles in conjunction with ongoing effects from baseline stressors. The monitoring program between 2016 and 2018 showed that the oil affected the grazing radius around acacia trees for the gazelle in both spill sites (Shapira 2018), but it is unclear if this has any implications for gazelle health and survival.

The greatest impact to wildlife, including the Dorcas gazelle, resulting from the 2014 spill will likely occur through indirect effects mediated by loss of key acacia habitat and associated food sources. While some of these effects became apparent immediately following the spill, there is also the potential for delayed effects that will not be apparent for some time. The most severe indirect effects will be caused by the loss or impairment of acacia trees, since these are keystone species that are important sources of food and shelter for many species (Gruner et al. 2015).

5.7. Conclusions

Based on evidence from the scientific literature and findings from the post-spill ecological surveys conducted by HaMaarag, observed ecological effects can be categorized as follows:

1. Reductions in abundance of specific, usually soil-associated wildlife, such as antlions and soil mesofaunal invertebrates in oiled soils;
2. Altered behaviors, including diurnal lizard activity patterns and summertime bat activity, that appear to be in response to oil exposure but have no clear impact on population viability or sustainability in the area; and
3. Significant current and future repression of acacia germination and seedling survival in oiled soils, as demonstrated by laboratory and field studies.

Given the importance of the acacia as a habitat-structuring keystone species, this impact is by far the most problematic for the sustained health of the spill-affected Evrona Nature Reserve ecosystem. It is further confounded by the fact that most of the injury to acacia populations is projected to occur over future decades and it is currently unclear when germination rates may recover in spill-impacted areas. Therefore, given the documented significant reduction in acacia germination in oiled soils, the long-term persistence of such effects in oiled soils (as demonstrated by scientific surveys in the 1975 spill area), and the importance of acacia to wildlife and ecosystem function, we conclude that loss of future acacia is the primary injury resulting from the 2014 oil spill.

6. Estimated Injury to Ecological Resources Following the 2014 Evrona Oil Spill

6.1. Injury to Acacia

The injury to acacia trees was determined by assessing ecological service loss associated with (1) the direct loss of mature acacia trees (i.e., no longer able to produce seed pods for future growth) and (2) the losses caused by the suppression of seedling germination in the 2014 oiled areas of the Evrona Nature Reserve.

Losses of adult acacia trees in the 2014 spill area were generated using available information from Ramboll Environ (2015) and Nelvitsky and Winters (2018). According to Ramboll Environ (2015), 10 acacia trees had been mechanically damaged during response activities or showed signs of stress following oiling. In addition, data from the post-spill acacia surveys indicated three trees demonstrated persistent signs of stress from the oil spill. However, it is currently unclear whether the three trees monitored by Nelvitsky and Winters (2018) were part of the group of ten stressed or dying trees reported by Ramboll Environ (2015). Therefore, as a conservative estimate, we conclude that adult acacia mortality resulting from the 2014 spill is 13 mature trees. Information from Gruner and Segev (2015) indicates no significant difference in adult acacia mortality in areas affected by the 1975 spill and control, no-impact areas. Hence, there is no evidence that there will be significant additional delayed mortality of adult acacia trees in the 2014 spill-affected area.

Most of the available data indicate that losses of acacia will occur primarily from long-term suppression of seedling germination and survival as previously summarized. Based on the scientific data and studies carried out at the 1975 spill site, it is expected that acacia germination is unlikely to occur within the 2014 spill area for at least the next 40 years and may be reduced for up to 100 years. Over time, this absence of germination and recruitment of new acacia trees will result in a reduced and aging population of adult acacia in the 2014 spill-impacted areas as the existing trees age and die off without being replaced by younger trees. As a keystone species, this scenario leads to an eventual loss of almost all of the ecological attributes that the acacia trees make possible in the ecosystem. In other words, a complete or near complete loss of the ecological services that are in one way or the other supported or made possible by the acacia trees.

Currently, there are insufficient site-specific data to completely quantify the future acacia losses in the 2014 spill area. However, data generated from surveys of acacia trees in the 1975 area can be used to predict the likely future losses in the 2014 spill area. Based on information from Nothers et al. (2017), it was estimated that the younger classes "lost" to oiling in the 1975 spill area comprised just over 25% of the entire population. To assess the injury caused by the suppression of seedling germination, two scenarios are considered. These are based on two different estimates for the number of affected trees that produce seed stock: a low estimate of 274 trees (Ramboll Environ 2015) and a high estimate of 400 trees (Shanas and Olek 2014). Currently, it is unclear how long the suppression of acacia germination and seedling survival is likely to persist in the 2014 spill area, but results from surveys of acacia in the 1975 spill area indicate that the suppression is likely to persist for at least 40 years. Hence, we have developed losses over hypothetical 40-, 60-, 80-, and 100-year time frames.

6.2. Injury to Wildlife

Direct injury due to death from oiling occurred during the spill for various wildlife species, including small mammals, reptiles, and invertebrates. However, data collected in the aftermath of the spill are insufficient to quantify the number of organisms lost as no standardized carcass searches appear to have been conducted. The estimates of species abundance reported by Shanas and Olek (2014) can place an upper bound on the number of individuals present, but presence in the spill area does not directly imply death from oiling. Based on risk calculations presented by Ramboll Environ (2015) and data from numerous post-spill wildlife surveys, it is unlikely that the oil caused direct mortality of Dorcas gazelles or other large wildlife. Although some losses of ground-dwelling arthropods and small reptiles or mammals may have occurred following the spill, these are considered minor compared to long-term effects of reduced acacia germination and recruitment over the next decades.

Overall, the most severe impacts to wildlife species are likely to occur in future years because of a reduction in abundance and quality of key resources, specifically the keystone acacia trees. Since complete recovery of acacia is expected to take many decades, the timing and magnitude of indirect effects to wildlife are challenging to predict at present. There is a fear by conservation biologists that the spill will lead to a reduction in Dorcas gazelle abundance. For example, the slight decrease in census numbers in the Evrona Nature Reserve in 2015 compared to 2014 was viewed as spill-related mortality, but counts in later years (see Figure 6) suggest this may have simply reflected a temporary displacement. As Shanas (2016) correctly notes, it is still too early to assess the impact of the spill on the gazelle population and multi-year surveys will be required to identify trends in abundance. However, as noted in Section 4, it is critical to remember that even absent the spill the long-term viability of the herd is threatened by other factors, including climate change, habitat loss and fragmentation, predation by jackals and dogs, collisions with vehicles, and encroachment of settlements (Frumkin 2015). Therefore, future changes in population abundance need to be evaluated in consideration of these baseline stressors before attributing causation to the spill.

For reasons outlined above, it is impractical to conduct a direct evaluation of injury to wildlife because the data currently available are insufficient to quantify numbers of individuals lost for any species (past or future) with any degree of reasonable certainty. Excluding direct mortality, the greatest impacts to all species will be related to the loss of key resources (food and habitat) from the reduction in quantity and quality of flora, especially acacia. The acacias are the keystone species in the Evrona Nature Reserve, and as trees recover following the spill, so will the flow of ecological services they provide to wildlife species. As noted above, because they are the keystone species in this ecosystem, quantifying the loss of services provided by the acacia trees because of the 2014 oil release into the nature reserve provides a direct proxy for assessing the loss of most other natural resources within this ecosystem and the ecological services they provide. To accomplish this, a resource equivalency analysis (REA) (Desvousges et al. 2018) for the nature reserves acacia trees has been constructed and is considered a suitable means of quantifying service losses for wildlife species. Details of the REA are provided in the following section.

7. Resource Equivalency Analysis

7.1. Overview

The concept of using equivalency analysis to scale injury and restoration of ecological resource services following an oil spill or chemical release is broadly established in NRDA guidance in the United States and the EU (Desvousges et al. 2018). Two equivalency methods are typically used, habitat equivalency analysis (HEA) and REA. A HEA is used when the service losses are being assessed on a habitat (area) basis, and a REA is used when a biological metric (e.g., number of organisms) is the basis for losses. A REA is appropriate in this analysis as the focus of ecological services assessment is on loss of individual acacia trees caused by released oil.

The objective of equivalency analysis is to provide compensatory services (i.e., new acacia trees) that provide equal value of services to those lost because of the spill. The approach used here calculates debits based on services lost because of the death of acacia trees and future suppressed germination of acacia seedlings caused by effects of residual oil. Because debits and credits can occur over different time frames a discount rate is typically used to standardize values to present-day amounts (Desvousges et al. 2018). For this analysis a discount rate of 3% is applied, a value typically used in U.S. NRDAs. Service losses and gains are discounted to 2018 equivalent values. Services provided by acacia include provision of food (e.g., seedpods) and habitat to wildlife, and enhancement of wadi habitat for other plant species. Because seedpod production is also critical for future regeneration of adult acacia, that is selected as the metric used for scaling purposes. Results are expressed in terms of discounted service tree-years (dSTYs), where one service-year is the service provided by one tree for a calendar year. Since losses are calculated on an annual basis and since the spill occurred in December 2014, service losses are estimated to start in 2015. Service losses are calculated separately for adult acacia and lost seedling germination, but because both are measured using the same service-year metric, the losses can be combined when calculating required restoration offsets.

The approach described here for performing the REA is comparable with the approach used by Ramboll Environ (2015). Both REAs estimate losses for mature trees and repressed future germination and calculate the number of acacias that need to be restored to offset those losses. There are differences between the models in assumptions for input parameters (number of trees that died, tree age, duration of suppressed germination, etc.). Also, Ramboll Environ chose not to apply a discounting rate, as is done here. The implications of varying input parameters and applying discounting are discussed below as part of a sensitivity analysis. The main conceptual difference between the models relates to how years of lost service are estimated for trees. Ramboll Environ (2015) estimates this based on tree age at time of death, such that a 100-year-old tree has lost 100 years of service. The approach used here calculates service loss based on the expected lifespan of the tree, on the assumption it is not the past services that are lost but rather future services that are no longer provided by the dead tree.

7.2. Service Losses to Mature Acacia Trees

As discussed in Section 6, it is estimated that 13 adult acacia trees were killed by oiling or response actions. The ages of the trees killed are not known, so we estimate an average age of 50 years for computation purposes. Hegazy and Elhag (2006) note that in their study population 50% of the trees were age 5–50 years, so 50 years likely reflects a median age. Hegazy and Elhag (2006) also state that individual acacia can live >600 years, but very few trees would be expected to survive that long, so we estimate a maximum age of 380 years based on the generation time calculated by Hegazy and Elhag (2006). Baseline tree loss from natural mortality needs to be considered since trees in the Evrona Nature Reserve would have experienced natural mortality in the absence of the spill. For this evaluation, we assume an annual natural adult mortality rate of 1.74% based on Peled (1988). The service being evaluated is seedpod production, and Hegazy and Elhag (2006) state that seed production is not evenly distributed over adult cohorts and peaks around 10 years then declines until age 150 years. For purposes of this analysis, it is conservatively estimated that trees age 10–150 years have maximal seed production (100% service) and trees >150 years provide 50% level of service until death. Input assumptions for the adult tree REA are summarized in Table 1.

Table 1. Assumptions applied in REA for estimating service losses from adult acacia trees

# Adult trees killed by spill	13
Average age at time of spill (yrs)	50
Maximum life-span (yrs)	380
Annual natural mortality rate (%)	1.74
Age range when maximum services are provided (yrs)	10–150
Maximum level of service provided (%)	100
Reduced level of service after 150 yrs (%)	50
Discount rate (%)	3
Base year for discounting	2018

The equation for calculating dSTYs is:

$\Sigma \; dSTY_x = (NT_x * SL_x) * 1.03^{(2018-x)}$

Where: $dSTY_x$ is the discounted service tree-years for year *x*;

NT_x is the number of trees alive in year *x*;

SL_x is the service loss for a tree in year *x*; and

$1.03^{(2018-x)}$ is the discount function to equate service loss in year *x* to the 2018 equivalent.

Based on these assumptions, the loss of 13 adult trees from oiling in 2014 results in a service loss of 307 dSTYs.

7.3. Service Losses from Suppressed Germination

As discussed above, it is uncertain how long suppressed germination may persist in oiled areas, but scenarios are assumed based on recovery times of 40, 60, 80, or 100 years. Two estimates are assumed for the number of affected trees that produce seed stock, a low estimate of 274 trees (Ramboll Environ 2015) and a high estimate of 400 trees (Shanas and Olek 2014). To estimate the potential number of seedlings that could be expected each year under unimpacted conditions, we use information from Wiegand et al. (1999) that estimates there are approximately 1.55 one-year-old seedlings for each adult tree. Applying this value to the low and high tree number estimates results in 425–620 seedlings potentially lost in every year when germination is suppressed. Seedlings must survive until 10 years of age before they start providing the modeled service (seedpod production). Ward and Rohner (1999) estimate that first year mortality of seedlings is 95%, so this value is used as a baseline adjustment to account for the number of seedlings that would die in the absence of oil (i.e., baseline loss). The same mortality rate is applied for seedlings up to 3 years old based on a finding by Wiegand et al. (2000) that mortality rates for seedlings are unchanged until 2.5 years of age. For seedlings older than 3 years, the annual adult mortality rate (1.74%) is applied. Once seedlings reach 10 years they start providing services according to the assumptions stated above for adult acacia. Service losses are estimated over the range of years with suppressed germination, with discounting applied to future losses as described above. Service loss estimates for the different scenarios are summarized in Table 2.

Table 2. Summary of projected acacia losses (dSTYs) resulting from suppression of seedling germination and survival in oiled soils

	Tree Service Losses (dSTYs)			
	40 years of repressed germination	60 years of repressed germination	80 years of repressed germination	100 years of repressed germination
Scenario 1 (low density estimate: 274 trees)	407	487	531	556
Scenario 2 (high density estimate: 400 trees)	594	711	776	811

7.4. Estimation of Restoration Requirements

Based on the analyses outlined in the previous sections, the total service losses for acacia range from 714 to 1,118 dSTYs depending on which scenario is used for the duration of suppressed germination.[34] Therefore, to fully offset these loses, sufficient acacia trees must be added to the existing population to provide an equivalent level of discounted services to those lost. For example, an acacia seedling established on unoiled soil in 2020 will, if it survives, start producing services (seedpod production) in 2029 when it reaches 10 years old. Accounting for natural mortality rates, that 10-year-old acacia would then produce 15.69 dSTYs over its lifespan. Dividing the services losses by the service gain per tree results in an estimated restoration requirement of approximately 46–71 10-year-old acacia trees (Table 3). Applying juvenile tree mortality rates discussed above, this number of 10-year-old trees equates to approximately 20,946–32,824 1-year-old seedlings.

Table 3. Summary of number of 10-year-old acacias required as a restoration offset, assuming restoration starts in 2020. All scenarios assume loss of 13 adult acacia, but with varying extent and magnitude of lost future germination.

	10-year-old acacia required for restoration			
	40 years of repressed germination	60 years of repressed germination	80 years of repressed germination	100 years of repressed germination
Scenario 1 (low density estimate: 274 trees)	46	51	53	55
Scenario 2 (high density estimate: 365 trees)	57	65	69	71

7.5. Sensitivity Analysis

The restoration requirement depends on the inputs used in the REA model. The inputs described in the previous sections are believed to be reasonably conservative values for the relevant parameters. However, a sensitivity analysis can be conducted to investigate how restoration requirements change if input parameters are adjusted and to determine which parameters have the greatest influence on estimated restoration requirements. To perform the sensitivity analysis, the value of one input parameter is changed while holding all other values constant. Part of the

[34] Calculated by summing adult tree losses (307 dSTYs) with low-end and high-end estimates of losses from repressed germination.

sensitivity analysis is presented above based on the different scenarios used to model future suppressed germination. The following additional sensitivity analyses were performed:

- **Number of adult trees killed by spill:** The model assumes 13 trees killed. Each additional adult tree killed would add 1.5 10-year-old acacia trees to the restoration requirement.
- **Age of adult trees:** The model assumes adult trees are 50 years old. If trees were 10 years old, this would add 0.1 trees to the restoration requirement. If trees were 100 years old on average, this would decrease the restoration requirement by 0.8 trees.
- **Lifespan of adult trees:** The model assumes an average lifespan of 380 years. If the maximum estimated age is used (600 years), this does not change the restoration requirement.
- **Service loss for adult trees:** The model assumes trees older than 150 years provide a reduced level of service (50%) for seed production. If service loss is increased to 100% for older trees, this adds 0.1 trees to the restoration requirement.
- **Estimated annual adult mortality rate:** The model assumes a background mortality rate of 1.74%. If this rate is halved, it adds 1.6 trees to the restoration requirement.
- **Number of 1-year-old seedlings/adult tree:** Based on literature values, the model assumes that under natural conditions there would be 1.55 1-year-old seedlings for each adult acacia in the population. If this ratio is increased to 3 seedlings/adult, this would add 24–49 trees to the restoration requirement depending on the scenario applied. Lowering the ratio to 1 seedling/adult would reduce the restoration requirement by 10–18 trees depending on the suppression scenario applied.
- **Annual seedling mortality rate:** The model assumes an annual seedling mortality rate of 95% up until age 3 years. Wiegand et al. (2000) note that in good years with adequate rainfall the annual mortality rate could be as low as 85%. It is extremely unlikely that good year conditions would occur in every

year when germination is suppressed, but if that did occur it would increase the restoration requirement by 206–414 trees depending on the seedling scenario applied. Alternatively, in bad years with no rainfall, all seedlings may die. Assuming 99% mortality for every year of suppressed germination would reduce the restoration requirement by 25–49 trees.

- **Year restoration starts:** The REA assumes restoration starts in 2020, but if restoration does not start until 2025, that would add 7–12 trees to the restoration requirement due to greater discounting of future service gains.
- **Discounting:** The REA applies a discount rate of 3% to all past and future service losses and gains. This is a typical rate applied in damage assessments. Ramboll Environ (2015) opted not to apply a discount rate in their evaluation. If no discount rate is applied this would reduce the restoration requirement by 11–14 trees.

As illustrated by this sensitivity analysis, assumptions for life-history parameters of adult trees have little influence on restoration requirements. Alternatively, varying juvenile life-history parameters, especially early life-stage mortality rates, can have a large influence on restoration requirements, as does the length of time that suppression of germination is expected to persist. Choice of discount rate also influences restoration requirements.

8. Potential Restoration[35] Options

8.1. Setting the Stage

The ecological analyses presented in Sections 5 and 6 result in several assumptions. The most significant of these is that while there may be some minor levels of injury to various wildlife and flora in the Evrona Nature Reserve from the 2014 Evrona oil spill, the keystone species in the Evrona Nature Reserve are the acacia trees, and absent the various ecological services they provide (shade, food, soil modification, etc.), the rich tapestry of abundance and biological diversity that makes the Evrona Nature Reserve such a unique ecosystem would be lost. The keystone species assumption is supported by the work of others (Noy-Meir 1973; Ward and Rhoner 1997; Munzbergova and Ward 2002) and is consistent with our understanding of the ecology of this part of the Arava Valley (e.g., Nothers et al. 2017; Stavi et al. 2016; Hackett et al. 2013).

This concept was also a key message from the presentations provided by many of the environmental scientists who participated in the mediation meeting in the Evrona Nature Reserve (March 26, 2018) and in Tel Aviv (March 27 and 28, 2018). For example, Dr. Asaf Tsoar's March 2018 presentation (2018b) on the national importance of the Evrona Nature Reserve clearly noted the importance and significance of the acacia as a keystone species, tying their presence to both the biodiversity and density of flora and fauna growing in the nature reserve. Professor Shanas (2018) also focused on the unique biodiversity of this desert ecosystem and noted the links between the health of the ecosystem and the presence of the acacia. Finally, this perspective was also presented by Dr. Sorenson (2018) regarding the environmental impacts to vegetation from the 2014 Evrona oil spill.

The importance of this assumption is that it allows us to identify specific restoration options that will have the effect of compensating for all or most of the persistent ecological injury that occurred because of the oil spill. The unique and central ecological role of the acacia trees in

[35] Under the U.S. NRD Claim model, the term restoration is used to describe the rehabilitation of the injured resources and the ecological services they provide.

shaping the ecosystem of this hyper-arid desert allows us to look at the potential restoration of these trees as an ecologically appropriate means to restore the injuries to the overall ecosystem. Such a restoration, appropriately discounted for time, would effectively compensate for the ecological injuries to the Evrona Nature Reserve caused by the 2014 oil spill, with the cost of this restoration being the damages associated with those ecological injuries. Other restoration considerations, such as the construction of wildlife corridors to help enhance the interconnection between the Evrona Nature Reserve Dorcas gazelles and other gazelle populations to the west and north would only benefit the gazelle. While the importance of the symbiotic relationship between the gazelle and acacia tree seed germination should not be discounted, if germination is primarily negatively impacted by oiled soils in areas along the major wadis, the influence of the change in gazelle population is of secondary importance. The continued problems with recruitment of acacia trees into the Evrona Nature Reserve population due to germination failure in oiled soils will ultimately lead to the exclusion of the gazelle in this area of the Arava Valley.

In Section 7, we have taken the concept of the acacia tree as the keystone species and used REA modeling to determine what amount of restoration would be required to compensate for the ecological losses/injuries from the 2014 oil spill. This approach was used by Ramboll Environ (2015) in their initial ecological impacts expert report and further expanded upon by Dr. Sorenson in her March 2018 presentation to the mediators in Tel Aviv (Sorenson 2018). As a possible solution, Dr. Sorenson suggested some type of acacia plantings should be done and noted that a program of "Adopt an Acacia" exists in the central Arava Valley. This program was expressly developed to counter the loss of acacia trees to development and population growth.[36]

As was noted by several ecological experts during the March mediations meetings, one cannot simply set up drip lines in the Evrona to ensure that sufficient water is available for the survival of successfully germinated acacias. Furthermore, it was noted that the programs in Central Arava focused on planting acacias not in a natural reserve setting but near villages and farms to leverage water currently being used for agricultural uses to sustain the acacias. The well-taken

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36 "Adopt an Acacia" project inaugurated in the Central Arava. Jerusalem Post, January 25, 2010. https://www.jpost.com/Green-Israel/People-and-The-Environment/Adopt-an-Acacia-Project-Inaugurated-in-the-Central-Arava, accessed September 6, 2018. See also http://www.kkl-jnf.org/about-kkl-jnf/kkl-jnf-in-public-discourse/in-the-press/jan-march-2014/adopt-acacia/, accessed September 6, 2018.

point was that such an effort would do nothing to restore the natural habitat of the Evrona Nature Reserve. Interestingly, throughout the mediation meeting, no real alternatives for restoration were provided by the ecological experts representing the INPA or any of the other plaintiffs.

8.2. Prior Restoration Suggestions

In an undated response to an undated PowerPoint presentation (titled - ppt.(005) מצגת), Environ Ramboll presented a number of potential responses dealing with potential restoration options and approaches. The following is a list from that undated Environ Ramboll response and illustrates the fact that options are available for consideration:

- *"Find and protect new seedlings in the reserve (within and away from soils with residual oil); develop an adaptive management plan so that sprouts that germinate are more likely to survive to adulthood (since the vast majority of sprouts do not). This may involve targeted irrigation that is intended to mimic normal rainfall in years of drought. This could also involve protection of sprouts from grazing by animals.*
- *The airport will bring about significant changes in water flow patterns and until now, according to our knowledge, water will flow through the new water passage and spread out over the eastern part of the reserve. This is an opportunity to control diverted water from the new airport in a way that potentially better benefits the main portion of the reserve impacted by oil (even if just the more southern portion). Alternatively, take advantage of the new path of water flow within the reserve to monitor and protect new seedlings so that the overall number of acacia trees in the reserve continues to increase.*
- *Install targeted and well-spaced mini-dams to divert water away from channels with oil residues and into areas without residual oil so that these areas get more water and can offer improved conditions for seed germination.*
- *Perform targeted and well-spaced removal (or bioremediation) in areas along the channel to allow more clean areas for germination. As I was informed, EAPC has engaged in a contract with Israel Nature and Parks Authority in which EAPC took upon itself an obligation to sponsor a conduction of a treatment of the entire area of the reserve (not only in areas adjacent to the water flow channels). According to the*

Contract, at the first stage the contractor (to be chosen in a tender) is supposed to conduct a scale-up of the treatment in the area of 1 dunam and at the second stage only if the scale-up succeeds, Israel Nature and Parks Authority will be entitled to conduct a treatment of the entire remaining part of the reserve (143 Dunam).

- *Plant trees and use irrigation in targeted areas only, recognizing that the National Park Authority has indicated that irrigation is not desired for the long term. The irrigation could be automated to mimic natural flood patterns in years of drought. We are aware of the opposition of the NPA to acacia irrigation from discussions in litigation. It is my understanding that NPA is potentially planning to plant and irrigate acacia trees along the ecological corridor between the reserve and airport in order to encourage the gazelles to use the ecological corridor, which is in conflict with NPA's opposition to watering in the reserve discussed during mediation.*
- *Monitoring groundwater levels and irrigate to simulate floods only during droughts.*
- *Preserve the 100 trees that will die west of the airport due to development of the area, and not due to the oil spill (if possible or logical)."*

Not all of these may be viable or desirable options, given the complexity of the growth issues being faced in this part of the southern Arava Valley and the resource management approaches most desired by the INPA, but they do illustrate a desire and focused effort to find solutions to the many challenging ecological issues being faced, including the oil spill, the habitat segmentation, etc.

8.3. A Path Forward

Exponent is unaware of any agreement between EAPC and the INPA regarding "targeted and well-spaced removal (or bioremediation) in areas along the channel to allow more clean areas for germination." However, such a pilot effort would be useful in assessing the efficacy of bioremediation of the oil-impacted soils in the Evrona Nature Reserve in overcoming issues associated with acacia seed germination in these soils. In absence of any knowledge of this approach (beyond that provided in the undated Environ Ramboll response), we present and discuss a restoration option that focuses on using the water diverted from the new international airport.

Following the March 2018 mediation meetings, a thorough review of the past, present, and future conditions at and around the Evrona Nature Reserve led to the realization that little use was being made of the runoff water from Wadi Raham.[37] Before building the airport, it appears from our reviews that water from wadi Raham crossed Route 90 north of the Be'er Ora junction and flowed south and farther east. With the building of the new airport, the water from wadi Raham appears diverted south of the airport but still flows to the eastern part of the nature reserve.

These observations led to the consideration of using this diverted flow as a potential source of additional water to the Evrona Nature Reserve, thereby opening up the possibility of creating additional areas within the nature reserve with enhanced water supply; with this enhanced water flow, areas of increased acacia density and ecological richness could naturally develop. With this concept in mind, additional information was requested regarding the engineering aspects associated with the diverted water to further assess whether this concept could provide a source of water to areas of the Evrona Nature Reserve, resulting in increased germination and growth of acacia trees.

Several responses were obtained from the parties. In a July 1, 2018 letter from Dr. Tsoar to Adv. Pink (Tsoar 2018b). Dr. Tsoar indicated that they (INPA) had "found that the original water runoff was not supposed to go to the reserve." He stated that they (INPA) had "changed this and the current plan is to return as much water as possible to the natural wadis in the reserve." At the same time, four .AVI movies were provided by the plaintiffs that appear to illustrate two different hydrological models, each under two different flow regimes.[38] In the initial set, it appears that the water is released from the infrastructure that has been built to capture the runoff west of the airport and divert it south and under the Be'er Ora/Route 90 intersection. This water flows predominantly to the east of the nature reserve, with little impact on the nature reserve itself. The second model includes a dike placed southeast of the Be'er Ora intersection and illustrates the flow of the Wadi Raham diverted water, with some percentage of it being further

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[37] Different documents seem to refer to the main wadi north of Be'er Ora, whose waters are being diverted southward from the airport as Wadi Racham and Wadi Raham.

[38] The .AVI files provided are titled Depth_5m grid-110km-1%, Depth_5m grid-110km-50%, scenario3_1%-2, and scenario3_50%-2. No additional information regarding the model parameters were provided.

diverted to the south by the dike. In this second model scenario, water appears to be diverted into the Nature Reserve. Dr. Tsoar (2018b) is unsure if this approach will successfully divert water into the Evrona Nature Reserve and notes that "Until it is constructed, we will not really know if this works or not."

Based on a review of these models, EAPC noted in a July 25, 2018 letter from Dr. L. Asaf[39] to myself, that much more work is required to understand the baseline conditions (i.e., the pre-airport construction water budget) and that without this, there is no way to analyze the effect that the flow diversion will have on the water balance in the Evrona Nature Reserve. Dr. Asaf sets out some suggestions/recommendations regarding hydrological monitoring and further notes (and I agree) that the four .AVI files are inadequate to fully evaluate the model. Dr. Asaf ends his comments to me by noting that as the smaller diversion dike is not currently built, "there is significant uncertainty about the potential of floodwater from Raham Wadi to enter into the center of the Evrona reserve, for at least two consecutive winters."

Despite all of this, the airport is built and the water from wadi Raham is being diverted southward along the western side of the airport and released southeast of the Be'er Ora/Route 90 intersection. Use of this water to support acacia growth and ecosystem evolution in the Evrona Nature Reserve is a logical step. Such a solution will effectively replace the ecological injuries sustained by the nature reserve from the 2014 oil spill and may even compensate for observed impacts associated with the earlier 1975 oil spill. The challenges that exist are to do the following:

1. Design the hydrodynamics of the system effectively such that excess water can be successfully diverted and nature can efficiently accomplish the restoration;
2. Develop and implement a comprehensive monitoring system to ensure that germination is occurring and to gain additional scientific understanding into the evolution of these ecosystems; and

[39] Dr. Lior Asaf is the Chief Hydrologist for LDD.

3. Continue to assess germination in the 1975 and 2014 areas to better understand the timeframes over which oiled soil impacts germination in this hyper-arid environment.

Finally, we must acknowledge that the most significant challenge is that there is little existing research to allow us to accurately estimate the number of new trees sprouted that will be needed to obtain the appropriate number of adult acacia trees that were injured by the oil spill. We are building a restoration option based on prior observations (e.g., Golan et al. 2016) that most vegetation in hyper-arid zones, like the Arava valley, is directly linked to rainfall and water redistribution through active stream channels.

Under the U.S. NRD Claim model, the costs associated with the design work, the implementation of the design, and the long-term monitoring would represent the damages associated with the ecological injuries caused by the release of the oil. In this case, it is unclear given the information in hand what, if any of these types of infrastructure costs are built into pre-existing agreements dealing with the new airport. To the degree that the INPA agrees, one additional option would be to set up a location where seedlings can germinate and then transplant these germinated seedlings into appropriate locations based on the new water flow networks that will occur because of the diversion of the wadi Raham water.

Conclusions

Based on my experience with oil spill injury assessment, on my meetings with the plaintiffs and the defendants, on discussions with the mediator, and on the review of information from the open literature and provided by the parties, the following opinions/answers are provided regarding the change questions presented by the parties:

1. *Was damage caused and ecological environmental hazards following the event, including to the ecological system and to biodiversity, damage to quality of life, convenience and wellbeing and the perception of the quality of life and if yes – what is this damage and hazards (whether they can be rehabilitated or no* [sic] *including damage which has not yet been finally formed including the cost of monitoring and the cost of rehabilitation as a result of the event and the cost as a function of the rehabilitation time to the extent it is possible to rehabilitate). All while referring to actions performed and that are being performed on the ground today, and referring to the chapters of damage in the pleadings filed by the Applicants/the Plaintiffs and the answers to these claims in the pleadings filed by the Respondents/the Defendants.*

As noted in my report, to ensure clarity in what is being discussed, I have defined "impacts" to the environment/ecology as injury to those resources and will reserve the term "damages" for the costs associated with restoring or rehabilitating the injury. In reviewing the pertinent information associated with the spill, the response, and the short- and long-term impacts from the spill, I find the following:

1.1. The release of oil from the EAPC pipeline on December 3, 2014 did result in ecological injury. Specifically, this injury occurred in the Evrona Nature Reserve because of the soil penetration and saturation of oil that flowed through active stream channels in the nature reserve. Golan et al. (2016) pointed out that most vegetation in hyper-arid zones, like the Arava Valley, is directly linked to rainfall and water redistribution through active stream channels. This explains the increased acacia density in the nature reserve associated with the active stream channels. Because the acacia trees are the keystone species in this ecosystem, the fate of the ecosystem is closely related to the fate of the acacia trees. Information from studies that evaluated the demographics (age/size) of the trees in the 1975 oiled-soil area indicated a near total absence of trees younger than about 40 years. Studies conducted as part of the ongoing monitoring efforts have demonstrated that germination failure caused primarily by the hydrophobicity of the oiled soils mechanistically explains the age distribution of acacia trees in the 1975 oiled-soils area. The data do not yet allow us to know whether or when there will be a time when the oiled-soils once again support germination. This negative recruitment impact on the keystone species implies that as a result of the 2014 oil spill, the existing Evrona ecosystem will slowly change over the next 40-100 years until few acacias trees are left in the areas of active stream channels that were impacted by the oil. The lack of recruitment of acacia trees in this area will also affect other elements of the ecosystem—the presence of the Dorcas gazelles and other flora and fauna—that rely on the acacia trees.

1.2. In terms of "damage to quality of life, convenience and wellbeing and the perception of the quality of life," I have noted (Section 1.2) that it is possible to quantitatively asses the injury to the Evrona Nature Reserve and to identify damages for the loss of recreational use of the public land. This is an explicit element of the U.S. Natural Resource Damages (NRD) model. Leaving aside the question of legal authority, on December 10, 2014, the Ministry of Environmental Protection (MoEP) officially closed the nature reserve to the public, and it remained closed until the MoEP re-opened it on April 2, 2015. Thus, it is clear that the public lost access to the recreational use of the nature reserve during this time. However, aside from anecdotal accounts that during the early days of the spill, as many as 200 individuals were turned away from birding in the nature reserve because of the oil spill, there is no quantitative information in the case file with the type of information (e.g., daily visitor counts) that could be useful in understanding to what degree the public was unable to use the resources at the Evrona Nature Reserve.

2. *To the extent that such damage and hazards were caused as mentioned above, what is the proven damage (whether it has been formed or whether it has not yet been fully formed) incurred as a result of the event* [sic].

2.1. Ecological Damages: As noted above and further discussed in Sections 5 and 6, data from field and laboratory studies conducted within the areas of the 1975 and 2014 oil spill sites, indicates a long-term impact to acacia tree recruitment. Unfortunately, the data are unclear as to exactly how long the oil-impacted soils in these areas will negatively impact germination of acacia seedlings. Date from the 1975 spill indicate that the underlying causes will last for a minimum of 40 years. While, there is some indication that the site may be close to beginning recovery (e.g., no apparent recruitment concerns for shrubs in the 1975 area), the current depth of knowledge make it impossible to predict exactly when successful acacia tree recruitment will begin. Consequently, (and as discussed in Section 7), ecological injuries (in terms of ecological services losses) have been quantified for recovery times of 40, 60, 80, or 100 years.

As noted in Section 8, the damages associated with the ecological injuries would be those costs associated with restoration option(s) that replaces the injuries. The same range of recovery times were used to provide a range for the restoration required to offset the ecological injuries caused by the 2014 oil spill. In this case, one proposed restoration option would be planning and implementing the diversion of Wadi Raham water into the central part of the Evrona Nature Reserve; with the costs associated with this restoration option being the ecological damages. Additionally, damages would include the costs for long-term monitoring of the effectiveness of this restoration option. Finally, the damages could include the costs of setting up and funding a facility where acacia trees can be germinated before being transplanted to clean areas being serviced by the new flow of water through the nature reserve.

2.2. As noted above, the Evrona Nature Reserve was closed to the public and thus, the public was unable to use the nature reserve for recreational activities, but also as noted above, the data to quantify this as an injury and determine a damage was not part of the case file.

3. *Was a risk caused as a result of the event to the population living in the area and especially to the residents of Beer Ora* [sic] *and Eilat, as well as to passersby on Route 90. If yes –*

furthermore, are there longstanding implications to the exposure of contaminants of this type [sic].

3.1. While there is always a desire for more information following events such as oil spills, particularly in support of a more in-depth understanding of exposure, as discussed in Section 3 (based upon a review of the available data, the body of literature pertaining to these types of exposures, the comments from the various experts, and on our own internal assessment of the data), the information collected during the Evrona oil spill does not support a conclusion for increased human health risk above acceptable regulatory levels.

4. *Does any impact exist of prior oil leaks, to the extent existing, in the relevant area and does any impact exist on building an international airport in this area and if yes- what is its impact on the disputes being examined?*

4.1. While I have not been presented with any evidence that prior oil spills occurred in the area of the 2014 oil spill (within or outside of the nature reserve), the impact of the 1975 EAPC pipeline crude oil spill seen farther to the south of the 2014 spill location has been noted. Both field and laboratory studies associated with this 40 year-old spill provide clear evidence of potentially catastrophic long-term injury to the ecosystem from acacia recruitment failure due to the hydrophobicity of oiled soils.

4.2. At a qualitative level, the presence of the new international airport severely enhances the fragmentation of the ecosystems in the Arava Valley. Despite a narrow corridor to the east, the placement of the international airport, coupled with the presence of Route 90 immediately west of the airport, severely minimizes the migration route of animals throughout the Arava Valley, an issue that, if not resolved, will potentially compromise the abundance of gazelles in the Arava Valley.

5. *Did the actions taken by EAPC and/or that EAPC undertook to perform lead to and/or will lead to a solution or remedy or improvement of the damage mentioned above, to the extent existing* [sic].

5.1. In my review of the case file, and based on over 25 years of dealing with oil spills, it is my opinion that, once the release occurred, much of the effort undertaken by EAPC, either by itself or in coordination with other agencies, resulted in minimizing what could have been a much larger environmental disaster. The ability to contain the oil as quickly as was done, to minimize further migration into the salt flats, to ensure that winter rains did not move the oil farther towards Eilat and Aqaba and ultimately into the Red Sea, and to ensure that penetrating oil did not reach an aquifer are all examples of how the response work performed by or on behalf of EAPC helped resolve a bad situation and, more importantly, prevented a bad situation from evolving into a much larger environmental disaster.

5.2. That said, the rehabilitation work that EAPC has conducted at the Evrona Nature Reserve (based upon my reading of the information provided to me through July 2018) will not lead to a solution or remedy of the most significant ecological injury—the inability of the acacia trees to germinate in the oiled soils found associated with the water pathways where the acacia trees prefer to grow.

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Appendix A

Resume of
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Professional Profile

Dr. Haddad has focused on the strategic evaluation and tactical resolution of environmental problems associated with CERLA and OPA specifically in the context of NRDA, for nearly 30 years; initially as an internal consultant for Unocal's Corporate Environmental Remediation and Technology group, later as an external consultant for industry in the private sector, and for the past 8 years, as the head of NOAA's Assessment & Restoration Division (ARD) and as one of three leads for NOAA's Damage Assessment, Remediation, Restoration Program (DARRP), and for the past year as the Environmental and Ecological Sciences Group Vice President and Principal Scientist at Exponent.

The skills brought by Dr. Haddad to these various efforts included expertise in Forensic Geochemistry and chemometrics, as well as the ability to strategically assess, manage, and resolve complex environmental challenges. During his career, Dr. Haddad has been involved in and helped resolve complex CERCLA environmental assessments, has successfully led complex Natural Resource Damage Assessments (NRDAs), and has provided litigation support in the roles of both expert and consulting witness.

Most recently, Dr. Haddad led the damage assessment program for NOAA on the Deepwater Horizon Oil Spill; the largest accidental marine oil spill in history and the largest NRDA in US history. In this leadership role, Dr. Haddad interacted extensively within the NOAA science community (NMFS, OAR, IOOS), the broader federal (USCG, DOI, USDA, EPA, and NRC/National Academy of Science), academia, and state (TX, LA, MS, AL, and FL) governmental science communities. He worked closely with senior leadership from across the government on various aspects of the case; including the White House (CEQ and OSTP), Congress, and DOJ where cross-cutting issues of national significance were addressed. During DWH, Dr. Haddad, managed a budget of over $120M per year, oversaw the supervision of over 300 FTEs, and briefed Senior Members of the Administration, Congress, state and local leaders. As part of the US Government's senior strategic group for this NRDA, Dr. Haddad was directly involved with developing and implementing the strategy that ultimately resulted in the settlement of the NRDA case between the Trustees and BP.

Prior to joining NOAA, Dr. Haddad provided litigation support and expertise in environmental forensics, human health and ecological risk assessments, and NRD assessments (under both OPA and CERCLA regulatory environments). He has participated in cases involving the fate and transport of petroleum, metals, and PCBs with a focus on both source evaluation and liability assessment and allocation. In the private sector, Dr. Haddad has worked for many corporations, including Unocal, Tesoro, Chevron, BP, Shell, Sherwin Williams, as well as confidential clients and several mining concerns.

Based on his work in both the private sector and for NOAA, Dr. Haddad has developed a strong national and international reputation. In 2015, Dr. Haddad was honored as the employee of the year for NOAA's National Ocean Service. And during his career, he has provided support and recommendations to the

European Union and to foreign governments, including the Republic of South Korea, Thailand, and The Peoples Republic of China, on various aspects of damage assessment and environmental assessment.

Academic Credentials & Professional Honors

Ph.D., Chemical Oceanography, University of North Carolina, Chapel Hill, 1989

B.S., Geology, University of California, Los Angeles (UCLA), 1979

NASA-Ames Research Center, National Research Council Fellow, 1988-1989

Carnegie Institute, Stanford University, Post-doctoral Fellow, 1988-1989

Woods Hole Oceanographic Institution, Guest Investigator, 1986

Licenses and Certifications

Incident Command Training

HAZWOPER Training

First Aid and CPR Training

Academic Appointments

Adjunct Faculty, Biology/Physics -Calif. Polytechnic State Univ., San Luis Obispo, 2001-2007

Woods Hole Oceanographic Institution, Guest Investigator, 2004

Prior Experience

Chief, Assessment & Restoration Division, Office of Response & Restoration, NOAA, 2007-2016

NOAA Trustee Management Team, Damage, Assessment, Remediation, & Restoration Program, 2007-2016

Deepwater Horizon Natural Resource Damage Assessment Trustee Council, 2010-2016

NOAA Science Lead - DWH Oil Spill Incident, 2010-2011

Applied Geochemical Strategies, Inc., President & Principal Scientist, 2002-2007

ZymaX Forensics, Subcontracting Principal Consultant, 2002-2005

ARCADIS JSA, Vice President and Principal Scientist, 1999-2002

ENTRIX, Inc., Manager West Coast Ecological and Human Health Risk, 1997-1999

ENTRIX, Inc., Associate, 1998-1999

ENTRIX, Inc., Senior Consultant (Geochemistry), 1995-1998

UNOCAL Environmental Technology, Research Associate, 1994-1995

UNOCAL Environmental Technology, Senior Geochemist, 1992-1994

UNOCAL Exploration Research, Senior Research Geochemist, 1990-1992

UNOCAL Exploration Research, Research Geochemist, 1988-1990

Global Geochemistry Corp., Marine Geochemist and Division Manager, 1979-1981

Professional Affiliations

American Association for the Advancement of Science

American Chemical Society

Society of Environmental Toxicology and Chemistry

Publications

Dr. Haddad has published in peer-reviewed technical publications and scientific journals, and has authored over 300 technical reports and confidential documents for a variety of projects. He has given numerous talks, seminars, and symposium presentations. Selected papers and presentation are listed below.

Haddad, R., Brighton, W.D., Durda, J.L., Levy, L.J., O'Connor, C.R. Alternative Dispute Resolution in NRDA: A Viable Pathway to Timlier NRD Settlements? The 11th Annual Santa Fe Advanced Conferences on Litigating Natural Resource Damages, Santa Fe, N.M., August 10, 2018 (Presentation).

Haddad R. Climate Change: Complex Issue, Complex Science. Chicago Bar Association Environmental Law Committee Seminar, Chicago, IL, March 21, 2018 (Presentation).

Haddad R, Domanski A, McNair D, and Tomasi, T. Science and Economics: A New, Integrated Approach to NRDA. Law Seminars International - Sixth Annual Advanced Conference on Natural Resource Damages, Washington, D.C., March 2, 2018. (Panel Presentation).

Haddad R, DiPinto LM, Gala W, Reynolds, KD, Jenkins, K, Debating the Leaps in Science from the Deepwater Horizon Case. Law Seminars International – 11th Annual Santa Fe Advanced Conference on Litigating Natural Resource Damages, Santa Fe, N.M., July 19, 2017. (Panel Presentation).

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Selected Project Experience

Unocal Guadalupe Oil Field - Restoration-based cooperative NRDA conducted with OSPR, SWQCB, USFWS, and NOAA. Technical lead and NRDA management.

Unocal Avila Beach Front Street Release (1997) - NRDA negotiation with OSPR. Technical support. Los Angeles Metrolink Oil Spill (1999) - NRDA response and negotiation with OSPR. Technical lead and NRDA management.

SS Mohican Oil Spill (1996) - NRDA response and restoration-based NRDA conducted with OSPR, CSP, NPS (Gulf of the Farallones National Marine Sanctuary), NOAA, and USFWS. Technical lead and NRDA management.

M/V Kure/Humboldt Bay Oil Spill (1997) - NRDA response and restoration-based NRDA conducted with OSPR, California State Lands Commission, and USFWS. Initial Technical lead and NRDA management.

Chevron Pipeline/Pearl Harbor (1996) - NRDA response and restoration-based settlement. Technical support.

Tesoro Barbers Point Harbor Oil Spill (1998) - NRDA response and restoration-based settlement. Technical support.

Grand Calumet CERCLA Site - NRDA negotiations with USFWS and Indiana DEM. Technical support. Fox River CERCLA Site - Technical support for restoration-based negotiations with Federal and State Trustees.

New Almaden Mine CERCLA Site - Cooperative, restoration-based NRDA negotiation with USFWS and OSPR. Technical lead and NRDA management.

Molycorp Questa Mine CERCLA Site - Cooperative restoration-based NRDA negotiation with New Mexico ONRT, USFWS, USDA-FS. Technical lead and NRDA management.

GE Hudson River PCB Site – CERCLA Case – Member of the NRDA Trustee Council with NY State DEC, NY State AGO, and USFWS.

BP Deepwater Horizon Oil Spill - OPA Case - Restoration-based NRDA negotiation with BP, DOI, USDA, EPA, TX, LA, MS, AL, and FL. Lead for NOAA's Damage Assessment.

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Appendix B

Attachment 1- Translation of the "Procedural Arrangement in the Framework of a Mediation Proceeding (Secret and Confidential)"

Attachment 1 – the Translation of the "Procedural Arrangement in the Framework of a Mediation Proceeding (Secret and Confidential)"

In the District Court in Beer Sheva | **Class Action 49319-12-14**
Before the Hon. Judge Gideon Gad
In the matter of

1. **Zadok Levy Pirsk, and 12 others**
   By adv. Assaf Pink, Adv. Yakov Sabo, Adv. Haya Erez
   (hereinafter the "Applicants in the Class Action")

<u>The Applicants</u>

-versus-

1. **The Eilat Ashkelon Pipeline Company Ltd. (EAPC)**
2. **Joseph Peled**
3. **Zvi Zamir**
4. **Eyal Cohen**
5. **David Sharan**
9. **Ori Lubrani**
10. **Mati Grossinger**
11. **Moshe Mor**
12. **Amos Loria**
13. **Eitan Padan**
14. **Zahi Havusha**
15. **Shachar Shaharabani**

Respondents 1 – 5 and 9 – 15 represented by Adv. Goldfarb, Zeligman & Co.
98 Yigal Alon St. Tel Aviv
Tel: 03- 7101635, Fax: 03- 7101618

6. **The State of Israel the Ministry of Finance**
7. **Benjamin Netanyahu**
8. **Michal Abadi – Boianjo**

Respondents 6 – 8 by the General Attorney's Office Southern District (Civil)
4 Keren Hayesod St. Karaso Building Beer Sheva
Tel: 073- 3801222, Fax: 02- 6467052

(hereinafter the <u>"Respondents in the Class Action"</u>)

And in the matter of:
<u>In the District Court in Beer Sheva</u> | **C.C. 44402- 06- 15**

Before the Honorable Judge Sara Dovrat **C.C. 62754- 01- 15**

1. The Hevel Eilot Regional Council
2. The Beer Ora Local Committee
Represented by Adv. Amnon Shibolet and/or Adv. Orit Marom
Of Shibolet & Co. Law Firm
4 Berkowitz St. Tel Aviv
Tel: 03- 7778333; Fax: 03- 7778444

(hereinafter the "Plaintiffs")

-versus-

The Eilat Ashkelon Pipeline Company Ltd. (EAPC) co. no. 510494842
Represented by By Adv. Arieh Neiger
Of the office of Amit, Pollak, Matalon & Co.
18 Raoul Wallenberg St. Tel Aviv
Tel: 03- 5100838; Fax: 03- 5100836

(hereinafter the "Defendant" and/or EAPC")

And in the matter of:

The State of Israel
Represented by Adv. Osnat Daphna

Procedural Arrangement in the Framework of a Mediation Proceeding (Secret and Confidential)

Whereas The Applicants in the Class Action have filed against the Respondents in the Class Action a motion to certify the class action in which they claimed, inter alia, damages that were caused during the event of the oil leak from the oil pipeline which is in the possession of the EAPC in the Arava near the community of Beer Ora on the 3rd of December 2014 all as set forth in the certification motion and in the Plaintiff's claim. The Plaintiffs filed a claim against the Defendant for alleged damages which were incurred by them as they claimed due to the event; and the State of Israel made verbal arguments that it is entitled to compensation for the alleged damage which was caused due to the event beyond it being a respondent in the class action.

And whereas All the claims raised by the Applicants in the Class Action have been denied by the Respondents in the Class Action and all the claims raised by the Plaintiffs have been denied by the Defendant, and all the claims raised by the State of Israel are denied by the Respondents in the Class Action (and EAPC included) (hereinafter the "**Disputes**").

And whereas The parties have approached a Mediator, Adv. Amos Gavrieli, requesting that he mediate between them with respect to the disputes (hereinafter the "**Mediator**");

And whereas The parties have reached agreements through the Mediator regarding the manner of clarifying the disputes in the framework of the mediation proceeding only, all as set forth in this procedural arrangement and subject to the fact that it is agreed and emphasized, that without derogating from the provisions of the law and the generality of the privilege which applies to the things and information presented in the framework of the mediation process, that nothing that will be filed and/or raised in the framework of the mediation proceeding according to this procedural arrangement will not constitute evidence in the legal proceeding and no use will be made of it of any type and kind, outside of the scope of the mediation, unless all the parties have agreed to this;

Therefore, it was declared, agreed and stipulated as follows:

1. In the framework of the mediation process the Mediator will address, inter alia, the following issues in dispute (hereinafter the "**Disputes**"):

    a. Was damage caused and ecological environmental hazards following the event, including to the ecological system and to biodiversity, damage to quality of life, convenience and wellbeing and the perception of the quality of life and if yes – what is this damage and hazards (whether they can be rehabilitated or no including damage which has not yet been finally formed including the cost of monitoring and the cost of rehabilitation as a result of the event and the cost as a function of the rehabilitation time to the extent it is possible to rehabilitate). All while referring to actions performed and that are being performed on the ground today, and referring to the chapters of damage in the pleadings filed by the Applicants/ the Plaintiffs and the answers to these claims in the pleadings filed by the Respondents / the Defendants.

    b. To the extent that such damage and hazards were caused as mentioned above, what is the proven damage (whether it has been formed or whether it has not yet been fully formed) incurred as a result of the event.

    c. Was a risk caused as a result of the event to the population living in the area and especially to the residents of Beer Ora and Eilat, as well as to passersby on road 90. If yes – furthermore, are there longstanding implications to the exposure of contaminants of this type.

    d. Does any impact exist of prior oil leaks, to the extent existing, in the relevant area and does any impact exist on building an international airport in this area and if yes- what is its impact on the disputes being examined?

e. Did the actions taken by EAPC and/or that EAPC undertook to perform lead to and/or will lead to a solution or remedy or improvement of the damage mentioned above, to the extent existing.

2. In order to assist the Mediator in his work, Mr. **Robert I. Haddad, Ph.D** will serve as a Professional Consultant of the Mediator for the purposes of the mediation proceeding with respect to the disputes (hereinafter the "Professional Consultant of the Mediator").

3. The parties will transfer to the Professional Consultant of the Mediator and to other parties, within 30 days after today, all the pleadings that were filed in the framework of the proceeding in the title and/or all the material which is relevant to their arguments, including opinions and/or any other material they shall see fit (hereinafter the "Documents"). The parties will be entitled to refer to relevant material to the extent this is material which they did not have.

4. Within 14 days after receiving the Documents, a meeting shall be convened with the participation of the parties and their attorneys before the Mediator and the Professional Consultant of the Mediator.

5. The Documents will be submitted to the Professional Consultant of the Mediator in the original version, to the extent existing, and/or in a copy which identical to the original, when they are translated into English, and in any event, they will be presented in their entirety, all by the parties' attorneys only, who will serve for this purpose as contact people on behalf of the parties towards the Professional Consultant of the Mediator. It is hereby clarified that a document which shall be found that it was delivered to the Professional Consultant of the Mediator, however not to the counter parties will be removed from the framework of the examination of the Professional Consultant of the Mediator and it shall not be given any consideration. Each party is responsible for translating the Documents filed on his behalf and he will bear the cost of the translation except for pleadings that have already been translated by the parties, in which case the party which has translated his pleadings is entitled to request a copy of the translation and to use it (without him having any claim with respect to the translation).

6. The Professional Consultant of the Mediator, will prepare position statements for him with respect to any of the disputes, according to requests that he shall receive from the Mediator at the discretion of the Mediator both with respect to the issue being examined and regarding the timing of the examination (hereinafter the "**Position Documents**").

7. The parties will be entitled to review the Position Documents at the Mediator's office only and following this each party will be entitled, within 15 days, to file to the Professional Consultant of the Mediator clarification questions and/or comments regarding the relevant

position document,'and the Professional Consultant of the Mediator will be entitled to refer to them. The Mediator will schedule, in accordance with his discretion, meetings in the presence of the parties, and anyone on their behalf and with the participation of the Professional Consultant of the Mediator, in which the parties will present their claims and/or objections regarding the statements in any of the Position Documents.

8. It is clarified and emphasized that the Position Documents are not an expert opinion and the parties expressly agree that they do not constitute an expert opinion in any respect.

9. It is further clarified and emphasized that the Position Documents will be kept in the Mediator's office only, and they will not be transferred to the parties themselves and the parties undertake that they and/or anyone on their behalf will not make any copies of the Position Documents and they will not transfer their contents in any form to any third party that is not a direct party to the mediation proceeding, except with the consent of all the parties to the proceeding. It is clarified that copies of the Position Documents will be placed in the Mediator's office in a quantity which is sufficient for concurrent reviewing of the parties to the extent necessary.

10. The parties will convene mediation meetings before the Mediator, as scheduled by him including after receiving the Position Documents or any of them, and they will negotiation in good faith, with the help of the Mediator for ending all of the disputes between them in an amicable manner.

11. It is hereby agreed that for preparing the Position Documents the Professional Consultant of the Mediator is entitled to consult with the Mediator, as a jurist, for clarifying and settling legal issues which would help during his examination. For the sake of avoiding doubt, it is hereby clarified that laws of evidence will not apply to this proceeding, however the Mediator will give his opinion based on the material rules of law and the principles of natural justice. The Mediator will be entitled to convene a mediation meeting with the Professional Consultant of the Mediator and/or the parties and/or their attorneys and/or the experts on behalf of the parties, whether at their request and/or of any of them and whether at his consent, at any time he shall think that this is necessary for the mediation proceeding.

12. The parties undertake not to turn to the Professional Consultant of the Mediator directly and/or indirectly except in writing, and in accordance with the provisions of this procedural arrangement, with a copy to the other party and to the Mediator and/or in the presence of the other party. For the avoidance of doubt, the Professional Consultant of the Mediator will not make any contact of any type and kind with any of the parties separately.

13. The visit of the Professional Consultant of the Mediator in the areas relevant to the dispute will be done without the parties' presence and their attorneys or alternatively in the

presence of all the parties and/or their attorneys and anyone on their behalf. Notwithstanding the aforesaid in this section at least a visit shall take place in the area with the participation of all the parties, including the Mediator and the Professional Consultant of the Mediator.

14. The parties will cooperate with the Professional Consultant in any manner or way that shall be required and/or by furnishing any document requested by him and they will not delay, to the extent this is in their hands, the performance of the work according to this arrangement (without derogating from the claims of privilege, secrecy and any other right).

15. Within 21 days after receiving the material at the Professional Consultant of the Mediator, the consultant may, but he is not required, give comments to the time schedule and to propose a time schedule to performing the actions set forth in this procedural arrangement (including the existence of the visit/s in Israel).

16. It is clarified that at this stage EAPC will bear the fees of the Professional Consultant to the Mediator, subject to his fees being approved by it in advance and in writing. The terms of this procedural arrangement coming into force is the approval of EAPC in advance and in writing and according to its absolute sole discretion to the fees of the Professional Consultant of the Mediator: EAPC will bear the fees of the Professional Consultant as mentioned when it is of the position that all of the parties to this proceeding (except the Applicants in the Class Actions and the Plaintiff in the council's action) must bear part of this payment; however it is agreed that this matter will be taken into account at the end of the mediation proceeding and in the Mediator's proposal.

17. By signing this arrangement, the parties declare that they are not acquainted with and/or have no conflict of interests with the Professional Consultant of the Mediator. The Professional Consultant of the Mediator will confirm, in writing and in a separate document, that he is not acquainted with and/or he has no conflict of interests with respect to the job for which he was appointed by the parties and that he will keep confidential all the Documents and/or Position Documents and/or their content.

18. It is hereby clarified that this procedural arrangement and/or its content does not derogate from any claim of any of the parties if at the end of the day the mediation procedure fails. Without derogating from the provisions of any law with respect to the privilege and secrecy of the mediation proceeding, it is expressly agreed that everything that shall be stated and conducted in the mediation proceeding, including the Position Documents and their content, will be privileged and not party will be able to make any use of the Position Documents and/or mention in any manner their existence and/or their content in any legal proceeding and/or quasi – legal proceeding that is conducted and/or shall be conducted between the parties and/or to enter into any such proceeding as mentioned with the Professional

Consultant of the Mediator. It is clarified that the provisions in this agreement will not prevent filing the Position Documents to the court to the extent that the mediation proceeding will end by a settlement agreement which will be filed for approval of the court, to the extent the parties will agree to this.

19. This arrangement was made in the framework of the mediation procedure only and it is secret and it will not be disclosed to any third party, unless all the parties have agreed to this in advance and this arrangement will not be submitted to the courts.

And in witness whereof the parties have signed today the 12th of the month of December 2017

(-)	(-)
Adv. Assaf Fink The attorney of the Applicants in the Class Action	Adv Aaron Michaeli The attorney of respondents 1- 5 -15- 9 In the class action
(-)	(-)
Adv Amnon Shibolet The attorney of the Plaintiffs	Adv. Arieh Neiger The attorney of the Defendant
(-)	(-)
Adv. Antonius Marshi The Attorney of respondents 6- 8	Adv. Osnat Daphna The Attorney for the State of Israel

I hereby confirm that this arrangement was achieved in the framework of the mediation proceeding that took place before me and I approve this arrangement and confirm it with my signature according to the provisions of regulation 9 (a) of the Court Regulations (Mediation), 5753- 1993.

Stamp and signature

Amos Gavrieli, Adv. - Mediator