BTC Pipeline Operations and Contingency Arrangements: Assessing and managing risks to the environment

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1. INTRODUCTION

The 1750 km BTC Pipeline System is designed to transport crude oil from the Caspian Sea to the Mediterranean through Azerbaijan, Georgia and Turkey. The pipeline route traverses terrain varying from semi desert to high mountain passes and crosses a number of significant geological features included large rivers and active faults. This paper describes how environmental risks were assessed and the findings applied during the various phases of the project from Corridor Evaluation, Engineering and Oil Spill Response Planning.

2. ENVIRONMENTAL RISK ASSESSMENT CONCEPTS

The concept of Quantified Risk Assessment (QRA) is well understood and used to assist in decision making for various disciplines. Within the oil industry HSE domain QRA has been used primarily for determination of risks to individuals and populations. The use of QRA to determine risks to the environment is less well defined. In developing Environmental Risk Assessment (ERA) methodologies for the BTC Pipeline a balance between theoretical concepts and the realities of time and budget constraints was required. The ERA process which was developed focused on the risks of Oil Spills on the environment and as such the different elements of the risk equation were separated as follows:

LIKELIHOOD OF FAILURE	**x**	**SPILL VOLUMES**	**x**	**ENVIRONMENTAL SENSITIVITY**	**=**	**ENVIRONMENTAL RISK**

3. ERA DURING CORRIDOR SELECTION "MACRO LEVEL ERA"

The "Macro Level" assessment undertaken during the corridor selection process assessed three main corridors. For those corridors requiring shipping through the Black Sea bypass options were also assessed as follows:

- Option 1 Baku-Supsa-Mediterranean via Turkish Straits
- Option 1a Baku –Supsa with bypass of Turkish Straits

- Option 2 Baku-Ceyhan-Mediterranean

- Option 3 Baku-Novorossiysk-Mediterranean via Turkish Straits
- Option 3a Baku-Novorossiysk with bypass of Turkish Straits

The environmental risks were assessed for each corridor from one common point in the Caspian to a common point in the Mediterranean.

Figure 1
Options Considered in Corridor Evaluation

Risks associated with the pipeline, terminals and shipping were assessed and the results combined to establish a single Environmental Risk Value (expressed in $ per year) associated with each option.

3.1. Failure Probabilities and Spill Volumes

The elements considered in determination of failure frequencies included:

- **Tankering**
  - Vessle design (Single or double Hull Tankers)
  - Vessel Traffic System
  - Response Resources (Turkish Straits)
  - Escort Tugs (Turkish Straits)
  - Waste Receptor Facilities
  - Insurance
  - High Level Contingency Planning
  - Ballast Water Procedures
- **Pipelines**
  - Fault Crossings
  - Geologic Hazards
  - River/Stream Crossings
  - Terrorism
  - Third-Party Intrusion

For each failure scenario various databases were reviewed and spill volumes for each failure applied.

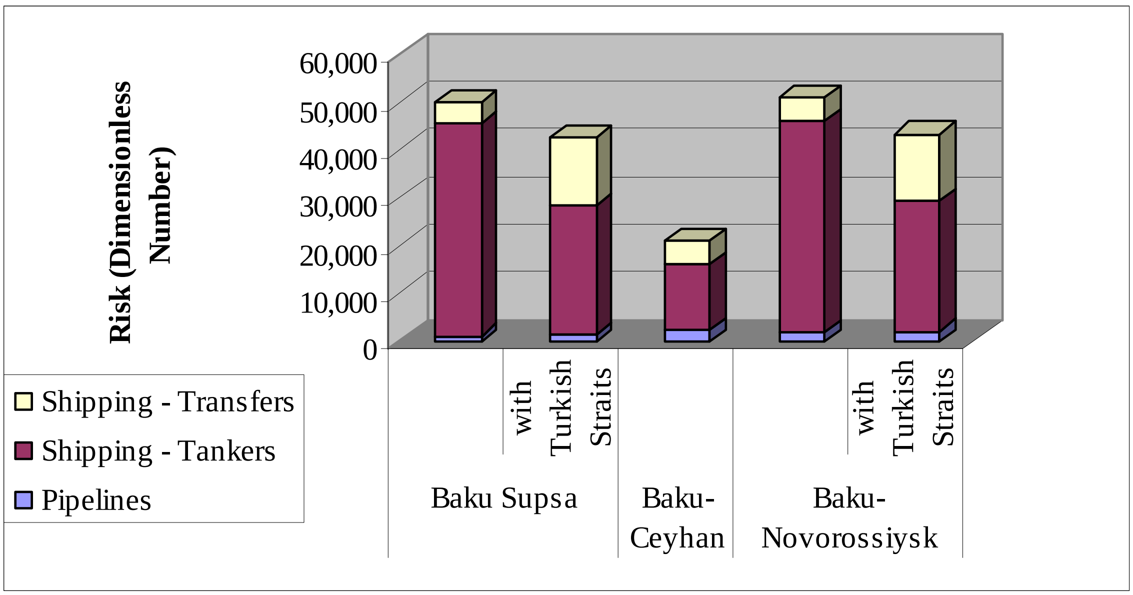
3.2. Environmental Sensitivity

A desk tope study was undertaken to determine significant environmental and social receptors along the pipeline and shipping corridors. This data was consolidated at a regional level for inclusion in the Risk Formular.

3.3. Determining Environmental Risk

A base case Environmental Risk Value was determined using the situation as it existed at the time and then a refined case was assessed with a number of mitigation measures included. An example of the outputs from this assessment is shown in Figure 2.

Figure 2
Example Output from Macro Level Risk Assessment



The findings from this and other assessments related to shipping in the Turkish Straits had a significant bearing on the final decision to pursue the BTC option.

4. DESIGN PHASE ERA

During the design phase a more detailed ERA methodology was developed with the involvement of the engineering and environmental teams. As a result of dialogue with the team the factors assessed for each elements of the ERA equation were agreed as follows:

4.1. Likelihood of Failure

The Likelihood of Failure was determined by considering the cause of failure and failure scenarios. The Cause of Failure was evaluated using failure categories as used in the CONCAWE[2] database ie: corrosion, natural hazards, third party damage and operator error. For each cause three failure scenarios were considered ie a 5 mm failure, a 50 mm failure and a rull bore rupture.

A spill frequency "benchmark" was developed on the assumption that failures on BTC would be similar to those of a pipeline in Western European. The benchmark data was then refined on a kilometer by kilometer basis to account for:

- Landslides
- River Crossings
- Fault Crossings
- The proximity of other pipeline systems (particularly the South Causes Pipeline -SCP)
- The likelihood of spills from block valves
- Threats from Third Party Intentional damage

Specialists involved in the design of the pipeline were asked to estimate the residual likelihood of pipeline failure from the areas in which they contributed to the design.

4.1.1. Faults

The design at each significant fault crossing was developed to ensure the likelihood of pipeline damage was minimised in the event of fault movement. Such designs include use of specific backfill material and trench cross section and minimisation of any facilities that may "anchor" the pipeline in the vicinity of the fault. Following completion of the design the specialists were asked to determine the average interval (recurrence interval) between events of sufficient magnitude to potentially damage the pipeline. This data was then incorporated into the ERA. Figure 3 provides an example of the expected failure frequencies at fault crossings as determined from the assessment.

4.1.2. Landslides

Routing of the pipeline was a significant challenge given the mountainous terrain and the associated high potential for landslides. In the few locations where it was not possible to avoid areas prone to landslides specific designs were developed to minimise the likelihood of pipeline damage. Upon completion of the pipeline routing and design the geotechnical specialists assessed the potential for pipeline rupture from first-time slides and from pre-existing slides along the pipeline corridor. This assessment was undertaken specifically for the ERA and for each segment along the pipeline. In defining failure probabilities the teams used terms such as None/Negligible (0.000001 annual probability), Improbable, Remote, Occasional, Probable, Frequent and Certain (annual probability of 1.0).

4.1.3. River Crossings

River crossings were identified as being locations for potential exposure and possible damage of the pipeline and were therefore considered in detail during the routing and subsequent design of the pipeline. A specialist consultancy was employed by BP to assist firstly in the route selection and subsequently in the crossing design. The teams evaluated hydrological and geotechnical data in assessing the amount of lateral migration and scour that could occur at major river crossings. This assessment was used to determine set back distances and burial depths as part of the river crossing design. In determining the failure probabilities for the ERA storm probability, crossing design criteria and pipeline structural evaluation data was combined. As shown in Figure 3 the failure frequencies determined from this evaluation were generally of the same order of magnitude as for Fault and Landslides.

4.1.4. Third Party Damage

In undertaking the design and ERA for BTC various studies were undertaken to provide the teams with a detailed understanding of the likelihood of third party accidental and intentional activities damaging the pipeline.

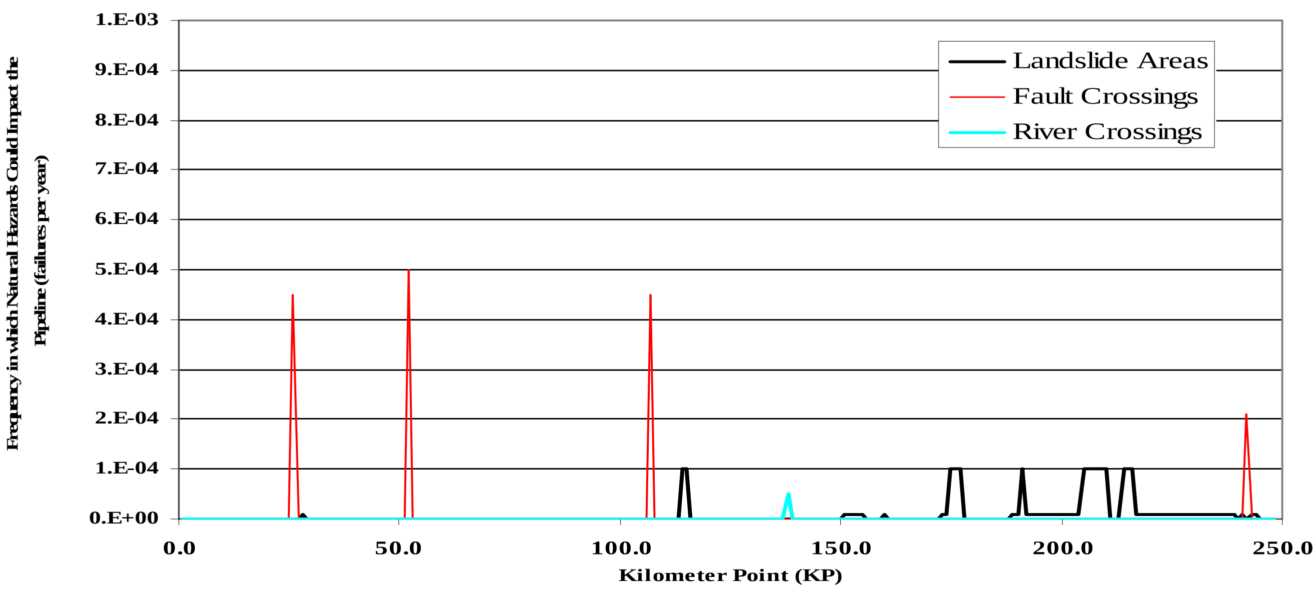
To minimize the possibility of unintentional damage specific designs were developed for areas such as road and stream crossings that were deemed vulnerable.

In the route selection process Governments and other specialist organizations were consulted to ensure areas of potential hostility were avoided. During initial phases of the ERA process damage due to 3rd party intentional activities on pipelines in the region was assessed and incorporated into the ERA. Following considerable dialogue and review of the security provisions along the pipeline CONCAWE data was used in preference to the Regional data on the basis that the routing and increased security measures brought the probabilities of sabotage down to European levels.

4.1.5. Presenting Failure Data

Figure 3 provides an example of how data from the Geohazard assessments was consolidated and presented in the ERA documentation.

Figure 3
Example of Out from Assessment of Failure Probability from Geohazards



4.2. Spill Volumes

To determine spill volumes the leak detection time, pump station shut down, valve closure time, elevation, operating pressure and valve locations were considered

Given the large number of variables and complexity of analysis a specifically developed computer programme, AUMEX, was used to model spill scenarios. This programme was developed by ILF, the design contractor for the Turkish section of the BTC pipeline and was adopted to determine potential spill volumes in Azerbaijan, Georgia and Turkey.

The model was used to calculate spill volumes associated with each hole size for each kilometre-point. For each spill event modelled, three distinct phases were considered and the spill volumes for each calculated. The first phase involved the calculation of leak volume, V_1, from the time the leak occurs until leak detection and initiation of pump shutdown and valve-closure. The second phase spill release volume, V_2, was a calculation of leak volume during the depressurisation of the pipeline section. The third phase was the free flow from the leak opening associated with gravity drainage and siphon effects. Table 1 provides details of the main assumptions used in calculating spill volumes V1, V2 and V3.

Table 1
Assumptions Used in Determination of Leak Volumes for ERA

ACTIVITY	5 mm (LEAK)	50 mm (HOLE)	Full Bore (RUPTURE)
Time to detect and confirm leak	48 hours	1 hour	1 minute
Time to shutdown pumps	10 minutes	10 minutes	10 minutes
Time to close block valves in affected section	10 minutes	10 minutes	10 minutes
Time to mobilise spill response team and contain/control leak	24 hours	24 hours	24 – 72 hours

4.3. Environmental sensitivity

The environmental sensitivity factor was established after dialogue with the three consultants developing the Environmental (and Social) Impacts Assessments (EIAs) for each country. The environmental sensitivity number comprised of ratings for: Surface water; groundwater, terrestrial ecological resources, land use and archaeology. The weighting applied and factors considered are depicted in attachment 1.

4.4. ERA Outputs

The kilometer by kilometer failure, spill volumes and environmental sensitivity were combined in a spreadsheet “model” with the data and interpretations desribed in the EIAs and ERA documents required under the Host Government Agreements (HGAs). The environmental risks were presented in various ways to facilitate evaluation and for different audiances. Figures 4 and 5 provide examples of how the data was presented in the EIAs and ERAs.

Figure 4
ERA Results Presented per Kilometer

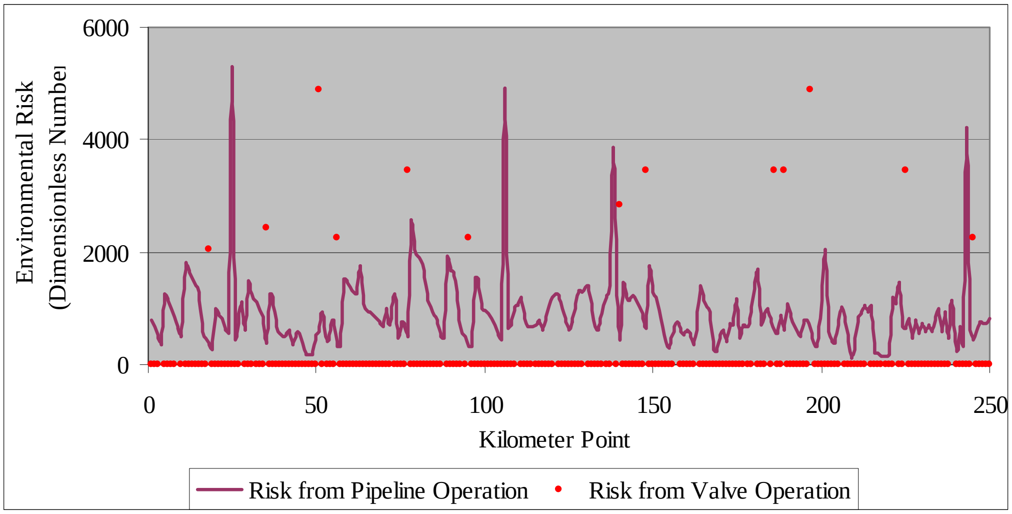
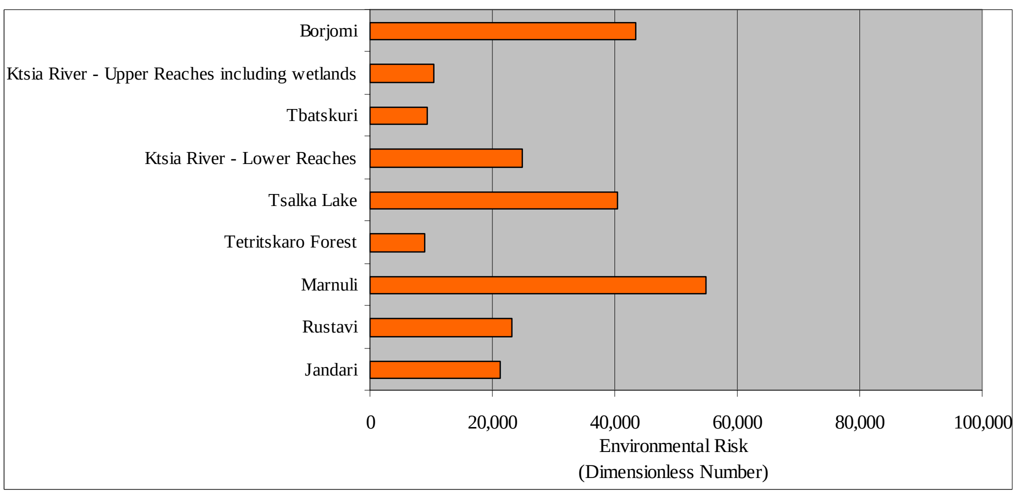
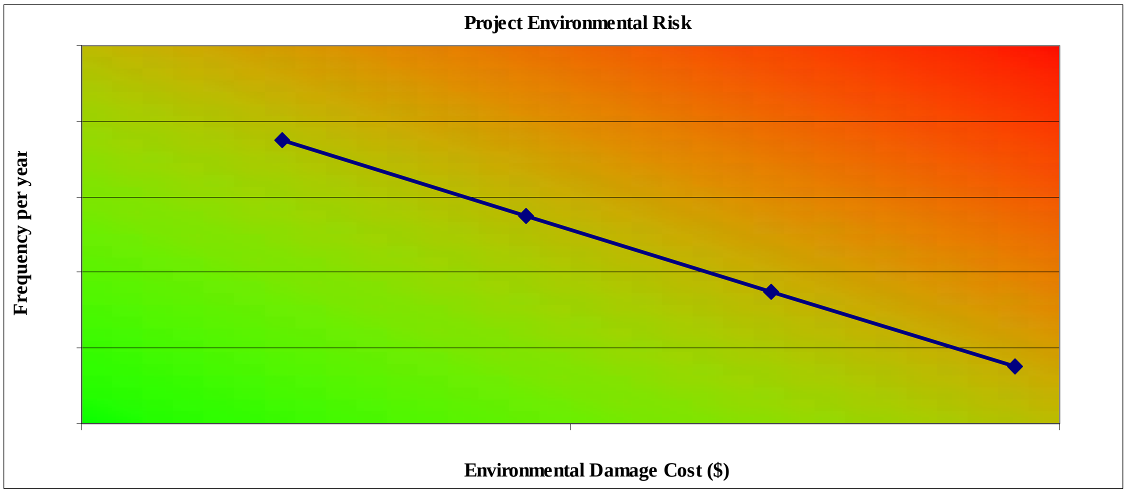


Figure 5
Comparative Environmental Risks to Important Receptors



Data was also consolidated for assessing the overall risks associated with the pipelines. Figure 6 provides an example of how the data can be presented in a manner used at a corporate level.

Figure 6
Overall Project Environmental Risk

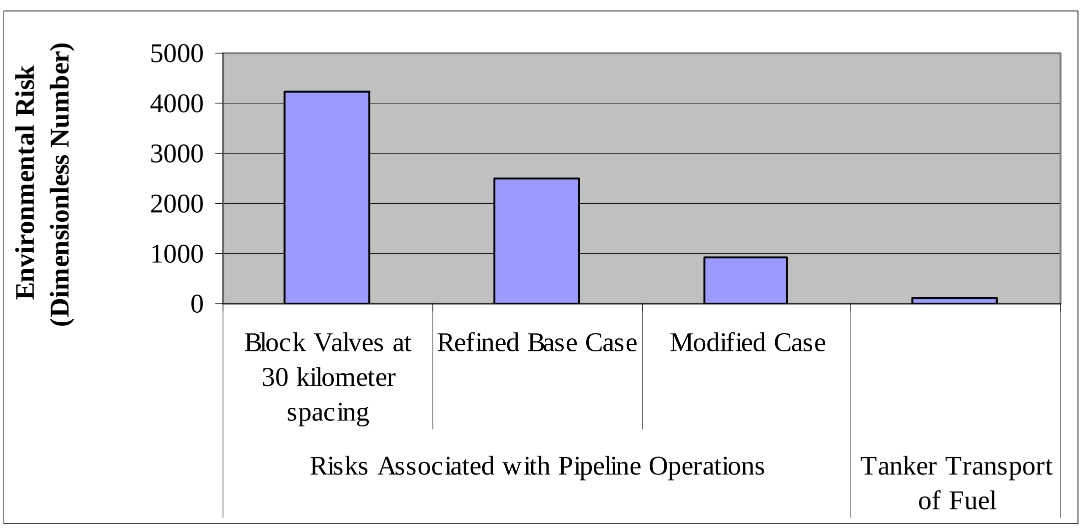


4.5. An Iterative process

In Georgia the regulator and their advisors took considerable interest in the ERA and the document was revised several times to reflect comments and suggested enhancements to the process. Enhancements included modifying the failure probabilities to better reflect the various BTC specific design characteristics such as thick walls and proposed mitigation measures such as intelligent pigging. In addition relative risks associated with tanking of fuel between sites were quantified and incorporated into the ERA report.

The risk assessment was used as a tool for considering a variety of possible design modifications and was the key tool in the selection of block valves locations. Figure 7 depicts the relative risks as they changed during the design process. This highlights the significant reduction in risk afforded by revising block valve locations to reduce spill volumes and to protect highly sensitive areas. Figure 7 also shows the relative risk of tankering fuel to the sites.

Figure 7
Example in Changes in Risk as determined from ERA (Georgia)



5. ERA IN THE OIL SPILL RESPONSE PLANNING PROCESS

The oil spill response planning process involved a number of steps including: Development of a containment manual, assessing oil properties, preparation of the Oil Spill Response Plan, defining response planning guidelines, determining oil spill response bases' location and selection of equipment and manning requirements. Data from the ERA was used in almost all of these planning steps. Examples of how the ERA data was used for some elements of the Oil Spill Planning process are set out below.

5.1. Siting Response Bases

In developing a philosophy for storage of oil spill equipment and staff along the pipeline corridor a review of similar pipeline systems and associated response capability was undertaken. Establishment of "first response" bases where staff and equipment would be situated was deemed the best approach for BTC given the relative remoteness of the pipeline corridor and the varying security situation. Response planning guidelines for the project were established to assist in the planning process and provide a basis for considering response bases, equipment and staff. To be useful it was agreed that the guidelines should be simple and applicable for all three countries. In considering the locations of bases the response time planning guidelines were of particular importance.

Response time planning guidelines were determined after considering the assumptions made in the ERA, the topography, climatic conditions, containment site data, road conditions, international legislative "benchmarks" and industry best practice. Data from the environmental ERA was consolidated on a catchment by catchment basis to better understand the relative risks to key receptors down gradient of the pipeline (figure 5). Whilst the ERA did not consider societal and community issues specifically, some "weighting" was undertaken in this exercise to better reflect the importance of particular receptors by scientists and the communities.

As described below the Oil Spill Planning volumes were determined at a country level to ensure consistency with the tiered approach to oil spill response. In establishing the Response Time Planning Guidelines BTC sought to locate bases in a manner that ensured these would be met at all locations and enable a more rapid response to containment sites protecting key receptors. The data from the ERA was particularly helpful in selection of response base locations that met this objective.

This same process was undertaken in all three countries and resulted in 2, 3 and 4 bases being established in Azerbaijan, Georgia and Turkey respectively.

5.2. Defining Tier 2

Tier 2 is often defined as "spills that require additional in-country resources and manpower than needed for a Tier 1 event". Such a definition is not however very helpful when a company is establishing resources in a country that has limited existing Oil Spill Capability. To assist in determining, as part of the planning stage, the amount of in-country resources which were needed BTC considered: international norms and legislation, BP policies,other projects for benchmarking purposes and information from the ERA.

As described in the General Oil Spill Response Plan (GOSRP)[3] BTC established Tier 2 spill volumes by taking a simple average spill volume associated with a 50 mm hole size. In recognition that response to an incident would be undertaken from several bases simultaneously a new “Tier 2 First Response” concept was introduced. On this basis the spill volumes depicted in Table 2 were adopted as the planning guidelines for BTC.

Table 2
Response Planning Guidelines for BTC

Activity	**Response Planning Volume (m3)**	**Target time from Call Out (hours)**
Notification		0
Mobilisation of staff to Response Base		2
Departure from Response Base with appropriate initial response equipment		4
Travel time to spill site		8
Deployment of initial Response Resources at single Containment site	520 m3	12
Full Tier 2 Capability in place at 2 containment sites using equipment and resources from two or more first response bases	2268 m3, 2815 m3, 2163 m3 for Az, Geo and Tk respectively	24

Communicating these volumes in the GOSRP was seen as an important means of conveying the intent by BP, BOTAS and BOTAS International Ltd (BIL) to follow a transparent process in determination of equipment requirements in each country.

6. POSSIBLE REFINEMENTS TO THE ERA PROCESS

The ERA process has been found to provide valuable information for many different teams involved in the design and planning of BTC. Should the process be adopted on other facilities there are a number of possible refinements that should be considered including revising the weighting applied to the environmental factor and in “calibrating” the outputs from the spill volume model.

6.1. Revising the Environmental Factor

In particular the relative “weighting” applied to each element of the risk equation needs to be considered. Consideration could be given to applying a logarithmic weighting to the environmental sensitivity factor. This is deemed appropriate as the probability data is presented in such a way. Different ways for combining the scores for each type of environmental receptor should also be assessed.

6.2. Calibration of the Spill Volume Assessment

During deliberations with the Georgian Government and their advisors further analysis of the data from the ERA was undertaken. These assessments included consideration of spill volumes from the ERA "calibrated" or weighted in recognition that the calculated spill volumes are higher than historical data suggests would occur. The model is likely to be conservative for the following reasons:

- The hole sizes selected as representative are too big with perhaps hole sizes of 1 mm, 20 mm and 50% of pipeline diameter being more representative of the leak, spill and rupture scenarios
- The model only uses a subset of the topographical data available and therefore does not allow for minor changes in pipeline elevation and associated extra storage afforded in the pipeline depressions in the event of a spill

A variety of approaches were considered to calibrate the model and several of these were discussed at the technical workshops with the Government of Georgia and their advisors. Calibration by reducing the spill volumes by 50% is however considered the most appropriate as:

- the mean spill volumes from the "calibrated" model are still higher than the CONCAWE data and therefore is still considered conservative
- maximum spill volumes are higher than any spills reported in the CONCAWE data again suggesting the approach is conservative
- The distribution of spills is similar to the distribution from CONCAWE

Data from the "calibrated" model were assessed in various ways and suggest that by establishing a Tier 2 capability of 2815 m^3 in Georgia BTC will have sufficient resources to respond to 94% of incidents. The probability of a Tier 3 event occurring (ie an event in which resources from outside of the country are required) is 1 in 592 years.

Similarly the benchmarking assessment undertaken suggests that the Tier 2 response volume planning guideline compares favourably with U.S. Coast Guard requirements (1,830 m^3) and the Canadian Coast Guard requirements (1,000 – 2,500 m^3).This assessment highlights the conservative nature of the BTC approach and suggests that for pipelines traversing regions with stable security environments and less sensitive environments Tier 2 response planning guidelines determined using a "calibrated" spill model would likely provide adequate capability.

7. REFERENCES

1. Advantica for UKOPA (2000) - UKOPA Pipeline Fault Database. Presentation at UKOPA conference 30 Nov 2000
2. CONCAWE 1998 (Report No. 98: Western European Cross-Country Oil Pipelines 25 Year Performance Statistics).
3. Reid, H., 2004. General Oil Spill Plan, Baku-Tbilisi-Ceyhan Pipeline Project, AGT 000-000-OP-PLN-00004, Issue A3. http://www.caspiandevelopmentandexport.com, 59 pp. + 11 appendices.
4. URS 2003 - Overland And Surface Water Modeling Of Oil Spills From The BTC Pipeline In Azerbaijan And Georgia - R4560C.02/45726-016-784/AJW/PR/AL

Attachment 1
Environmental Sensitivity Matrix

ENVIRONMENTAL SENSITIVITY RATING	ENVIRONMENTAL RECEPTORS								
	SURFACE WATER				GROUNDWATER		TERRESTRIAL ECOLOGY	LAND USE	ARCHEOLOGY
	Gradient to nearest downhill surface water	Proximity to downhill surface water	Sensitivity of surface water downstream	Capacity of surface water to transport oil	Soil (permeability)	Groundwater sensitivity	Terrestrial ecological resources	Land use	Proximity to downhill known archaeology
WEIGHING	0.25	0.25	0.25	0.25	0.5	0.5	0.75	0.25	0.25
Not Sensitive = 0.1	less than 5 degrees	greater than 1.6km	No local surface water	No evidence of irrigation channels	Very low permeability	Non-aquifer	No ecological resources of value	Unused	greater than 1.6km
Low = 0.3	5 - 10 degrees	0.4 - 1.6km	Artificial pond/dam for irrigation +/o livestock	Irrigation channels present	Low permeability	Confined aquifer - local importance	Disturbed habitat with minor ecological value	Extensive rough grazing	0.4 - 1.6km
Med = 0.5	10 - 15 degrees	0.2 - 0.4km	Potential water supply	Natural streams not able to be diverted / controlled	Medium permeability	Confined aquifer - regional importance	Locally important habitat and/or flora/fauna	Intensive grazing, no local populations	0.2 - 0.4km
High = 0.7	15 - 25 degrees	0.1 - 0.2km	Major source of local water +/o wetland of national importance*	Seasonal river	High permeability	Unconfined aquifer - local importance	Nationally important habitat and/or flora/fauna	Horticultural / Arable Agricultural Use +/o national reserves, local populations	0.1 - 0.2km
Very High = 1.0	greater than 25 degrees	Less than 0.1km	Major local and regional water supply +/o wetland of international importance*	Permanent river	Very high permeability (Fissure Flow)	Unconfined aquifer - regional importance	Internationally important habitat and/or flora/fauna	Horticultural / Arable Agricultural Use +/o reserve of international importance, local populations	less than 0.1km