Transportation Association of Canada

Study of Natural Gas Pipeline Placement in Rural Road Right-of-Ways

March 2001

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Study of Natural Gas Pipeline Placement in Rural Road Right-of-Ways

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Abstract

The placement and location of hydrocarbon pipelines with respect to road geometries and cross sections can have an effect on the safety of the highway system, its users and adjacent residents, as well as operational and economic impacts on highway maintenance, construction, and modification activities. To assess these risks and impacts, this in-depth, comprehensive study directed at generating a qualitative and quantitative understanding of the implications of locating pressurized natural gas pipelines in various locations within rural road right-of-ways was conducted. The study covered four primary representative road types together with their variations in ADDT, vehicle speed, and cross section, as well as three representative pipeline sizes and pressure categories for three different pipeline locations: in the shoulder, below the ditch, just inside the edge of the right-of-way, and a control location where the pipeline is away from the effects of the roadway. The method for systematically quantifying the risks to the public, considering the effects of the pipeline-roadway synergy, including effects on the pipeline failure rate as well as consequences of possible failure including ignition by vehicles, was developed and applied to each of the 108 generic cases. Both individual and collective risks and their variations for each of the different combinations were evaluated, and discussed. Similarly, economic impacts, including increases in the unit cost of common maintenance, construction, and reconstruction activities for the road operators were also identified. A series of conclusions and recommendations was generated, including definition of compatible and incompatible combinations of pipeline and location installations in terms of safety, cost, and constructibility; various risk and impact mitigation measures to enhance safety and reduce costs; and long-term approaches to optimize the situation. Although previous studies have been done on the use of common utility and transportation corridors, no comprehensive quantitative assessment of risks and economic impacts for representative combinations of road and pipeline characteristics has appeared previously, resulting in a significant volume of new observations and information available from the work reported herein.

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Study of Natual Gas Pipeline Placement in Rural Road Right-of-Ways

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Résumé

L'emplacement des gazoducs par rapport à la conception géométrique et au profil en travers des routes peut influer sur la sécurité du réseau routier, de ses utilisateurs et des résidents des zones adjacentes; il peut également avoir des effets sur les aspects opérationnels et économiques de l'entretien des routes et des travaux d'entretien, de construction et de modification qui y seront entrepris. L'étude exhaustive et approfondie dont il est ici question visait à fournir des données qualitatives et quantitatives sur les répercussions de la présence de conduites de gaz naturel sous pression dans différentes parties des emprises de routes rurales; à la lumière de ces données, on a également évalué les risques et les effets pouvant découler d'une telle pratique. L'étude couvre quatre exemples représentatifs de routes primaires et prend en compte les variations de leur débit quotidien moyen de trafic, de leur profil en travers et de la vitesse des véhicules. Elle englobe également trois exemples représentatifs de diamètres de gazoducs et de catégories de pression pour trois types d'emplacement (dans l'accotement, sous le fossé, à la limite intérieure de l'emprise routière) et dans un emplacement de contrôle où le gazoduc ne subissait pas les effets de la route. On a élaboré une méthode prenant en compte les effets de synergie gazoduc-axe routier, y compris les effets sur le taux de défaillance du gazoduc et les conséquences d'une défaillance allant jusqu'au déclenchement d'un incendie par des véhicules. Cette méthode a ensuite été appliquée à chacune des 108 études de cas, et un calcul systématique des risques encourus par le public a été effectué. On a évalué et commenté les risques individuels et collectifs ainsi que leurs variations pour les différentes combinaisons envisagées. On a également identifié les répercussions d'ordre économique, y compris l'augmentation du coût unitaire des activités communes liées à l'entretien, la construction et la reconstruction pour l'exploitant de la route. On a également formulé une série de conclusions et de recommandations, notamment sur les aspects suivants : définitions des combinaisons compatibles et incompatibles pour ce qui est du type de gazoduc et de son emplacement (sécurité, coûts et facilité de construction); mesures de réduction des risques et des effets en vue d'améliorer la sécurité et de limiter les coûts; stratégie d'optimisation à long terme. Bien que certaines études aient déjà porté sur l'utilisation de corridors communs pour les services et les transports, on ne disposait jusqu'à présent d'aucune évaluation quantitative exhaustive sur les répercussions économiques et les risques découlant de combinaisons représentatives des caractéristiques des routes et des gazoducs. Par conséquent, les travaux dont il est ici question ont généré une quantité significative de données et d'observations inédites.

Mots-clés

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EXECUTIVE SUMMARY

A. Introduction

The placement and location of hydrocarbon pipelines with respect to road structural cross sections and geometrics can have an effect on the safety of the highway system and its users and adjacent residents, and an operational and economic impact on highway maintenance, construction, and modification activities, as well as on the integrity of the pipeline itself.

Pipeline operators in Nova Scotia and British Columbia have proposed locating natural gas pipelines within rural road right-of-ways (ROW's). Due to the concern regarding the impacts on both road operations and on public and personnel safety resulting from such natural gas pipeline placements, the Transportation Association of Canada (TAC) has initiated the present study of the operational, economic, and safety implications of natural gas pipelines in different locations within primary and secondary highway right-of-ways in Canada.

B. Summary of Work Done

Essentially, the work was directed at generating a qualitative and quantitative understanding of the implications of locating pressurized natural gas pipelines in various locations within rural road right-of-ways.

The following different characteristics of locations, road types, and pipeline types were quantitatively included in the study:

- Road Types - Freeway, arterial, collector, and local with associated variations in Average Design Daily Traffic (ADDT), vehicle speed, and cross section.
- Pipeline Types - Nominal Pipeline Size (NPS) 6, 8, and 12 (inches) for medium-, high-, and very-high pressure natural gas.
- Pipeline Locations - With respect to road system, Location 1, within the road shoulder; Location 2, below the ditch; Location 3, approximately 1 m inside the right-of-way boundary; and Location 4, a location away from the effects of the road providing a control location.

Considering the above combinations, as applicable, three cases were investigated; namely, the general case, and two case studies as follows:

- The general case for all combinations of road types, pipeline types, and pipeline locations, utilizing representative Canada-wide conditions to the fullest extent possible.

- Case Study #1, Nova Scotia – An NPS 6 very-high pressure line in locations within the right-of-way of arterial roads in Pictou County.
- Case Study #2, British Columbia – An NPS 6 very-high pressure natural gas pipeline within various locations of a two- to four-lane arterial road ROW, through both flat and mountainous terrain from Squamish to Whistler, BC.

For the above combinations and cases, an operational and economic impact and a public safety risk assessment were conducted. Operational and economic impact analysis consisted of the definition and classification of all road, pipeline, environmental, and other events with impact potential; identifying those with significant impact potential; and evaluation of the economic or operational impacts in a quantitative form whenever possible.

In the risk assessment, a similar classification and screening of significant risks was carried out followed by evaluation of risks. The risk evaluation consisted of hazard scenario definition, frequency analysis, consequence analysis, and risk analysis.

For both operational and economic impacts and risks, methods of mitigating their frequency and magnitude were reviewed and specific impact and risk mitigation methods were recommended for all three cases considered. Finally, a review of applicable regulatory provisions in Canadian and US jurisdictions was carried out and documented, together with a commentary on their relevance.

C. Significance and Limitations of the Work

Although previous studies in the public domain have been conducted on utility corridor concepts, these have been largely qualitative, and restricted to localized regions. No previous work on a qualitative and quantitative level, covering both generic and specific cases and integrating concepts of road and pipeline constructability, maintainability, and operability with risk and economic impacts has ever been carried out previously. The present work combines interactively the results of expertise in risk and reliability engineering; road and pipeline engineering, construction, operation, and maintenance; cost estimating and economic impact assessment; and regulatory experience and knowledge to provide a unified study of the problem of natural gas pipeline placement in right-of-ways in rural areas, with possible applications in urban areas as well. Thus, the comprehensive nature, multi-disciplinary approach, quantitative detail, rigorous methodology, and enormous volume of significant results from the present study is unprecedented and likely to set standards for new approaches to the problem.

It should be noted that the general case of impact and risk analysis was necessarily comprehensive in nature, but not site-specific. Its general indications should be taken as the definition of trends, but should not be expected to apply site specifically, except as a methodological basis for more detailed investigations. Even the case studies, although specific to certain site characteristics, and satisfactory for the identification of the principal factors creating impacts and risks, lack the level of detail that would be expected in a rigorous risk or impact analysis to be submitted to a regulatory body. The case studies do, however, bring out the predominant impact and risk factors germane to their geographic locations, and as such form a good basis for further advancement in the optimization of the subject projects.

D. Conclusions

D.1 General Conclusions

The placement of high-pressure natural gas pipelines in highway right-of-ways impacts on highway operations and creates additional risks. The impacts and risks are closely related. The majority of impacts to the highway system relate to the modification of highway maintenance and construction activities to manage risks from the pipeline presence. Modifications to the pipeline installation are also often required. These adjustments consist primarily of the integration of industry standard practices for construction and operation in the vicinity of high-pressure natural gas pipelines, and entail additional time, equipment, and manpower, and often reduce highway efficiency through full or partial closures. Without incurring these impacts, and making the necessary safety provisions, risk from the pipeline generally would be unacceptable, producing a high probability of property damage and loss of life. There are a few cases where the impacts relate mainly to constructability, such as dropping new culvert inverts so that the culverts can go below the pipeline. But even here, a portion of the impact relates to safe construction procedures in the vicinity of the pipeline.

The significant impacts of the pipeline location, caused largely by risk management provisions, were identified (from all potential impacts) and summarized as shown in Table 1. The majority of the impacts were generated as a result of the need to modify approaches to avoid pipeline hazards, by surveys, slower operation, extra equipment, and/or additional manpower. Some of the impacts of this were sufficiently high to make the activities unfeasible or to require an alternate pipeline location. As can be seen, the economic impacts varied, with their inflationary effects ranging from small percentages to very high percentages in the order of 2000% for selected activities. Most of the economic impacts ranged between 1 and 50 % inflationary effect on unit cost, with the higher impacts in excess of 50%. Certain activities' impacts could not be economically quantified, so were simply ranked in terms of their severity. This included impacts on road traffic, which were described but are difficult to quantify except on a site-specific basis. Similarly, where the impacts were to the pipeline operator, generally involving the relocation of the pipeline in order to accommodate road activities such as addition of a climbing/passing lane, estimates were also not made as they are highly dependent on site-specific and pipeline-specific conditions. Costs of pipeline relocation can range from $50,000 to $500,000 per kilometre. Some of the impacts appear to be sufficiently large to make the activity unfeasible, or require alternate pipeline routings.

In the conduct of the general case risk analysis, risks were assessed with the key assumption that all industry safety measures necessary for safe construction and operation in the vicinity of high-pressure natural gas pipelines were implemented. The public and personnel risks thus estimated provided an estimate of expected individual specific risks for people with different levels of exposure to potential pipeline accidents, and collective risks.

Table 1
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading - Continuous - with Backhoe	ALL	2	M-H	Use hydrovac or hand excavation - per CPEP	m3	6.00	114.00	120.00	1900
B.5.12 M	Ditch Grading - Continuous - with Grader	ALL	2	M	Use caution over p/l	$1m^3$	7.00	0.50	7.50	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock Scaling	ALL	ALL	H	Additional nets, p/l protection	day	1200.00	800.00	2000.00	67
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R, 4R Projects)***									
C.1.2	Major Section Repair, Excavation of Embankment	ALL	1&2	M	CPEP and Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add Climbing/Passing Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.12	Blasting for Wider Road Surface	ALL	ALL	M	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading; 3m3 CPEP	ea	2869.00	870.00	3739.00	30
			2	H	CPEP and 2m3 Hydrovac	ea	2869.00	231.00	3100.00	8
		GH	1	H	CPEP Drop invert .5m, 30m3 extra grading; 3m3 hand excav	ea	1189.00	935.00	2124.00	79
			2	H	CPEP and 2m3 Hydrovac	ea	1189.00	319.00	1508.00	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2342.00	440.00	2782.00	19
			2		25m culvert; locate p/l	ea	2342.00	219.00	2561.00	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench; daylight p/l CPEP		1959.00	2200.00	4159.00	112
C.2.4	New Utility II	ALL	1&2	H	Assume 32-inch separation new NPS 12 p/l per Fig. 3.6	m	140.00	121.00	261.00	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km, total 100, scan p/l and hydrovac 100 holes	100	23045.00	5115.00	28160.00	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	66550.00	8250.00	74800.00	12
C.2.7	New Overhead Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	80000.00	5000.00	85000.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	250000.00	10000.00	260000.00	4
C.2.9	New Power Poles	ALL	3	M	3km, 100 std. wood posts at 30m; locate p/l and hydrovac holes	100	39050.00	14850.00	53900.00	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					
C.2.11	New Guard Rail	ALL	1	M	1 km,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	74681.00	13770.00	88451.00	18
C.2.12	New Driveway - Gravel	ALL	ALL	M	Locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1155.00	560.00	1715.00	48
C.2.13	New Road Bridge	ALL	ALL	M	Design to suit; locate p/l hydrovac 5m3	ea	250000.00	2000.00	252000.00	1

Table 1
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
C.2.14	Borrow Pit Access Driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1155.00	760.00	1915.00	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline Failure	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
D.3	Suspected Pipeline Damage	ALL	ALL	H	Road closure - 2-8 hr and lane closure TTC 8-24 hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline Repair (Major)	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (new parallel pipeline) -10 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 2-4 wks					H
F.2	Tap with Lateral Directed away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.3	Tap with Lateral Directed under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.6	Section Replacement -1 km	ALL	ALL	M	Road closure - 4-12 hr and lane closure TTC 1-2 wk					H
F.7	Lateral away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.8	Lateral under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic Protection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					H
F.10	Instrument Installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for New Trench	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.13	New Pipeline Construction - 25km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 1-2 months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1 - Settlement; Yr 2-3 - Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

***Note re CPEP:** If excavation more than 0.3 m deep planned:*

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

Thus, risks were assessed with the key assumption that all activities will be carried out with proper safety precautions at an industry standard, including pipeline location, daylighting, and the necessary hand or air tool excavation in close proximity areas. If safety measures are not strictly implemented, risks can become intolerable, with unacceptable risk of major damage of property or loss of life.

Based on risk management implementation, the individual specific risks for all members of the public and work forces likely to be exposed to pipeline accidents were expressed as risk transects as shown in Figure 1. As explained in the background to risk analysis, generally risk levels in the order of 1 in 1 million are deemed to be acceptable. The following general conclusions may be drawn from the risk assessment on the assumption that risk mitigations to an industry standard level are in place:

- All of the general case risk levels thus quantified with risk mitigations in place were found to be less than 1 in 1 million.
- For comparative purposes, hypothetical residents near the roadway system and near the control location, Location 4, were also subjected to individual specific risk assessment and it was found that the risks for locations adjacent to the road system, such as Locations 1 and 2, were approximately 10 times greater for pipelines adjacent to freeways than they were for pipelines in the control or unaffected location.
- From sensitivity studies and the case study work, it was found that the risk model is quite robust, with generally insignificant effects on risk results from small (less than an order of magnitude) changes in input parameters. However, the complete absence of any risk mitigation measures can amplify the risk to unacceptable levels.
- Table 2 gives a summary of the variation of risks at maximum risk location (pipeline centre line) associated with different road types, pipeline types, and locations.
- In general, risks are higher for Location 1 than for 2, and least for Location 3.
- Similarly, as the traffic density on the road decreases as represented by a decrease in ADDT, risks also decrease.
- Risks associated with the smaller NPS 6 and 8 pipelines are slightly higher than those associated with the NPS 12 pipelines due to the higher failure rates associated with smaller diameter pipelines.
- Collective risks were also quantified and generally found to be in the insignificant region as shown in Figure 2 by the region entitled “mitigated”.
- Reference to the unmitigated risks shown in Figure 2 will be made with respect to each of the case studies discussed below.

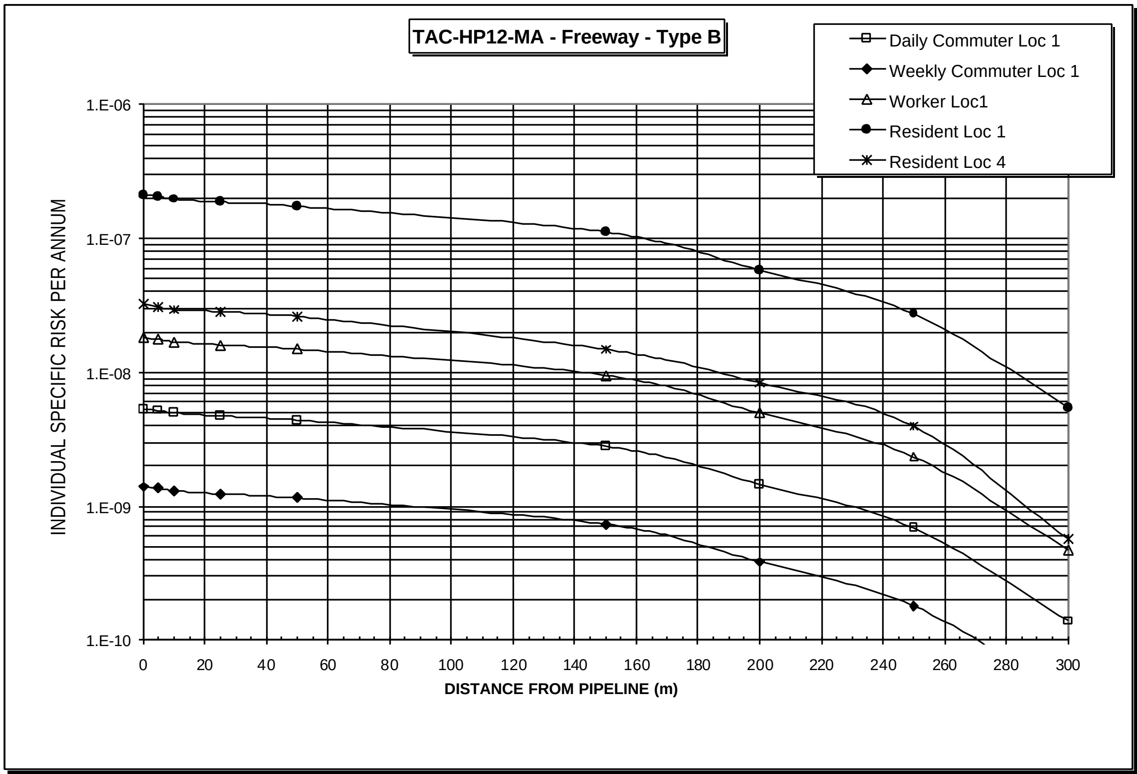

Figure 1
Transects – Freeway HP12 – Location 1

Table 2
Variations in Risk with Road and Pipeline Parameters

Road Type	HP P/L TYPE (inches)	MAXIMUM RESIDENT RISK (ANNUAL CHANCES OF FATALITY PER MILLION)			
		Loc. 1	Loc. 2	Loc. 3	Loc. 4
Freeway	12	0.21	0.20	0.18	0.03
	8	0.27	0.25	0.23	0.04
Arterial	12	0.16	0.15	0.14	0.03
	8	0.20	0.18	0.17	0.04
Collector	12	0.12	0.11	0.10	0.03
	8	0.15	0.14	0.12	0.04
Local	12	0.08	0.07	0.06	0.03
	8	0.10	0.09	0.08	0.04

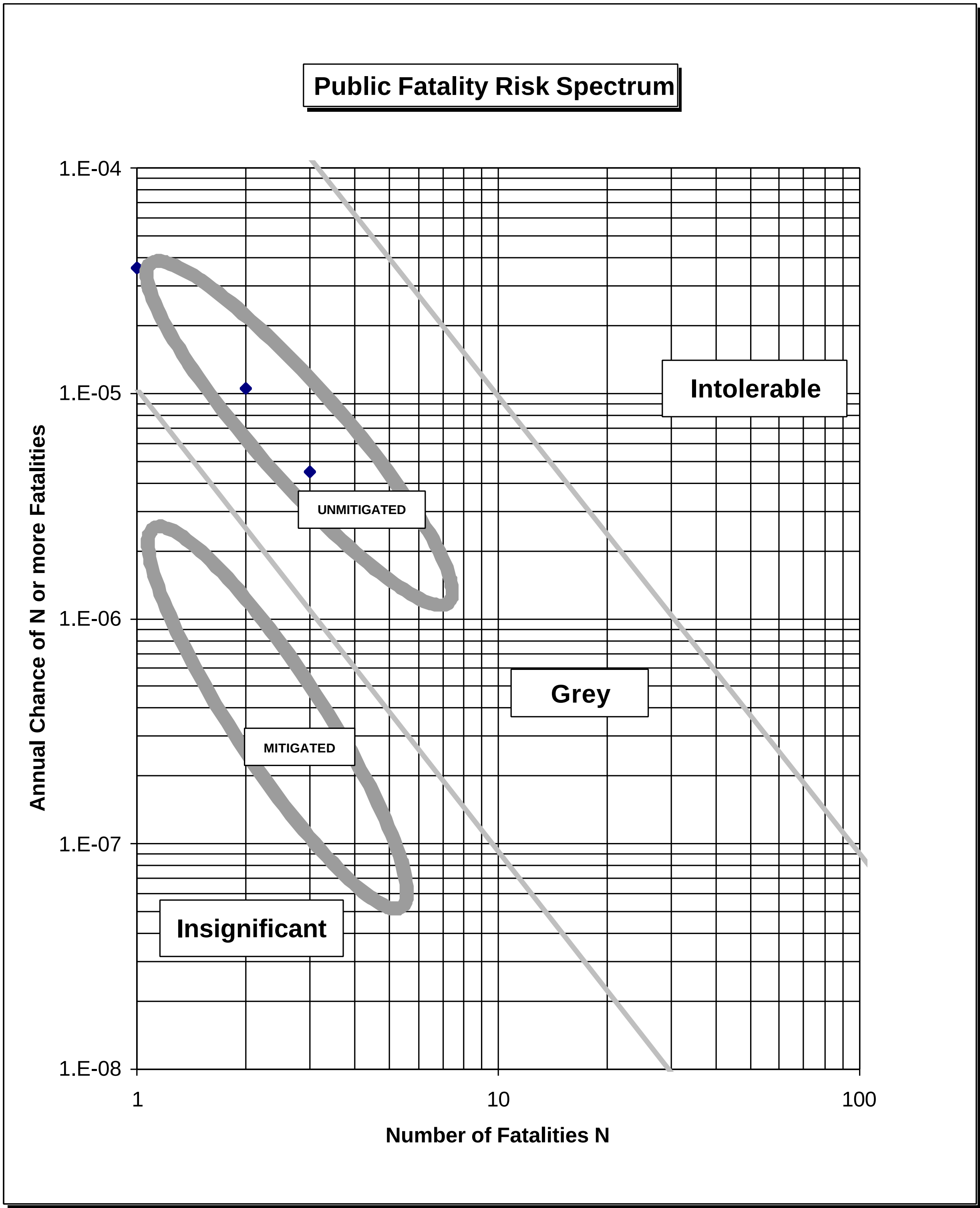

Figure 2
Collective Risk for Case Study #2

A variety of risk mitigation measures was identified for each of the significant risk causes. As mentioned above, it is essential to mitigate risks; without risk mitigation, risks are likely to be unacceptable. These risk mitigation measures are summarized in Table 3. A very common risk mitigation measure designed to avoid third party damage during excavations in the vicinity of pipeline locations is the Close Proximity Excavation Procedure (CPEP) summarized at the bottom of Table 3. Various risk mitigation measures are given for each of the risk causes, and it is expected that the optimal ones would be selected in accordance with a site-specific risk-cost-benefit assessment. In some cases, as will be pointed out later, risk mitigation may not be feasible, and the pipeline simply cannot be placed in one or all of the locations in the right-of-way, or must be constructed with special provisions.

D.2 Case Study #1

Case Study #1 involved the investigation of a proposed roughly 15-km length of NPS 6 very-high pressure natural gas pipeline largely within road right-of-ways within Pictou County, Nova Scotia. Significant risks were found to be associated with the following activities for the specified road conditions:

- Continuous ditch grading utilizing a backhoe for several kilometres of ditch, on a periodic, roughly 10-year return basis
- Installation of new guard rail posts using an impact auger.

Risk calculations were carried out considering these (and other) activities proceeding in an unmitigated fashion, with the result that risks to the workers and to the public would be at an unacceptably high level, requiring risk mitigation. The “Unmitigated” risk shown in Figure 2 corresponds to the unmitigated situation. Although it cannot be claimed that an optimal risk mitigation method (other than not locating the pipeline under the ditch or shoulder) was developed, several alternative risk mitigation methods were proposed, and selected ones were analyzed for economic impacts. As before, it was found that if an acceptable risk mitigation method is used with associated impacts then risks from the proposed development could be brought into the acceptable region. Naturally, the estimated cumulative effect of these impacts and determination of its acceptability must be done by the right-of-way owners.

As mentioned earlier, it should be noted, that although the predominant factors affecting impact and risk have been identified and quantified, this case study should not be viewed as a replacement for a detailed quantitative impact and risk assessment as may be required by the regulatory authority having jurisdiction.

Table 3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
External Corrosion				
	Percolation	ALL	ALL	1-Ensure adequate protective coating for expected soil ph/moisture conditions
				2-Ensure adequate drainage control
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	EMF	ALL	ALL	1-Ensure adequate Cathodic protection system and check regularly
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	Salt Effects	ALL	ALL	1-Ensure adequate protective coating for expected salt concentrations
				2-Ensure adequate drainage control to minimize road salt drainage to p/l
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
Third Party Damage				
	Roadway Clearing - Debris, Rockfall	ALL	ALL	1-Identify pipeline locations from p/l markers if grading to max .3m ok
				2-Use care with excavators or loaders CPEP within 30m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Culvert Maintenance	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Supply, Remove, & Install Minor Culverts	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Minor Signs (Single Post)	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Major Signs	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Guide Posts	ALL	ALL	1-Locate p/l and use CPEP
				2-Ensure guide post holes do not exceed .5m depth if within 3m
	Installation of Extra or Repl. Power Poles	ALL	ALL	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Ditch Grading - Continous, Grader	ALL	2	1-Locate p/l and use CPEP
				2-Conduct depth of cover survey prior to commencement of grading of ditches
	Ditch Grading - Continous, Excavator	ALL	2	1-Ditch grading with excavator not permitted if p/l installed less than 2m below ditch invert
				2-Install p/l in alternate location
				3-Develop safe ditch grading procedure and p/l installation method
	Snow Ploughing	1	ALL	1-Locate p/l (from markers) and use care if over p/l
	Rock Scaling	1	ALL	1-Avoid locating p/l in frequent (<20yr) rock fall locations
				2-Use nets/deflectors to deflect rockfalls from p/l locations
				3-Protect p/l with grade surface protectors -slabs, plates adequate to absorb rock fall impacts
				4-Design and install p/l for maximum rock fall impact resistance
	Mud Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Land Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Washout Repairs	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m

Table 3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
Third Party Damage - *Continued*				
	Major Section Repair, Excavation of Embankment	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
				5-Conduct full scale p/l resistance/integrity tests for expected dynamic compaction methods
				6. P/l should be located at as depth where it is safe fromheavy equipment/vibratory compaction
	New Culvert X	1	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Culvert II	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Utility X (e.g., FOC)	ALL	ALL	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
	New Utility II	ALL	1,2	1-Locate p/l
				2-Use CPEP within 2m of p/l
	New Minor Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Major Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Power Line	ALL	ALL	1-Locate p/l and use CPEP
	New Ditch	ALL	1	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
			2	1-No new ditch over 1.2m cover p/l location
				2-Relocate p/l to alternate location
	New Guard Rail (Unmitigated)	ALL	ALL	1-Locate p/l and use CPEP
				2-Plan ahead and install p/l in location 3 or 4 where guardrail work expected
	New Guard Rail (Mitigated)	ALL	1,2	1-Locate p/l and use CPEP
	New Driveway	ALL	ALL	1-Locate p/l
				1-Locate p/l and use CPEP
				3-Plan ahead-Install new access grade at time of p/l installation
	Railway Crossing Accident Derailment	ALL	ALL	1-Install p/l as far as possible from railroad, preferred >20m to avoid derailed train impact
				2-Implement derailment ERP, including immediate p/l shutin and blowdown
Earth Movement				
	Vibration from Traffic	1	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Conduct regular inspection pigging to detect incipient damage and permit repairs
	Frost Heave	3	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Drainage control to avoid water/ice buildup in vicinity of p/l
	Landslide	5	ALL	1-Locate outside landslide zone
				2-If in landslide zone design and install p/l for maximum landslide survival
				3-Shut in and blowdown if landslide warning red alert
	Flood	10	ALL	1-Locate outside flood zone
				2-If on flood plain design/install to maintain integrity in max flood
				3-Shut in and blowdown if flood buildup predicted and underway

Note re CPEP: ***If excavation more than 0.3 m deep planned:***

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

D.3 Case Study #2

Case Study #2 consisted of the impact and risk assessment of the proposed NPS 6 very-high pressure natural gas pipeline from Squamish, BC to Whistler, BC. In the risk and impact assessment, the approximately 40-km pipeline was subdivided into two representative segments, the flat terrain segment in the valley and flood plain north of Squamish, and the mountainous portion just south of Whistler. Economic and operational impacts and resultant mitigated risks along the flat terrain, other than potential flooding, were generally similar to those assessed under the general case. For the mountainous terrain portion, however, the frequency of avalanches and rockfalls and associated mountainside hazard management involving rock scaling, appeared to pose significant hazards to the pipeline if left unmitigated. An unmitigated risk assessment was conducted for these operational and environmental hazards, and it was found that risks would be in the unacceptable region for both members of the public and workers on the road. Collective risks, similarly, were found to be in the gray (requiring mitigation) region marked “Unmitigated” in Figure 2.

A variety of mitigation methods, including some suggested by the proponents, were reviewed. Although it is beyond the scope of this work to comment on their quantitative reliability and operational cost-benefit, for the mitigated risk assessment, reliance was placed on the documentation and purported efficacy of the risk mitigation methods, and it was found that if such appropriate risk mitigation methods could be devised to eliminate risks from rock scaling and rockfalls in the mountainous region, and all other safety procedures were implemented, risk levels could be in an acceptable range.

D.4 Regulatory Review

Applicable regulations were reviewed for Canadian jurisdictions in Alberta, British Columbia, Manitoba, and Ontario, as well as federally. It was generally found that, although guidelines existed for depth of cover for utilities in the vicinity of roadways, together with provisions in some jurisdictions (BC) for different risk levels, location of pipelines in right-of-ways is not permitted except by special permit, and if allowed, preference was generally given to locations on the outside of the right-of-way (Location 3). No detailed regulations in regard to placement, construction methods, and maintenance operations existed. Detailed regulations for construction in the vicinity of pipelines are set out by the National Energy Board. Alberta industry associations also setout explicit safety regulations for construction and operation in the vicinity of natural gas pipelines. These safety regulations are generally summarized at the bottom of Table 3, under CPEP. Although jurisdictional and franchising requirements are more specific, detailed regulations were not evident for the US locations reviewed, California and Minnesota. Railway regulations on both sides of the border, however, do have provisions for utilities installed parallel to railroads, and include provisions such as variability in the depth of cover between 6 feet in close proximity to tracks, to a minimum of 5 feet further away on the right-of-way.

E. Recommendations

E.1 General Recommendations

In general, it is recommended that this work be viewed as a comprehensive treatment of the problem of locating natural gas pipelines in various locations of rural road right-of-ways including identification of impacts, risks, risk and impact mitigation, and applicable regulations. It should be viewed as a foundation for more site-specific detailed risk and impact investigation by regulators, road system or pipeline designers, and other interested parties. Although the methodology established, described, and applied is rigorous, results of the general case should be used primarily as indicators of possible trends. For the specific case studies, illustrating more specific applications of the methodologies devised, good estimates of the factors predominating the impacts and risks are given, but should not be expected to replace a detailed risk and impact assessment.

General recommendations made on the basis of the work may be summarized as follows:

- If high-pressure natural gas pipelines are located in the road right-of-ways (with 1.2 metres cover in Locations 1, 2, or 3), all industry standard and other appropriate safety measures must be defined, publicized, implemented, and strictly adhered to in all private or public road maintenance construction activities.
- If these safety measures are not in effect (as described above), high-pressure natural gas pipelines should not be installed in Locations 1, 2, or 3 with 1.2 metres of cover.
- When pipelines are in the right-of-way, road maintenance and construction contractors will need to change their basic approaches to avoid accidents. This will involve a change in attitude or culture, to one similar to that adopted by oil and gas facility contractors. Described safety measures alone will not assure adequate safety; the attitude regarding safety is needed in addition to adherence to safety measures as not all situations may be covered by these safety measures.
- Alternative specially mitigated pipeline installations in the right-of-way may be acceptable but must first be evaluated for risk and impact on a case-by-case basis.
- In general, Location 3 on the edge of the right-of-way is associated with the lowest risk and impact.

Although in general there are many possible risk mitigations, with associated impacts on both the pipeline installation and road activities, to be arrived at through risk-cost optimization, there are several combinations of pipeline locations, local conditions, and activities which are difficult to resolve in a practical fashion and in some cases may be mutually exclusive because of excessive costs, intolerable risks, or simple impracticability of adjustments either to the road activity or pipeline installation. Table 4 summarizes these combinations of activities and conditions. There may be others, but the final judgement on acceptability should be made by the stakeholders weighing all factors within the framework set out in this work.

Table 4
Location Excluding Activities and Conditions

LOCATION	ACTIVITY	CONDITION	REQUIREMENT	EXCLUSION FACTOR
1	New guardrail installation within 2 feet of 1.2 m cover pipeline.	Narrow shoulder, rocky soils, making Hydrovac ineffective.	Hand excavation of post holes.	Impractical
	All road widening activities including adding passing, climbing, turn, or extra lanes.	Adequate sub-base to limit excavation/fill to 0.3 metre depth so that pipeline need not be relocated.	Static compaction over pipeline.	Possible but often Impractical
	Paving of shoulder.	Adequate sub-base to limit excavation/fill to 0.3 metre depth so that pipeline need not be relocated.	Static compaction over pipeline.	Possible but often Impractical
2	Continuous ditch grading with backhoe over p/l originally installed with 1.2m cover.	Ditch eroded/silted and steep sided.	Daylight pipeline at close intervals and hand excavate within 0.6 metres of pipeline surface. Bury p/l initially with 2m cover, conduct pre-grading daylighting survey, mark on cut stakes, and proceed with Gradall or equal.	Impractical Possible
	New ditch.	New ditch within 3 metres of old one, extending several km.	Daylight pipeline, hand excavate within 0.6 metres.	Impractical
	Any road widening requiring excavation and backfill within 3 metres of ditch (pipeline).	Need to excavate and backfill roadways.	Static compaction only.	Impractical
1, 2, 3	High avalanche, rockfall, mudslide area.	Geotechnical instability.	Pipeline protection. Development of pipeline burial and protection method (foam, fillcrete, increased depth Directional drill through rockfall area at adequate depth (eg10m)	High Risk Possible High cost
	Rock scaling.	Cliff instability.	Pipeline protection.(as above)	High Risk
	Major road reconstruction and upgrading.	Reconstruction over pipeline locations.	Relocate pipeline. Replace p/l backfill with Fillcrete or equal	High Cost Possible

Note: Exclusion factor means the reason or potential reason that either the pipeline cannot be located at the given location, or the subject activity cannot be carried out.

To deal with the less obvious situations such as those identified in Table 4, it is recommended that a project or process be initiated to identify, develop, test, assess, and implement road maintenance and construction and associated pipeline installation and operation procedures and technologies to cost effectively and efficiently achieve the objectives of traditionally conducted activities. Such technologies, as an example, could include:

- Sensor/alarm systems on excavation equipment buckets or ploughs to warn operator of pipeline proximity, with ability to set the warning distance, with an increasing alarm intensity as the proximity increases.
- Excavation depth governors for augers, drills, and other post hole diggers.
- Pipeline installation and backfill methods to allow for future overpaving, including dynamic compaction.
- Pipeline installation and backfill methods (excluding directional drilling) to allow adequate protection in rock fall areas.
- Method for remotely but accurately surveying pipeline cover thickness.

E.2 Case Study #1

Case Study #1 has revealed that activities with the highest risk, and therefore impact potential, are the continuous ditch grading and guardrail installation. If the risks are unmitigated and the normal procedures applied, risks will be unacceptable. Mitigations, however, other than location of the pipeline in an alternative site, although imaginable and identifiable, are not obvious from a feasibility point of view, and will require further study.

Both the impact and risk assessments for Case Study #1 have been made on the assumption that the segment and surroundings modeled are homogeneous, other than the variation between Locations 1 and 2. In reality, there will be a significant variation in both risk and impact throughout the proposed project region, with possible risk hot spots, but this variation could be quantified only through a detailed risk and impact analysis.

Although the impact scenarios quantified for Case Study #1 are based on those of the general case, with adjustments for regional cost factors, they should serve as a good basis for a (recommended) cumulative cost assessment that can be made by the highway operators in the area. Similarly, because of the relatively robust nature of the risk model, and therefore its lack of sensitivity to small variations in inputs, it is expected that the predominant risk factors have been adequately identified, and should be addressed through more detailed operational and analytical assessments, to identify final cost and risk mitigation methods.

E.3 Case Study #2

In Case Study #2, the primary concern for both impacts and risks is the mountainous segment south of Whistler, extending approximately 12 km through the Civil Defense Zone. If no mitigation for the pipeline integrity risks are provided for this region, risks to the public, and incidentally, also to the pipeline system itself, would exceed acceptable bounds. Various risk and impact mitigation measures have been suggested by the proponents, and if indeed these are as effective as purported, risks and impacts would be manageable. The risk mitigations proposed, however, appear to be largely based on theory, and may require validation utilizing appropriate full-scale tests. Thus, in Case Study #2, most impacts and risks appear to be manageable except for those associated with the mountainous regions where rockfalls and the associated rockfall management practices of rock scaling result in unacceptably high levels of risks, and further study, and full-scale experiments as required.

Again, as for Case Study #1, even though it is believed that the dominant risk factors have been adequately identified in this relatively high level analysis carried out, a more detailed assessment to quantify the risk variation in a detailed fashion over the length of the pipeline alignment and to investigate specific risk mitigation measures remains to be done before the question of risk is sufficiently addressed to be able to stand before a regulatory authority and members of the public.

E.4 Regulatory Recommendations

At this time no uniform and comprehensive regulations addressing the control of impacts and risks and associated distribution of liability associated with placement of natural gas pipelines in road right-of-ways appear to exist in Canadian or US jurisdictions.

Similarly, although detailed standards for excavation in the vicinity of pipelines exist in various guidelines, including Canada-wide standards promulgated by the NEB, their existence is not widely publicized, and certain conflicts among the standards from various jurisdictions exist. No widely applicable standards exist, however, for liability, cost sharing, or authorities having jurisdiction for the location of pipelines in road right-of-ways. One basis for parallel installation standards could be the depth of cover and class of construction required for road and railway crossings (as opposed to parallel installations), excluding the casing requirements which are often included for crossings.

In order to develop such standards and regulations, one possible approach would be the formation of a Task Force under the Transportation Association of Canada, the Canadian Energy Pipeline Association (or other industry associations), and the National Energy Board to define the problem and finalize approaches. The present study would provide a good foundation for such a Task Force by giving the general trends in risks and impacts associated with different combinations of pipeline and road types and pipeline locations within the right-of-way, but issues of jurisdiction, liability, and method of promulgation of the regulations need to be generated.

E.5 Summary of Recommendations

The salient recommendations from this work may be summarized as follows:

- The work should be used as a basis or framework for site-specific detailed impact and risk assessments when pipelines are planned to be installed in right-of-ways. Specific assessments, on a relatively broad level of detail were illustrated by Case Studies #1 and #2. More detailed assessments may be required for final definition of impacts and risks together with appropriate mitigation measures.
- A process for the adoption of specific guidelines for close proximity excavation procedures, the development of standards for cost and liability distribution, and authority designation for the location of pipelines in road right-of-ways should be initiated.
- A process or project should be initiated to identify, develop, test, assess, and implement road maintenance and construction and associated pipeline installation and operation procedures and technologies to cost effectively and efficiently achieve the objectives of traditional activities (when no pipelines are present) on road right-of-ways.
- As the above two projects are unlikely to be completed in a short-term time framework, it is recommended that the methods set out in the present work be adopted as an interim basis for dealing with the problem of high-pressure natural gas pipeline on road right-of-ways.

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CHAPTER 1 - Introduction

1.1 General Introduction

The placement and location of hydrocarbon pipelines with respect to road structural cross sections and geometrics can have an effect on the safety of the highway system and its users, residents and businesses adjacent to the system, and an operational and economic impact on highway maintenance, construction, and modification activities, and on the pipeline system itself. Due to interactions between the road system and the pipeline, the safety of road users and maintenance personnel can be affected by hazards posed by the pipeline. The natural gas pipeline poses the potential to release a flammable mixture of natural gas, which can be ignited with resultant damaging consequences including casualties and property damage. Also, the presence of a pipeline within the road structure will have an impact on the full range of road activities from construction to maintenance, through its very presence.

Pipeline operators in Nova Scotia and British Columbia have proposed locating natural gas pipelines within road right-of-ways. Other natural gas pipelines are located in road structures elsewhere in Canada. Due to the concern regarding the impacts on both road operations and safety resulting from these proposed placements, the Transportation Association of Canada (TAC) issued a Request for Proposal (RFP) to qualified organizations for a study of the operational, economic, and safety implications of the placement of natural gas pipelines at different locations within primary and secondary highway systems in Canada. Bercha Engineering Limited (Bercha) responded to the RFP and was awarded the contract on November 10, 2000. The current report represents a summary and documentation of the work carried out under this contract.

1.2 Scope of Work

The scope of work has been subdivided under six tasks as follows:

- Task 1 – Data Assimilation
- Task 2 – Principal Factor Definition
- Task 3 – Public and Personnel Risk Assessment
- Task 4 – Cost and Operational Impact Assessment
- Task 5 – Conclusions and Recommendations
- Task 6 – Reporting

1.3 Outline of Report

Successive chapters, following this brief introduction, deal with the following aspects of the work, covering the entire scope of work delineated above:

- Chapter 2 – Data and Information (Task 1)
- Chapter 3 – Operational and Economic Impacts (Tasks 2 and 4)
- Chapter 4 – Public Risk Assessment (Tasks 2 and 3)

- Chapter 5 – Risk and Impact Mitigation (Tasks 3 and 4)
- Chapter 6 – Case Study #1 (Tasks 3 and 4)
- Chapter 7 – Case Study #2 (Tasks 3 and 4)
- Chapter 8 – Regulatory Review (Task 4)
- Chapter 9 – Conclusions and Recommendations (Task 5)

Essentially, Chapter 2 summarizes the Task 1 data assimilated. Task 2 is incorporated primarily in Chapters 3 and 4, where the predisposing factors for impacts and risks, respectively, are discussed followed by their application and generation of relevant results. Chapter 3 deals with the operational and economic impact assessment. Although in the scope of work the cost and operational impact assessment is given as Task 4, following the Task 3 risk assessment, in this report it is dealt with prior to the risk assessment because it forms a foundation for parts of the risk assessment inputs. Next, Chapter 4 deals with the public and personnel risk assessment, corresponding to Task 3. Chapter 5 deals with risk and impact mitigation, generally corresponding to Tasks 3 and 4. Next, the case studies have been included in dedicated chapters, with Chapter 6 dealing with Case Study #1 and Chapter 7 with Case Study #2. Chapter 8 deals with the regulatory requirements in Canada and elsewhere relevant to the problem at hand. Finally, Chapter 9 gives conclusions and recommendations. The reporting was covered through the generation of Progress Reports #1 and #2, the Draft Final Report, and the Final Report.

The appendices give detailed information on calculations, and are subdivided as follows:

A Terms of Reference
B Operational and Economic Impact Calculations
C Risk Analysis Calculations
D Case Study #1
E Case Study #2
F Mitigation Measures

CHAPTER 2 – Data and Information

2.1 General Description of Data and Information

The principal categories of data and information generated as input to the current study include the following:

- Road types and characteristics
- Pipeline locations
- Pipeline types and characteristics
- Case study information

With the conduct of the study, additional information was generated including information on road operation, maintenance, and construction activities; pipeline operation, construction and maintenance activities, and other data and information on the relevant regulatory practices and existing regulations in jurisdictions in Canada and elsewhere. Data for conduct of both the case studies and generic studies in the areas of public and personnel exposure factors, meteorological conditions, traffic conditions, and other factors affecting impacts and risks were generated. This additional information and data are discussed as required in their related chapters.

2.2 Road Types and Characteristics

Four primary road types were utilized as a basis for the study; namely, the freeway, the arterial, the collector, and the local road. These types were further sub-classified into subtypes as summarized in Table 2.1. As can be seen, this table gives additional information including average design daily traffic (ADDT) and other characteristics necessary for characterizing the road types and pipelines location effects to the road system. A typical cross section for each of the major road types graphically depicts their characteristics and is shown in Figures 2.1, 2.2, 2.3, and 2.4 for freeways, arterials, collectors, and local roads respectively. The classification given here is that of the TAC RFP, reproduced in Appendix A. there are some differences between these classifications and other accepted ones [36][*], but the TAC RFP governs here.

2.3 Pipeline Locations

Three pipeline locations were documented as follows:

- Location 1 - In the shoulder.
- Location 2 - Under the ditch.
- Location 3 - At the edge of the right-of-way (approximately 2 metres toward the road from the edge of the right-of-way).
- Location 4 - Away from the effects of the road system (the control location).

[*] Numbers in square brackets correspond to References.

Table 2.1
Summary of Road Subtypes

HIGHWAY CLASSIFICATION, TRAFFIC VOLUME, DESIGN STANDARDS									
	FREEWAY	ARTERIAL		COLLECTOR		LOCAL			
	TYPE B	TYPE C	TYPE D	TYPE E	TYPE F	TYPE G	TYPE H	TYPE I	TYPE J
Design Year Traffic, ADDT	<10000	>5000 (*1)	<5000	>3000 (*1)	<3000	>300 (*1)	<300	<50	
Design Hourly Volume	<450	>450	<450	>250	<250				
Design Speed Range, km/h	110-90	100-80	90-80	90-80	80-70	80-60	70-50		50
Gradient – Maximum %	8	7	7	8	9	10	12		8
Surface Type	Paved	Paved	Paved	Paved	Paved	Optional	Unpaved	Unpaved	Optional
Lane Width, m	3.7	3.7	3.5	3.5	3.3	3.0			3.0
Shoulder Type	Paved 1.0	Paved 0.5	Paved 0.5	Opt. 0.2	Unpaved	Unpaved			Optional
Shoulder Width (Usable, m)	2.5	2.2	2.2	2.0	1.5	1.2			1.6
Shoulder Rounding, m	0.8	0.6	0.6	0.4	0.4	0.4			0.4
Finished Top Width, m	14.0	12.6	12.6	11.8	10.4	9.2	8.0	6.6	10.0
Side Slopes (a)	4:1	3:1	3:1	2:1	2:1	2:1	1.5:1	1.5:1	2:1
Back Slopes (b)	2:1	2:1	2:1	2:1	2:1	2:1	1.5:1	1.5:1	2:1

NOTES:

1. While Arterial Type C, Collector Type E, and Local Type G have standard design year traffic ADDT's, it is common for these types of roads to experience a range in ADDT's.

   In a sample from Nova Scotia, the following ADDT's were found:
   - Type C – 360 to 19,770 ADDT
   - Type E – 430 – 11,000 ADDT
   - Type G – 100 to 8,820 ADDT

2. On embankments over 3m, side slopes may be reduced to 2:1 with the installation of guardrail if economically feasible.

3. Maximum back slopes to be 2:1 but flatter slopes will be permitted for slope stability as determined by laboratory tests. Back slopes in cuts over 3m must be determined by laboratory tests prior to construction.

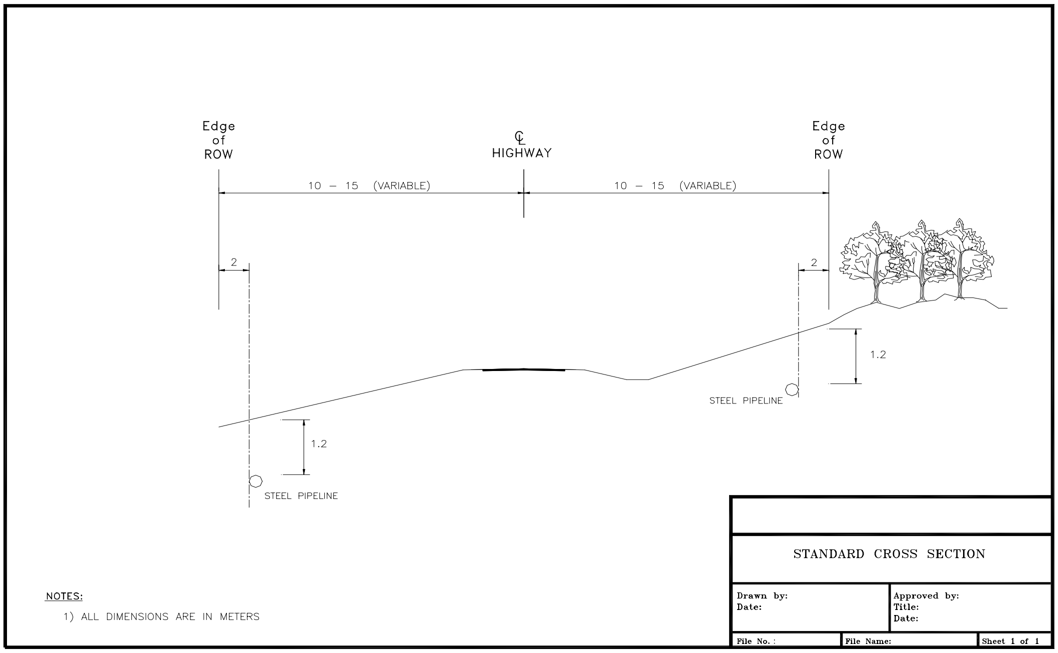


Figure 2.1
Standard Cross Section

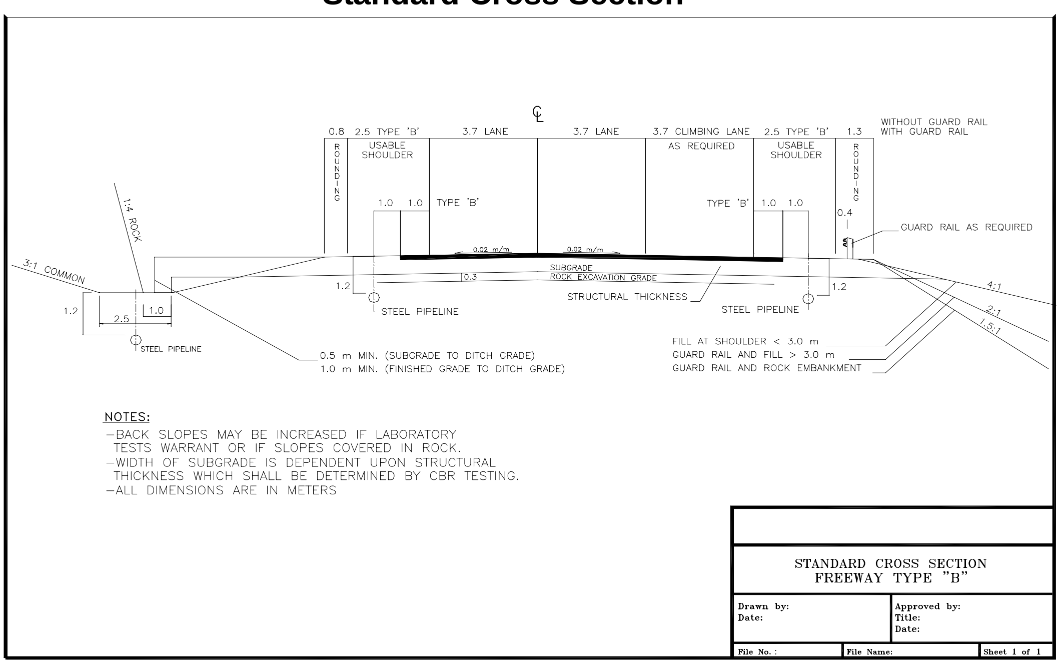


Figure 2.2
Standard Cross Section, Freeway Type "B"

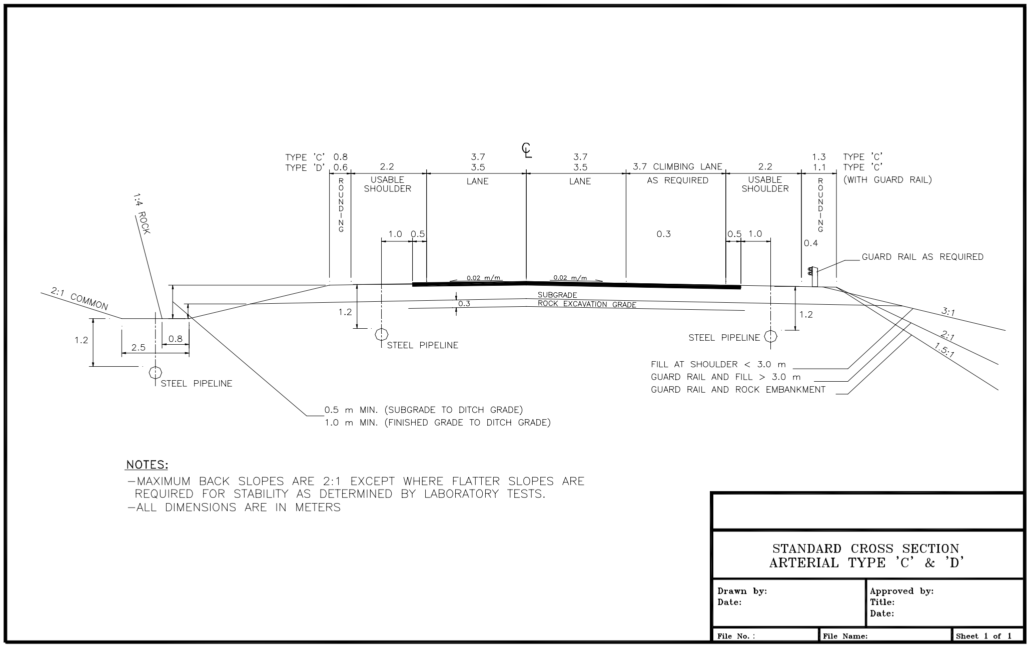
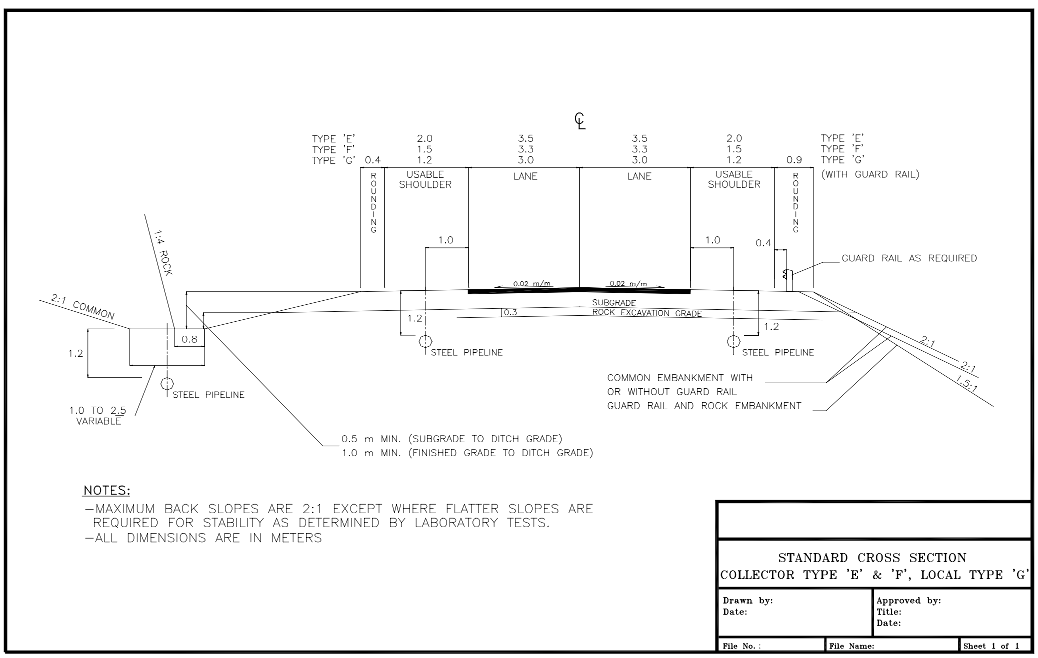


Figure 2.3
Standard Cross Section, Arterial Type “C” & “D”



Figured 2.4
Standard Cross Section, Collector Type “E” & “F”, Local Type “G”

These pipeline locations were also shown in the cross section and Figures 2.1 to 2.4.

In the balance of this study, these four locations will be referred to simply as Location 1, 2, 3, or 4. Locations 1, 2, and 3 are called adjacent locations, because they interact with the roadway system, while Location 4 is also called the control location because it forms a basis for the characteristics of the pipeline behaviour unaffected by the roadway system.

2.4 Pipeline Types and Characteristics

Although four categories of pipeline types were required in the original contract, this has been extended to nine pipeline types and characteristics in order to accommodate the specific characteristics of the pipeline types in each of the case studies. Table 2.2 summarizes the pipeline types and characteristics studied in the work. As can be seen, there are essentially three pipeline size categories, those of Nominal Pipe Size (NPS) 6, 8, and 12, with each having three different Maximum Allowable Operating Pressures (MAOP). The segment length used for the general case was 25 km, with natural gas pipeline Class 2 construction under CSA Z662. Table 2.2 also gives the acronym used for each pipeline type in the scenario characterization for modeling pipeline effects (in Chapter 4).

2.5 Case Studies

2.5.1 Case Study #1 – Nova Scotia

Case Study #1 is the proposed Sempra Atlantic Gas (Sempra) high-pressure gas distribution lines in Pictou County, Nova Scotia. The following principal parameters based on pipeline alignment sheets [61] characterize the case study:

- Pipelines are primarily in Location 1, in the shoulder, and Location 2, under the ditch.
- Pipelines will be NPS 6, Class 2 construction, with a maximum allowable operating pressure of 6,900 kPa or 1,000 psi.
- The Average Annual Daily Traffic (AADT) of the road system is in the order of 5,000 vehicles per day.
- The length of the pipeline as proposed is approximately 13.6 km for one segment described in drawings PI-101 and 2.6 km for those in PI-201. [48]

These input parameters together with local climatic characteristics for the area have been entered into the risk model developed for this study. Full details for this Case Study are given in Chapter 6.

Table 2.2
Summary of Pipeline Types and Characteristics Studied in the Work

SIZE NPS	SEGMENT LENGTH (km)	MAOP kPa (psi)	ACRONYM
6	25	2070 (300)	LP6
		4826 (700)	HP6
		8272 (1200)	VP6
8	25	2070 (300)	LP8
		4826 (700)	HP8
		8272 (1200)	VP8
12	25	2070 (300)	LP12
		4826 (700)	HP12
		8272 (1200)	VP12

2.5.2 Case Study #2 – British Columbia

Case Study #2 deals with the proposed Centra Gas B.C. Inc. (Centra) pipeline from Squamish to Whistler in British Columbia. As a basis for this study, alignment drawings [25], the Design Basis Memorandum [26], and responses to information requests [27] were reviewed, and discussions with B.C. Ministry of Transportation and Highways were held.

Essentially, the following general characteristics of the pipeline have been identified:

- There are two principal categories of terrain through which the pipeline passes, and these are level terrain (Case 2.1), and mountainous terrain in the Civil Defense Zone (Case 2.2).
- The pipeline is approximately 45 km with approximately 12 km of this in mountainous terrain.
- The pipeline is NPS 6, can be approximated as operating in 12-km isolatable segments at a maximum allowable operating pressure of approximately 900 psi.
- AADT of the road is 9,000, with road speeds in the order of 80 to 90 km/h. Generally the pipeline is proposed for Locations 1 and 2.

Full details for this case study are given in Chapter 7.

2.6 Terrain Classification

The following terrain classifications are used where needed in this study:

- Level - Any combination of horizontal and vertical alignments which permits heavy vehicles to maintain approximately the same speed as passenger cars; this generally includes short grades of no more than 1 to 2 percent.
- Rolling - Any combination of horizontal and vertical alignments causing heavy vehicles to reduce their speed substantially below that of passenger cars, but not causing heavy vehicles to operate at crawl speeds for any significant amount of time.
- Mountainous - Any combination of horizontal and vertical alignments causing heavy vehicles to operate at crawl speeds for significant distances or at frequent intervals.

CHAPTER 3 – Operational and Economic Impacts

3.1 General Description, Classification, and Screening of Impacts

This chapter deals with the definition, classification, screening, and quantification of operational and economic impacts on the road system as a result of the existence of a pipeline at one of the three designated locations for each of the principal road categories. In addition, because many of the impacting activities also have risk associated with them, a preliminary screening of risks is also carried out.

The general approach to operational and economic impacts involved, first, identification of road and pipeline activities, which have a potential for operational or economic impact on the road system and its operation. Next, these activities were classified according to the following principal categories:

- Normal road operation
- Road maintenance
- Road construction
- Normal pipeline operation
- Pipeline maintenance
- Pipeline construction
- Long-term effects

Next, each of the activities was qualitatively studied and described with detailed descriptions as given in Sections 3.2 for road activities, 3.3 for pipeline activities, and 3.4 for long-term effects. Next, an impact screening process was defined. A screening process has the objective of identifying or eliminating activities which have no to insignficant impacts, and selecting those with higher potential impact. Accordingly, an impact severity ranking has been assigned in accordance with the following criteria:

- L - Low - No change in cost and minimal effect on operation.
- M - Medium - Estimated change in cost less than 10%; operational disturbance equivalent to lane closure.
- H - High - Change in cost estimated to be greater than 10%; operational disturbance equivalent to complete road closure for several hours or more.

Similarly, a risk severity has been developed and assigned in order to identify those activities with higher risk potential for further analysis as described in Chapter 4. The risk severity ranking criteria were as follows:

- L - Low - No quantifiable increase in risk.
- M - Medium - Quantifiable increase in risk less than one order of magnitude (factor of 10).
- H - High - Potential to increase risk by one order of magnitude or more.

For both sets of rankings, activities that did not have a low ranking (L) were subjected to further analysis.

Finally, a summary of the impact and risk screening information is given in Table 3.1, which gives the following information:

- The item number and classification as described above.
- A short description of the activity (to be expanded in the technical discussions of activities in the following three sections).
- Description of impact on the road system or its operation.
- The road types and pipeline locations for which the impact is applicable.
- The impact severity ranking.
- The risk severity ranking.

3.2 Road Activities

3.2.1 Normal Road Operations

Normal road activities that may be impacted by the pipeline presence include vehicle traffic flow, various accident related activities, and travel off the road surface on the shoulder or right-of-way. In general, these activities are more likely to impact Locations 1 and 2, and in all cases the impact would be of a low severity.

3.2.2 Road Maintenance

3.2.2.1 General Description of Road Maintenance Activities

Road maintenance activities have been investigated and defined in considerable detail, due to their ongoing nature and possible continuous interaction with the pipeline existence. Table 3.2 defines in more detail the road maintenance activities which were summarized in Table 3.1. In general, these road maintenance activities were derived with the assistance of Carmacks Enterprises Ltd., the Alberta private provincial road maintenance organization for the Calgary area. These maintenance activities have been supplemented based on discussions with the BC Ministry of Transportation and Highways, the Nova Scotia Transportation and Public Works Department, and with members of the Steering Committee during Steering Committee Meetings.

Table 3.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H): IMPACT	SEVERITY (L, M, H): RISK
A	**NORMAL ROAD OPERATION**	**IMPACT OF P/L ON ACTIVITY**				
A.1	Vehicle Traffic Flow	Pipeline warning signs visible	ALL	ALL	L	L
A.2	Road Accident Follow Up-emergency vehicles	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.3	Road Traffic - Pulling Over	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.4	Emergency Vehicle Passing Offroad	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.5	Road Accident Cleanup	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.6	Wide Load Transit	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
A.7	Detour on Shoulder	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
B	**ROAD MAINTENANCE**	**IMPACT OF P/L ON ACTIVITY**				
B.1	***Routine Maintenance***					
B.1.1	Daytime Road Inspections	None	ALL	ALL	L	L
B.1.2	Litter Pickup	None	ALL	ALL	L	L
B.1.3	Minor Fence Repairs	None	ALL	ALL	L	L
B.1.4	Inspecting Culvert Ends for Damage or Blockage	None	ALL	ALL	L	L
B.1.5	Removing Road Kill (mostly deer)	None	ALL	ALL	L	L
B.1.6	Cleaning Signs and Guide Posts	None	ALL	ALL	L	L
B.1.7	Straightening Sign and Guide Posts	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.1.8	Replace Reflector Strips on Guide & Guardrail Posts	None	ALL	ALL	L	L
B.1.9	Removing Illegal Signs	None	ALL	ALL	L	L
B.2	***Road Surface Maintenance***					
B.2.1	Roadway Sweeping	None	BCE	1&2	L	L
B.2.2	Raised Median Washing	None	BCE	1	L	L
B.2.3	Line Painting	None	BCE	1	L	L
B.2.4	Message Painting	None	BCE	1	L	L
B.2.5	Maintaining Gravel Roads	None	H	1	L	L
B.2.6	Re-Gravelling	Minimize driving or parking heavy equipment over p/l	H	2	L	L
B.2.7	Dust Control	None	H	1	L	L
B.2.8	Livestock Guard Cleaning	Use Close Proximity Excavation Procedure-CPEP (see note below)	H	1&2	L	L
B.2.9	Roadway Clearing - debris, rockfall	Minimize driving or parking heavy equipment over p/l, if using excavator use CPEP	ALL	1&2	L	M
B.3	***Roadside Maintenance***					
B.3.1	Mowing	None	ALL	ALL	L	L
B.3.2	Hand Trimming	None	ALL	ALL	L	L
B.3.3	Brushing	None	ALL	ALL	L	L
B.3.4	Chemical Vegetation Control	None	ALL	ALL	L	L
B.3.5	Drainage Maintenance/Improvements	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.3.6	Culvert Maintenance	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.3.7	Bridge Washing	None	ALL	ALL	L	L
B.3.8	Beaver Control	Use Close Proximity Excavation Procedure-CPEP and blast mats if blasting	ALL	3	L	L
B.3.9	Removal of Large Road Kill	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
B.3.10	Ditch Grading - Localized	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	M
B.4	***Road Surface Repairs***					
B.4.1	Pavement Surface Failures	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.2	Fog Coat	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.3	Crack Sealing	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.4	Spray Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.5	Pothole Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.6	Paver Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.7	Grader Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L

Table 3.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H) IMPACT	SEVERITY (L, M, H) RISK
B.4.8	Milling	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.5	***Roadside Repairs and Installations***					
B.5.1	Supply, Remove, & Install Minor Culverts	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	L	M
B.5.2	Installation of Minor Signs (single post)	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.3	Installation of Major Signs	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.4	Installation of Guide Posts	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.5	Installation of Wildlife Reflectors	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.6	Installation of Guardrail (box beam, W-Beam)	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.7	Installation of Concrete Barriers	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.5.8	Installation/Repair of Fencing – Chain Link or Barbwire	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.9	Bridge Maintenance and Repair	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	L
B.5.10	Erosion Control/Repairs - Minor	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.11	Installation of Extra or Replacement Power Poles	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.12	Ditch Grading - Continuous	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	M-H	H
B.5.13	Railway Crossing Repairs	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.6	***Winter Operations***					
B.6.1	Application of Sand and Salt	None -increased corrosion potential	ALL	ALL	L	L
B.6.2	Snow Ploughing	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	M
B.6.3	Installation of Snow Fencing	None	ALL	ALL	L	L
B.7	***Mountain Operations***					
B.7.1	Rock Scaling	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	H	H
B.7.2	Mud Slide Cleanup	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.3	Land Slide Cleanup	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.4	Washout Repairs	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.5	Avalanche Stabilization	Avoid locating cannon near p/l; assure that avalanche avoids p/l locations	ALL	ALL	L	L
C	**ROAD CONSTRUCTION**	**IMPACT OF P/L ON ACTIVITY**				
C.1	***Road Surface (3R, 4R Projects)***					
C.1.1	Resurface	Minimize driving or parking heavy equipment over p/l	ALL	1&2	L	L
C.1.2	Major Section Repair, Excavation of Embankment	Locate p/l and use CPEP if within 5m; static compaction within 3m	ALL	1&2	M	M
C.1.3	Add Climbing/Passing Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.4	Add Turn Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.5	Widen Road	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.6	Pave Shoulder	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.7	New Exit/Entry	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.8	New Overpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L

Table 3.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H): IMPACT	SEVERITY (L, M, H): RISK
C.1.9	New Underpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.10	Test Section	Locate p/l and use CPEP if within 5m	ALL	1&2	L	L
C.1.11	Rumble Strips	Locate p/l and use CPEP if within 5m	ALL	1&2	L	L
C.1.12	Blasting for Wider Road Surface	Shut down and blowdown p/l for duration of blasting operations; use blast mats	ALL	ALL	M	L
C.1.13	Geotechnical Drilling	Locate p/l and avoid drilling within 6m	ALL	ALL	L	L
C.2	***ROW (Off Surface)***					
C.2.1	New Culvert X	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.2	New Culvert II	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.3	New Utility X (e.g., FOC)	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.4	New Utility II	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.5	New Minor Sign	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	M	M
C.2.6	New Major Sign	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.7	New Overhead Sign Structure	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.8	New Pedestrian Bridge	Engineering design to avoid conflict with p/l	ALL	ALL	M	L
C.2.9	New Power Line	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.10	New Ditch	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	H	M
C.2.11	New Guard Rail	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	M	H
C.2.12	New Driveway	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.13	New Road Bridge	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.14	Borrow Pit Access Driveway	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.15	Farm Animal Fencing	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	3	L	L
C.2.16	Diking	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.17	Emergency Detour Road Designation and Operation	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
C.2.18	Construction Detour Road Construction	Minimize driving or parking heavy equipment over p/l min 1.5m cover	ALL	ALL	L	L
C.2.19	Wildlife Control Fencing	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.20	Private Sign Installation	Use Close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
D	**NORMAL PIPELINE OPERATION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
D.1	Pipeline Remotely Operated	As described above	ALL	ALL	L	L
D.2	Pipeline Failure	Close road until isolation and blowdown completed	ALL	ALL	H	H
D.3	Suspeected Pipeline Damage	Close road until damage repaired or p/l confirmed ok	ALL	ALL	H	L
E	**PIPELINE MAINTENANCE**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
E.1	Pipeline Repair (Major)	P/l segment blowdown and isolation; construction zone speed restriction, road closure during equipment mvmt	ALL	ALL	H	L
E.2	Leak Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L

Table 3.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H): IMPACT	SEVERITY (L, M, H): RISK
E.3	ROW Surveillance	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.4	Leak (Sniffer) Inspection	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.5	Cathodic Protection Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.6	Pipeline Exposure for Coating/Pipe Inspection	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
E.7	Internal Pigging	None	ALL	ALL	L	L
E.8	Valve Testing (Valve in Underground Pit)	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.9	Pipeline Repair (Minor) - Exposure	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
F	**PIPELINE CONSTRUCTION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
F.1	Looping (new parallel pipeline)	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
F.2	Tap with Lateral Directed away from Road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.3	Tap with Lateral Directed under Road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.4	New Valve	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.5	Valve Replacement	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.6	Section Replacement	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.7	Lateral away from Road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.8	Lateral under Road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.9	New Cathodic Protection	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.10	Instrument Installation	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.11	Blasting for New Trench	Road closure	ALL	ALL	H	L
F.12	Hydrotesting	Road closure	ALL	ALL	H	L
F.13	New Pipeline Construction	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
G	**LONG TERM**	**IMPACT OF P/L ON ACTIVITY**				
G.1	ROW Usability	Usability of a strip approximately 1m width on each side of p/l c/l for other utilities eliminated, and cost increases for Close proximity construction within 2m of p/l c/l significant	ALL	ALL	H	L
G.2	Road System Structural Integrity	Settlement of p/l backfill and possible deformation and localized failures of roadbed	ALL	ALL	H	L
G.3	Chronic Health Effects	None	ALL	ALL	L	L

***Note re CPEP:* If excavation more than 0.3 m deep planned:**

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

Table 3.2
Typical Highway Maintenance Programme Activities

ITEM	ACTIVITY	DESCRIPTION
B	**ROAD MAINTENANCE**	
B.1	***Routine Maintenance***	*The following miscellaneous minor work items are undertaken by field staff on a routine basis.*
B.1.1	Daytime Road Inspections	Patrolmen look for road surface debris, damaged guardrail, missing signs, etc.
B.1.2	Litter Pickup	
B.1.3	Minor Fence Repairs	
B.1.4	Inspecting Culvert Ends for Damage or Blockage	
B.1.5	Removing Road Kill (mostly deer, wild ungulates)	
B.1.6	Cleaning Signs and Guide Posts	
B.1.7	Straightening Sign and Guide Posts	
B.1.8	Replace Reflector Strips on Guide & Guardrail Posts	
B.1.9	Removing Illegal Signs	e.g., real estate signs, roadside vendors, garage sales, small businesses
B.1.10		
B.2	***Road Surface Maintenance***	
B.2.1	Roadway Sweeping	Removal of sand and gravel from pavement surface
B.2.2	Raised Median Washing	Flushing of raised concrete medians to remove mud and debris
B.2.3	Line Painting	Centerlines and shoulder lines, skipped lines or solid lines, yellow or white
B.2.4	Message Painting	Stop bars, directional arrows, pedestrian/school crossings
B.2.5	Maintaining Gravel Roads	Regular grading of gravel surface to remove 'washboard' and ruts.
B.2.6	Re-Gravelling	Supply, haul and spread crushed gravel on existing gravel roads
B.2.7	Dust Control	Application of calcium chloride on gravel roads, typically in front of adjacent homes
B.2.8	Livestock Guard Cleaning	Supply, installation and maintenance
B.2.9	Roadway Clearing - debris, rockfall	Removal of debris, earth, from flood or wind effects
B.3	***Roadside Maintenance***	
B.3.1	Mowing	For aesthetics, and safety (i.e. so motorists can see wildlife approaching road)
B.3.2	Hand Trimming	Cutting of vegetation where mowers cannot reach (i.e. around the bases of sign posts)
B.3.3	Brushing	Cutting of brush from within, and along the edge of, the highway right-of-way
B.3.4	Chemical Vegetation Control	To kill noxious weeds, which can spread into farmers' fields
B.3.5	Drainage Maintenance/Improvements	Excavating or cleaning out drainage channels in the right-of-way ditch to ensure efficient drainage of runoff from the highway
B.3.6	Culvert Maintenance	Cleaning and repairing damaged culverts to ensure proper drainage
B.3.7	Bridge Washing	Flushing of the bridge and interchange structures to remove sand, gravel and winter salt residue
B.3.8	Beaver Control	Removal of beaver dams and in some cases eradication of beavers causing drainage problems
B.3.9	Removal of Large Road Kill	Removing large road kill (over 40 kilograms) with loader and truck
B.3.10	Ditch Grading-localized	Removal of debris at specific locations in ditches
B.4	***Road Surface Repairs***	
B.4.1	Pavement Surface Failures	Excavation of failed pavement, base, and subgrade materials, and reconstruction with suitable gravel and pavement mix
B.4.2	Fog Coat	Asphalt sealant for older (weathered) pavements to seal small cracks, surface voids and prevent raveling and aggregate loss
B.4.3	Crack Sealing	Application of liquid asphalt to seal expansion cracks from rainwater infiltration into the embankment
B.4.4	Spray Patching	Application of a mixture of liquid asphalt and washed 7 mm gravel chips to fill shallow depressions on the pavement surface

Table 3.2
Typical Highway Maintenance Programme Activities

ITEM	ACTIVITY	DESCRIPTION
B.4.5	Pothole Patching	Application of an asphalt pavement mix to fill broken out holes in the pavement layer
B.4.6	Paver Patching	Full width paver laid hot asphalt pavement mix on depressed or structurally weak localized areas on the pavement surface, compacted with vibratory steel drums
B.4.7	Grader Patching	Grader laid mixture of asphalt pavement mix on localized weak, depressed or failed areas on the pavement surface
B.4.8	Milling	Mechanical grinding of the pavement surface to remove undesirable high spots
B.5	***Roadside Repairs and Installations***	
B.5.1	Supply, Remove, & Install Minor Culverts	Drainage of highway right-of-way
B.5.2	Installation of Minor Signs (single post)	i.e. Stop signs, curve signs, regulatory speed signs
B.5.3	Installation of Major Signs	Information and directional signs. (e.g., cluster frames, concrete bases, breakaway posts)
B.5.4	Installation of Guide Posts	Round white plastic reflective posts installed at intersections and around the outside of curves to aid motorists in negotiating turns
B.5.5	Installation of Wildlife Reflectors	Reflectors mounted on wooden posts to reflect light from approaching vehicles to startle wildlife and prevent them from crossing the highway
B.5.6	Installation of Guardrail (box beam, W-Beam)	Interconnected lengths of steel beam mounted on wooden posts to prevent errant vehicles from colliding with fixed objects in the right-of-way or from rolling down steep slopes
B.5.7	Installation of Concrete Barriers	Used primarily to separate lanes of traffic traveling in opposite direction
B.5.8	Installation/Repair of Fencing – chain link or barbwire	Chain link or barbwire fencing installed along the edge of the highway right-of-way to separate property and prevent wildlife from wandering onto the highway
B.5.9	Bridge Maintenance and Repair	Regular structural maintenance and repairs to bridges and interchanges
B.5.10	Erosion Control/Repairs-minor	Repair of localized eroded or washed out areas on the shoulder, backslopes or in ditches
B.5.11	Installation of Extra or Replacement Power Poles	
B.5.12	Ditch Grading - Continuous	Removal of sediment and regrading of ditch using backhoe
B.5.13	Railway Crossing Repairs	
B.6	***Winter Operations***	
B.6.1	Application of Sand and Salt	Abrasive and sodium chloride (rock salt) spread onto road surface to increase traction, and melt ice
B.6.2	Snow Ploughing	Snow removal with trucks and graders on road surface and shoulder
B.6.3	Installation of Snow Fencing	To prevent drifting snow across highway
B.7	***Mountain Operations***	
B.7.1	Rock Scaling	Removal of rocks from cliff surface threatening road, including loosening, dropping, and removal from shoulder, ditch area of boulders
B.7.2	Mud Slide Cleanup	Removal of debris and earth from road system following mudslide
B.7.3	Land Slide Cleanup	Removal of debris and earth from road system following landslide
B.7.4	Washout Repairs	Similar to above
B.7.5	Avalanche Stabilization	Initiation of avalanches using cannon located on roadside.

Road maintenance activities vary significantly among different jurisdictions and regions. For example, in the prairie regions grading of ditches is quite different from that in the Maritimes. On the prairies, ditches are generally wide and parabolic, requiring only limited maintenance which can generally be done utilizing a grader. In the Maritimes, and particularly in Nova Scotia, ditch sideslopes are steep, and the shoulder and ditch are relatively narrow. Ditch grading is done on a regular (approximately 10-year cycle) utilizing a backhoe with soil loaded directly onto gravel trucks.

3.2.2.2 Ground Disturbance in the Vicinity of Pipelines

Ground disturbance in the vicinity of pipelines such as those under consideration can be hazardous if not conducted with proper safety measures. Implementation of these safety measures will have an impact on the excavation activity, by slowing it down, requiring additional equipment, and more manpower. A procedure for safe ground disturbance in the vicinity of pipelines adopted in Alberta [29] is used as a basis for the impact estimates made here. This procedure (described in more detail under risk mitigation Section 5.3.4) may be summarized as follows:

- All rural transmission pipelines are protected by a 30-metre control strip on each side of the pipelines.
- No excavation deeper than 0.3 metres may occur within 30 metres of the pipeline until the surface location of the line is marked by the owner/operator of the facility. Once the surface location is marked, mechanical excavation is permitted to within 5 metres of the pipelines.
- No mechanical evacuation is allowed within 5 metres of the pipeline until the line has been hand exposed and positively identified.
- Once the pipeline has been hand exposed and identified, mechanical excavation is permitted to within 60 cm (2 feet) of the pipeline. Mechanical excavation with 60 cm (2 feet) of the pipeline may only take place when the excavating is directly supervised by the pipeline owner/operator or their representative. Hand exposure or excavation can be done with approved water or air jet or vacuum (Hydrovac) tools.
- The pipeline owner/operator may choose to exceed the above mentioned minimum standards, and if that is the case our workers are expected to adopt the higher standards while working in the other party's right-of-way.

This procedure is also referred to as Close Proximity Excavation Procedure (CPEP) in this report.

3.2.3 Road Construction

3.2.3.1 Road Construction Activities

Road construction activities are differentiated from road maintenance activities primarily by the magnitude of the activity in terms of cost. Generally, one-time activities costing in excess of $100,000 would fall into the road construction activity area. Table 3.3 summarizes the principal road construction activities which have been identified to date. Some of these individual activities would not exceed $100,000, but have been classed there, because they would be components of a general road construction contract. The nature of the road construction activities listed is self-explanatory.

3.2.3.2 3R/4R Projects

3R/4R projects entail resurfacing, restoration, rehabilitation, and/or reconstruction to new or existing roadway features listed below:

A. Grade widening/reconstruction versus overlay
B. Horizontal curvature
C. Vertical curvature (including crests and sags)
D. Intersections
E. Passing/climbing lanes
F. Rumble strips
G. Improvements to sideslopes, ditch, and backslopes
H. Barrier (maintenance and repair)
I. Superelevation

3.2.3.3 Activity Background Information

A. Grade-Widening/Reconstruction
In choosing between grade-widening and reconstruction, many activities must be considered including: width after overlay, collision rate, and existing geometrics.

B. Horizontal Curvature
Curve flattening is warranted only on curves that do not meet the minimum radius for reconstruction. For larger radius curves, factors such as superelevation rate, collision rate, intersections or hazards on curves, consistency, horizontal-vertical alignment coordination, and road user savings should be considered.

C. Vertical Curvature
Crests should be reconstructed if there is a safety problem, a hazard near the crest, the AADT greater than 3000, and the stopping sight distance (SSD) is marginal. Sags are generally not cost-effective to improve unless there is a collision problem that is caused by the sag curve.

Table 3.3
Summary of Principal Road Construction Activities

ITEM	ACTIVITY	DESCRIPTION
C	**ROAD CONSTRUCTION**	
C.1	***Road Surface***	
C.1.1	Resurface	*Major Maintenance:* Full depth patching, heater scarification, texturizing, slurry sealing, micro surfacing, chip sealing. *Rehabilitation:* Reconstruction, resurfacing, milling and resurfacing, hot in-place recycling, cold in-place recycling, full depth reclamation, other techniques (ie. white topping).
C.1.2	Major Section Repair, Excavation of Embankment	Reconstruction with suitable fill material on a backslope or sideslope.
C.1.3	Add Climbing/Passing Lane	Addition of 3.5 – 3.7 m of paved cross section plus tapers for up to 2 km for a passing lane and up to 6 km or more for a climbing lane depending on climbing lane warrants, design truck and length and slope of the upgrade.
C.1.4	Add Turn Lane	Addition of 3.5 – 3.7 m of auxiliary lane to the paved cross-section. The length of left turn lane, acceleration lane or deceleration lane depends on storage requirements, road classification, and design speed but can be up to several hundred metres. Taper lengths can be over 200 m.
C.1.5	Widen Road	Widening the road involved increasing the lane width and/or shoulder width up to 3.7 m and 3 m respectively.
C.1.6	Pave Shoulder	Paved shoulders enhance operations and safety and can be up to 3 m in width.
C.1.7	New Exit/Entry	Depending on the roadway classification and type of access a new exit/entry can involve acceleration and deceleration lanes, turning lanes, increased turning radius, and access road.
C.1.8	New Overpass	Components include bridge abutments, piles, footings, on and off ramps, changes to sideslopes, backslopes, and drainage. Utilities may have to be relocated. Ducts for luminaires.
C.1.9	New Underpass	Excavation for approach and leaving grades. Utilities relocation. Retaining walls, abutments, ramps, changes to sideslopes, backslopes, and drainage. Ducts for lighting if required.
C.1.10	Test Section	Access on shoulder and sideslope for constructability. Excavation of sub-grade, GBC and ACP.
C.1.11	Rumble Strips	Milled or rolled-in installed on outside shoulders 2m wide or inside shoulders 1.2 m wide. Rumble strips are 600 mm wide and are placed 75 – 150 mm from the edge line.
C.1.12	Blasting for Wider Road Surface	Carried out as part of a 3R/4R reconstruction program, adding auxiliary lanes such as passing/climbing lanes or part of a twinning program.
C.1.13	Geotechnical Drilling	The soils logs are the results of auger borings made during preliminary surveys along the highway right-of-way. The borings are typically 5 – 6 m in depth but can extend as deep as the bedrock.

Table 3.3
Summary of Principal Road Construction Activities

C.2	***ROW (Off Surface)***	
C.2.1	New Culvert X	Maximum sizes of culverts are often specified even though these sizes may have capacity exceeding the discharge requirements, to account for ice or debris. For example, in Alberta the minimum diameter for cross drains is 800 mm on the main alignment and 600 mm on the main access road. The minimum depth of cover should be 300 mm, or span divided by 6. Culverts over 1400 mm in diameter are considered bridge structures by some agencies. *Culvert Installation:* The excavation for a culvert must be wide enough to allow pipe assembly and to accommodate the operation of compaction equipment on either side of the culvert. When existing culverts need to be replaced or rehabilitated due to corrosion or extended due to roadway widening or sideslope improvement, a variety of methods are available. These methods include conventional open-cut excavation, trenching, or coining and pushing smooth wall steel or concrete pipe for culvert replacement.
C.2.2	New Culvert II	The minimum diameter for field approaches is 400 mm. *Culvert Installation:* See notes above.
C.2.3	New Utility X (e.g., FOC)	Specifications include minimum depth of cover (approximately 1 m) and built within a specified horizontal distance of the pavement.
C.2.4	New Utility II	Requirements specify minimum depth of cover and distance parallel to the road. Regulations usually specify that the utility be parallel to the centreline of the road.
C.2.5	New Minor Sign	Signs are placed 2 – 4.5 m from the edge of the traffic lane. Posts may be buried up to 1 m in depth.
C.2.6	New Major Sign	Large information signs may require two posts 2 – 4.5 m from the edge of the traffic lane and 5 – 7.5 m for the second post.
C.2.7	New O/H Sign Structure	These large sign bridges may also require protection such as W-Beam or N-J barriers.
C.2.8	New Pedestrian Bridge	Construction involves footings and abutments. As these are in close proximity to the traffic lane, roadside barriers such as blocked W-Beam or N-J barriers are required. *Note:* Note that abutments near the traffic lane and even barriers are considered roadside hazards. The clear zone is defined as the border area standing at the edge of the traveled lane that should be clear of hazards and available for use by errant vehicles. Tests have shown that on moderate sideslopes, approximately 85% of errant vehicles leaving the road on tangent alignments will recover within 9 m. Clear zone will thus vary with slope ratio, design speed and AADT. For example, on a 6:1 fill slope, a design speed of 90-100 km/h and an AADT of 6000, the clear zone is 9 m; whereas on a 3:1 cut slope, design speed is less than 80 km/h, and fewer than 800 vehicles/day, the clear zone is 3.5 m.
C.2.9	New Power Line	Outside the clear zone barrier will not be required. However, within the clear zone mitigation measures such as a blocked W-Beam will be required.
C.2.10	New Ditch	Common ditch configurations include the Vee ditch, round ditch, narrow trapezoidal ditch or wide trapezoidal ditch. Of all configurations, the wide trapezoidal ditch is the safest for errant vehicles which must leave the road and traverse the roadside area including sideslope ditch and backslope.

Table 3.3
Summary of Principal Road Construction Activities

C.2.11	New Guard Rail	For rural highway applications, the W-Beam guardrail is generally preferred over concrete barrier. Concrete barriers are generally used only when deflection is undesirable such as in narrow medians, at bridge piers, or overhead sign structures. Post size can be 150 mm x 200 mm and post depth is approximately 800 mm – 1000 mm. With increased emphasis on highways, it is expected that there will be more barriers installed.
C.2.12	New Driveway	Typically involves a parallel culvert and a fill slope.
C.2.13	New Road Bridge	Approaches, fills, abutments, retaining walls.
C.2.14	Borrow Pit Access Driveway	8-m cross-section gravel road. Depending on main highway classification, grade, and traffic volume, an acceleration lane may be required.
C.2.15	Farm Animal Fencing	Required by Highway Agencies.
C.2.16	Diking	Earth berm to contain high water flows, trapezoidal in shape.
C.2.17	Emergency Detour Road Designation and Operation	Unlike TTC, there is not a lot of time to plan and emergencies are unique random events. Emergency detours may utilize shoulders, sideslopes or adjacent (opposing) lanes.
C.2.18	Detour Road Construction	Must follow accepted TTC procedures during construction. Can involve design speeds up to 80 km/h. Detour roads on main highways follow geometric design guidelines.
C.2.19	Wildlife Control Fencing	Above ground fencing 2.4 m high and posts up to 1 m in the ground. Below ground aprons are buried at 45° and 1 m in depth.
C.2.20	Private Sign Installation	Private signs are generally not permitted within the highway right-of-way. However, posts may be 1 m in depth and placed without knowledge of pipeline location.

D. Intersections
Intersection sight distance is based on providing sufficient sight distance so that the design vehicle, after having come to a stop on the minor road, can safely make a left turn without being struck by a vehicle approaching from the left.

E. Passing/Climbing Lanes
Provinces such as Alberta, British Columbia, Ontario and Saskatchewan have warrants to determine the needs for passing and climbing lanes.

F. Improvements to Sideslopes, Backslopes, and Ditches
Roads with an 85^{th} percentile running speed of 100 km/h or more and sideslopes of 3:1 are candidates for improvement. Sideslopes of 4:1 are a minimum, and 6:1 desirable for an AADT greater than 6000. If the ditch width is being reduced to accommodate the sideslope requirements, the minimum width is 1.2 m. It is desirable to provide 3:1 or flatter backslopes.

G. Roadside Barrier Systems
It may be more cost-effective to flatten the sideslope than reinstall the guardrail. Because guardrail on the shoulder is a hazard in itself and can be the cause of snow drifting, it may be desirable to offset the guardrail from the shoulder or flatten the sideslope.

H. Superelevation
Superelevation improvements may be considered if it is determined that a horizontal alignment will not be undertaken.

3.3 Pipeline Activities

Pipeline activities have been subdivided into pipeline construction activities, normal pipeline operation, and pipeline maintenance activities. As indicated in the introduction to this section, it is the impact of these activities on the road system in terms of operational impact and economic impact that is the primary objective of the analysis of pipeline activities.

3.3.1 Pipeline Operations

Normal pipeline operations without any incidents are covered by the impact of the different pipeline locations on the road operation, maintenance, and construction activities. However, if during normal pipeline operation an incident occurs or the potential for an incident is suspected by the pipeline operator, road closures of different durations would be expected to take place in order to avoid potential hazards.

3.3.2 Pipeline Maintenance

The general area of pipeline maintenance activities includes inspection, servicing, maintenance, and minor and major repairs. Principal pipelines maintenance activities considered for impact to the road system and its operation are summarized in Table 3.4. As can be seen, the majority of the activities are unlikely to have any significant impact on the road system. Only those activities such as major pipeline repairs involving the mobilization of heavy equipment and possible interference with the road operations are expected to have a high impact, while minor activities involving intrusive inspections or repairs are expected to have moderate impacts.

3.3.3 Pipeline Construction Activities

North American hydrocarbon liquid and gas pipeline design and construction methods are a well-established technology with recognized technical and safety standards. Pipeline construction methods are discussed in detail in numerous publications such as that by McAllister [41]. Only a brief summary of certain aspects of the pipeline construction process which will be referred to in the current work, is given in this section.

Table 3.4
Summary of Pipeline Maintenance Activities

ITEM	ACTIVITY	DESCRIPTION
E	**PIPELINE MAINTENANCE**	
E.1	Pipeline Repair (Major)	Mobilization of heavy equipment, excavation of pipeline, removal, replacement including welding in place and coating, backfill, and right-of-way restoration.
E.2	Leak Check	Localized check utilizing personal portable gas chromatograph or equivalent, generally carried in light truck or van parked in vicinity of suspected leak area.
E.3	ROW Surveillance	Visual inspection of right-of-way either by a motor vehicle or from helicopter flying over right-of-way.
E.4	Leak (Sniffer) Inspection	A continuous monitoring along pipeline with a portable combustible gas indicator (carried by walking operator) to locate any potential areas of leakage.
E.5	Cathodic Protection Check	Localized measurements of electric current flow in vicinity of pipeline in aboveground appurtenances utilizing portable equipment carried in light truck or van.
E.6	Pipeline Exposure for Coating/Pipe Inspection	Mobilization of excavating equipment and exposure of pipeline to inspect coating and repair if necessary in place.
E.7	Internal Pigging	Pigs are devices which are sent down through the pipeline for either cleaning purposes or inspection purposes. Pigs are launched at a pig trap, a normally isolated pipe end with a pressure resistant door and bypass system for entry or egress of the pig.
E.8	Valve Testing	Various tests of valve function and integrity carried out with portable equipment normally carried in light truck or van.
E.9	Pipeline Repair (Minor) - Exposure	Mobilization of excavation equipment and necessary repair (weld or coating) equipment, exposure of pipeline, and repair of damaged segment in place. Can use stoppage fittings to create temporary bypass.

New Pipeline Construction – Location 4

The major portion of the construction of high-pressure natural gas distribution pipelines consists of construction through rural areas. Such trunk line construction is carried out by a spread, the crew and equipment needed to build the pipeline. In essence, the spread is a moving assembly line which can consist of as many as 100 pieces of major equipment and up to 350 workers, supported by a team of management, engineering, and administration professionals maintaining safe and efficient progress and completion of the construction.

Spread activities for normal trunk line construction consist of a series of activities ranging from initial surveys, through trenching and welding, to final testing and clean up, as follows: surveys, clearing, grading, stringing, ditching, bending, pipe gang, welding, pipe coating, lowering in, tie in, testing, back fill, and clean up. Figure 3.1 [41] shows a pipeline construction spread associated with rural environment open field construction while Figure 3.2 [14, 15] shows a cross section of the construction work area. As can be seen, the working area utilizes a width of approximately 15 m (50 feet).

New Pipeline Construction – Locations 1, 2, and 3

Not all conditions along a pipeline route, however, can be handled by a normal pipeline construction spread. Rocky ground, swamp and marsh, steep terrain, major rivers and lakes, give rise to special construction categories resulting from natural conditions. Urban congestion, roads, railways, are man made conditions requiring special construction approaches. A general summary of the special construction categories to deal with natural or man made physical features follows:

- Normal trunk line (cross country)
- Swamp or marsh
- Lake or marine
- Rock
- Desert (sand or loose gravel)
- Steep terrain
- Urban
- Special Subcategories
  - Road crossing
  - Railway crossing
  - Other pipeline crossing
  - River crossing
- Roadside Locations (1, 2, 3)

Certain conditions along a pipeline route may be sufficiently unique and extensive that a specific construction procedure must be developed to deal with them safely and successfully. For example, construction of a segment of pipeline in a narrow road right-of-way, with road, railway, and utility crossings, and other pipelines requires a site-specific design and construction approach.

Figure 3.1
Pipeline Construction Spread Associated with Rural Environment Open Field Construction

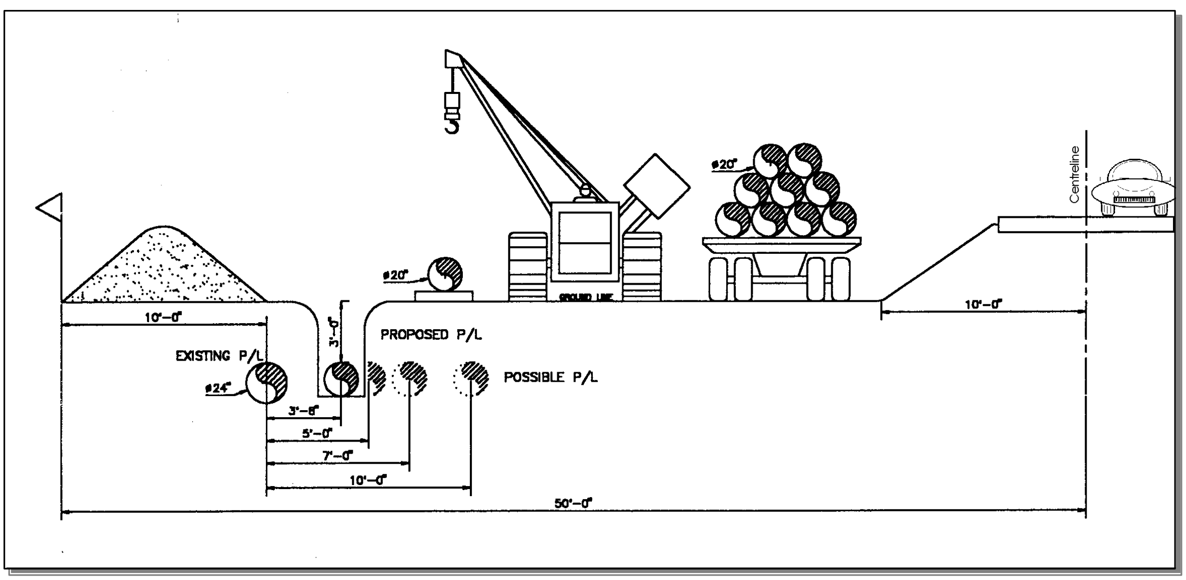


Figure 3.2
Typical Cross Section of Construction Work Area

Such an approach is shown in Figure 3.3 [13]. In this figure, to reduce the working surface width, work is done off the flattened spoil pile resulting in a reduction of width of the working area to approximately 10 m (32 feet). A similar adaptation of the spread approach will be required, particularly for the narrow right-of-ways presented by the roads in the Case Studies #1 and #2 described subsequently.

Figure 3.3
Pipeline Construction Spread – Working Off the Flattened Spoil Pile

For the purposes of the present assessment, pipeline construction activities have been classified as shown in Table 3.5. The primary new pipeline construction activity requiring a modified spread approach as described above (Figure 3.3) is the construction of looping, or installation of a second pipeline in order to increase the capacity of the pipeline system. In addition, of the activities enumerated, replacement of a section of pipeline, if that section is sufficiently long, is equivalent to new pipeline construction. The other activities listed in Table 3.1 are less onerous, but still have potential impact on the roadway and its operation.

Table 3.5
Summary of Principal Pipeline Construction Activities

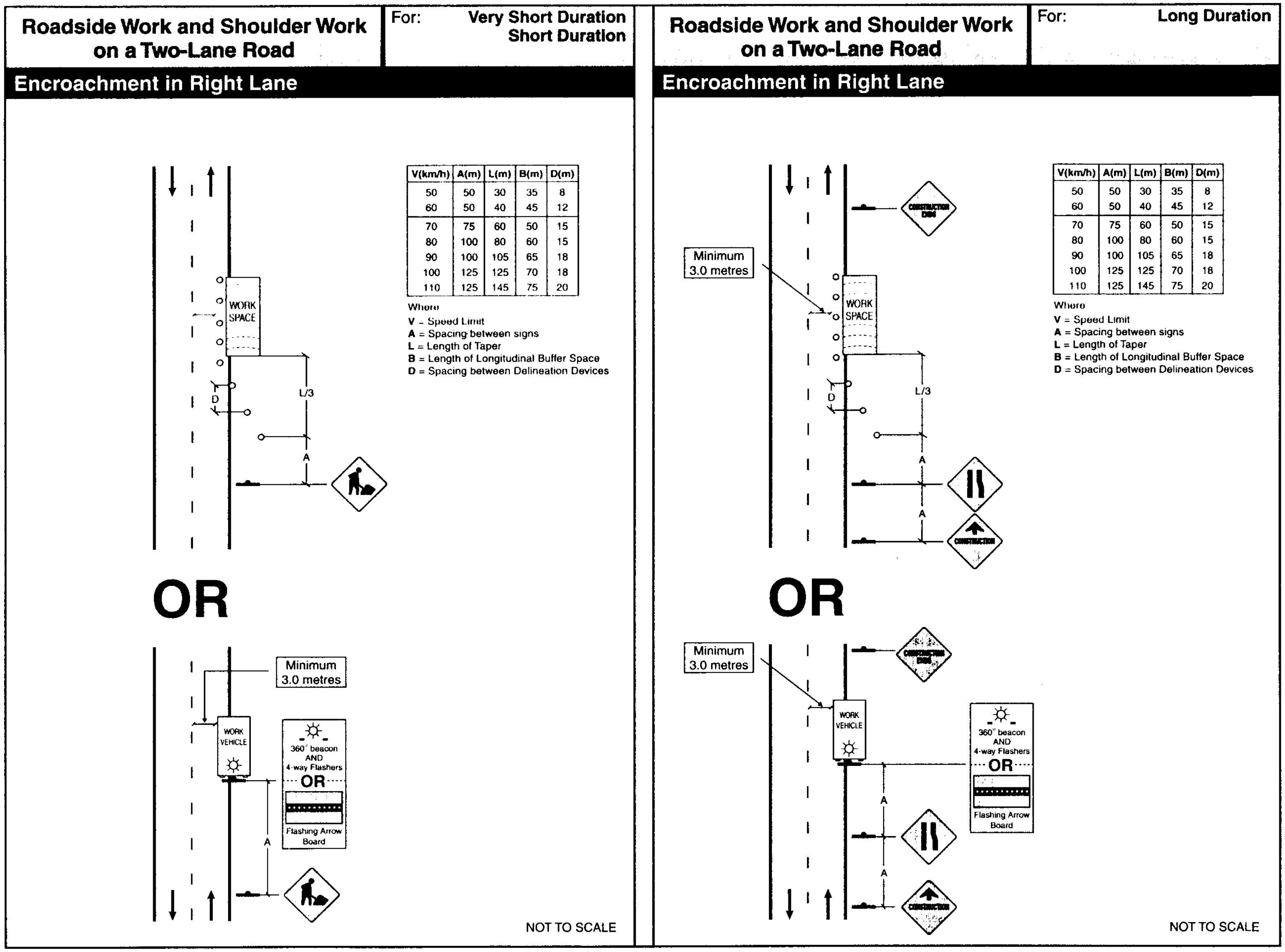
ITEM	ACTIVITY	DESCRIPTION
F	**PIPELINE CONSTRUCTION**	
F.1	Looping (new parallel pipeline)	Mobilization of full spread, utilizing modified construction technique to reduce working area to fit right-of-way.
F.2	Tap with lateral directed away from road	Excavation to expose existing pipeline, and installation of a hot tap (with pipeline service) using accepted procedure and trenching from pipeline location in a direction away from the road.
F.3	Tap with lateral directed under road	Exposure of existing pipeline and either trenching across road with resultant road stoppage or boring under road to accommodate lateral from the tap.
F.4	New Valve	Exposure of pipeline, taking pipeline out of service, and installation of new valve.
F.5	Valve Replacement	Again, taking pipeline out of service and replacing valve normally in a valve vault underground.
F.6	Section Replacement	Depending on length of section, mobilization of pipeline spread and operations similar to F.1.
F.7	Lateral away from road	Taking pipeline out of service and installation of lateral from existing pipeline including trenching away from road.
F.8	Lateral under road	Taking pipeline out of service, and installation of lateral utilizing either open trench or boring under road.
F.9	New Cathodic Protection	Limited excavation, installation of cathodes and anodes and associated wiring and power sources.
F.10	Instrument Installation	Varies with location of instrument, but probably requires excavation to exposed pipeline and installation of instrument stem without taking pipeline out of service.
F.11	Blasting for new trench	Pipeline taken out of service, with use of blast mats in blasting area to minimize projectile effects.
F.12	Hydrotesting	Pressurization of pipeline for a period of 1 to 3 days to detect any leaks.
F.13	New Pipeline Construction	Modified spread approach in vicinity of roadway to accommodate available working area including approaches such as working from top of spoil pile as shown in Figure 3.3.

Traffic Control During Pipeline Construction

When activities such as pipeline construction or maintenance/testing are performed on or adjacent to a public highway, the contractor performing the work must make suitable provisions to safely accommodate the traveling public through the work zone by means of a traffic accommodation strategy. This consists of plans and written procedures which address the traffic accommodation issues relevant to the specific activity being performed by the contractor and sub-contractors. To be effective, the traffic accommodation strategy must provide road users with adequate warning of the activity being performed, protection for workers and equipment within the work area and must allow traffic to pass safely through the work zone. A typical temporary traffic control setup is shown in Figure 3.4 [65]. Highway Departments in Canada have developed guidelines for traffic accommodation in work zones. It is noted that in general these guidelines are for construction and planned maintenance activities. For non-planned maintenance activities or emergency situations, it may not be practical to develop a site-specific traffic accommodation strategy. In these cases a generic strategy which covers the activities may be used. In general, the actual requirements for traffic accommodation at the work zone may vary depending on the complexity of the activity, traffic volumes, traffic speeds, visibility and weather conditions and other specific conditions.

While the primary purpose of temporary traffic control is safety, it is important to minimize delay to the travelling public. There are a number of accepted procedures for estimating highway user costs, air pollution, and noise effects as well as vehicle operating costs for stopping/speed changes as well as associated delay times for stopping/speed changes [46, 58]. In 1994, Transport Canada [66] and the provinces reviewed the investment decision-making process, in light of new needs and the availability of new methods and microcomputer tools. The result was a decision that MicroBENCOST [42] software provided an acceptable common platform for benefit-cost analysis. MicroBENCOST developed by the Texas Transportation Institute [63] has gained acceptance across Canada and the United States. One of the most comprehensive studies of the cost of user delays in work zones may be found in a recent report published by the Federal Highway Administration [38]. This report presents a rational step-by-step procedure to allow the analyst, based on capacity flow analysis to determine user costs associated with establishing a work zone. In Canada, a model has been developed to estimate vehicular delays and the economic cost of road closures [43]. For a traffic volume of 350 vehicles/hour on the Trans-Canada Highway, the economic cost of delay due to a single 2-hour road closure ranges between $50,000 and $90,000 depending on the proportion of heavy vehicles in the traffic stream during the closure period [44].

Figure 3.4
Typical TTC Plan for Two-Lane Roadside Work
(Source: [65])



V(km/h)	A(m)	L(m)	B(m)	D(m)
50	50	30	35	8
60	50	40	45	12
70	75	60	50	15
80	100	80	60	15
90	100	105	65	18
100	125	125	70	18
110	125	145	75	20

Where
V = Speed Limit
A = Spacing between signs
L = Length of Taper
B = Length of Longitudinal Buffer Space
D = Spacing between Delineation Devices

V(km/h)	A(m)	L(m)	B(m)	D(m)
50	50	30	35	8
60	50	40	45	12
70	75	60	50	15
80	100	80	60	15
90	100	105	65	18
100	125	125	70	18
110	125	145	75	20

Where
V = Speed Limit
A = Spacing between signs
L = Length of Taper
B = Length of Longitudinal Buffer Space
D = Spacing between Delineation Devices

3.4 Long-Term Impacts

3.4.1 Impact on Road Structure Integrity

Settlement is defined as the downward movement of a foundation unit or soil layer due to rapid or slow compression of the soils located below the foundation unit or soil layer, when the compression is caused by an increase of effective stress. The impact of pipeline construction adjacent to a highway in terms of affecting the integrity of the roadway structure depends on a number of factors. These include the distance of the pipeline from the highway, soil type, and construction method. A pipeline located, for example, at the edge of the road right-of-way (Location 3) would have minimal, if any, impact on the integrity of the parallel roadway structure. There could be impacts on the backslope, however, but this should not affect the integrity of the roadway structure. A pipeline trench in the sideslope or shoulder (Location 1) could affect the integrity of the roadway structure in terms of settlement resulting in settlement of the shoulder or longitudinal cracking. In addition (especially for Location 2), settlement would affect drainage and weaken the roadway structure. Poor drainage could also affect the safety of errant vehicles. Soft shoulders or poorly draining ditches can cause an errant vehicle to trip and roll over even on recoverable (5:1 or 6:1) sideslopes. The amount of settlement depends on the soil type and amount of compaction. For example, compacted sand will shrink about 5% while ordinary earth and clay will shrink about 10%. The amount of acceptable settlement is approximately 1 metric inch (20 mm – 30 mm). In general, then, for pipelines adjacent to roadway structures both total settlement and differential settlement must be evaluated utilizing geotechnical methods on a site specific basis considering road structure priorities, pipeline trench geometry and location, and pipeline trench backfill specifications, estimates for road rehabilitation cost increases range from $20,000 to $50,000 for base per-kilometre cost of $150,000/km.

3.4.2 Impact on Usability of Right-of-Way

Although the pipeline physically takes up a relatively small amount of space within the road right-of-way, whether it be in Location 1, 2, or 3, the nature and hazardous characteristics of a high-pressure natural gas pipeline in fact considerably magnify the area of the right-of-way which it effectively influences [13, 14, 15]. This influence is essentially a reduction in the usability of the right-of-way in the vicinity of the pipeline, and may be translated into a decrease in the value of the right-of-way [15]. Figure 3.5 is a diagram of procedures needed to install a new pipeline adjacent (within 0.4 m) to an existing one [15]. Bercha has made extensive studies [14, 15] of the effects on right-of-ways of high-pressure hydrocarbon pipelines in support of various investigations involving disputes over the values of pipeline easements on transportation right-of-ways. From these studies, it was generally concluded that the usability of the right-of-way decreases with proximity to the high-pressure hydrocarbon pipeline. In fact, as a rule of thumb, it was found that a section roughly equal to the depth of trench (approximately 4 feet on either side of the pipeline centre line) is practically useless for the installation of other parallel utilities such as other pipelines or fibre optic cables. Thus, although an NPS 8 pipeline only occupies a plan strip of 8 inches in the right-of-

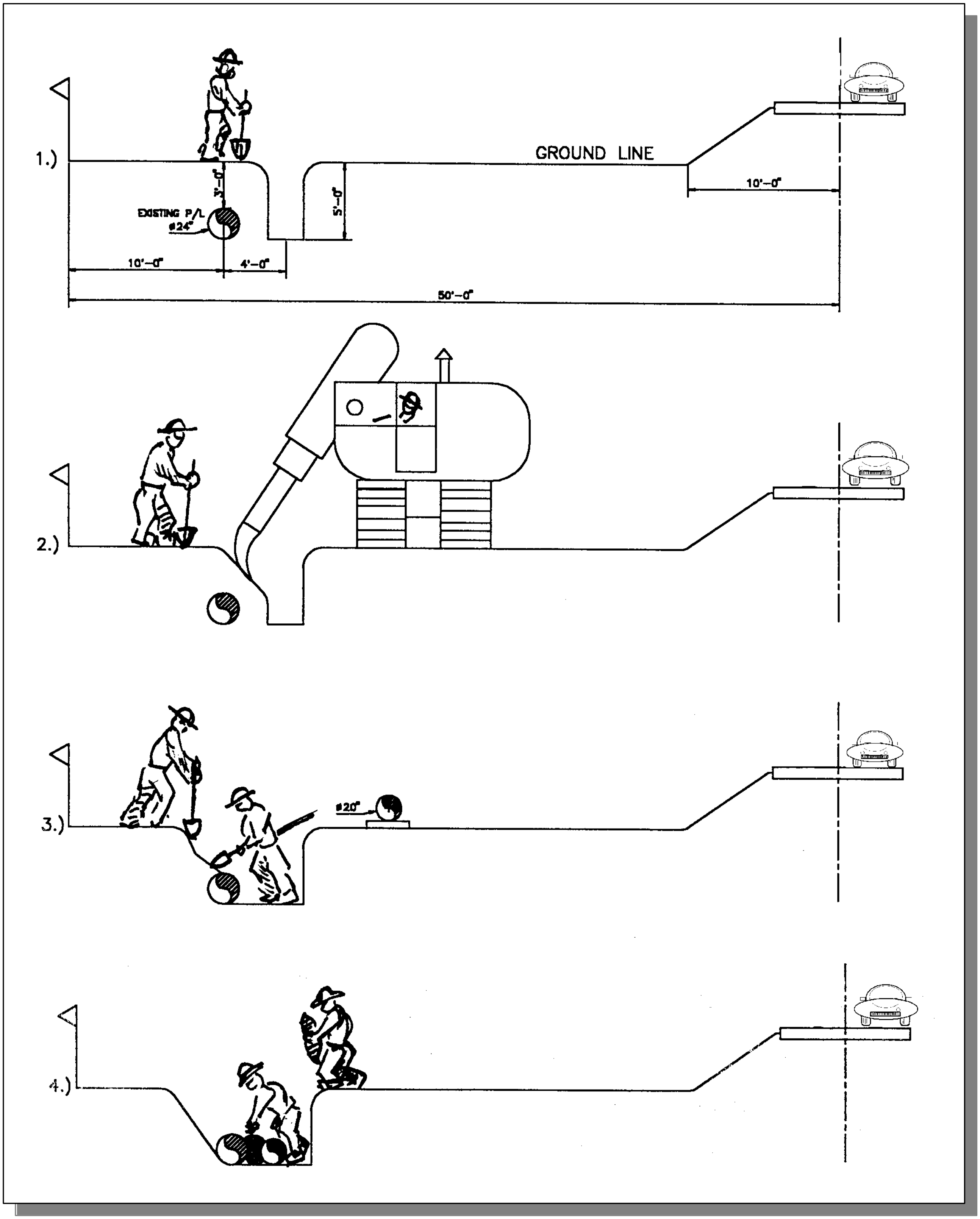


Figure 3.5
Close Proximity Construction Scenario

way, it effectively sterilizes the use of an 8-foot (2.5 m) strip of the right-of-way by virtue of its presence.

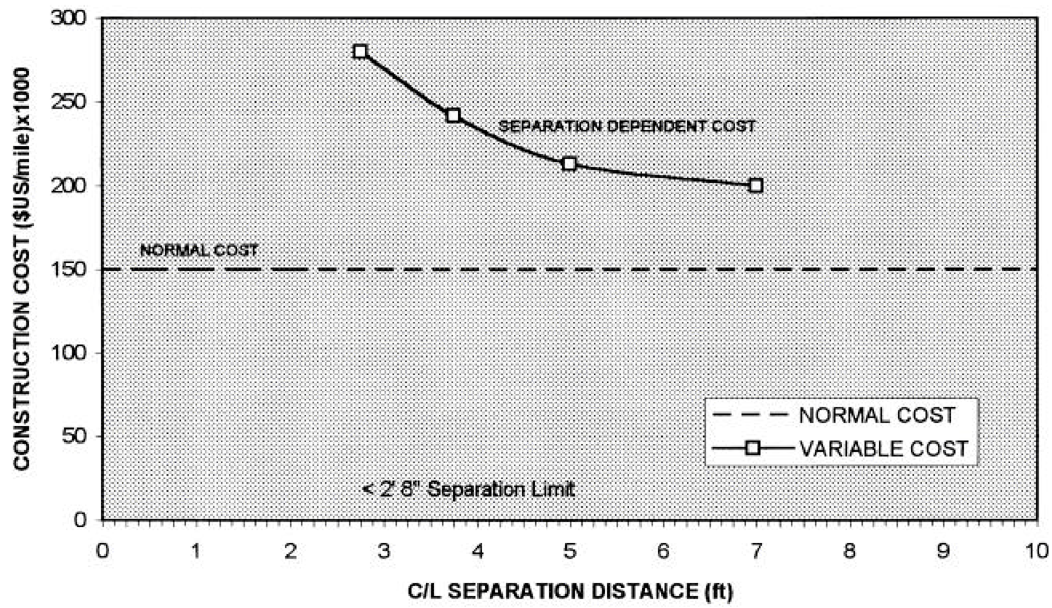
The estimated variation in costs with proximity distance from an existing high-pressure hydrocarbon pipeline for the construction of other pipelines and fibre optic cables is illustrated in Figures 3.6 and 3.7, respectively [15]. As can be seen from Figure 3.6, the costs of construction of parallel pipelines in proximity of existing pipelines increase dramatically as the pipeline separation decreases, more than doubling for separations less than 1 m (3 feet). For the case of fibre optic cable, which is normally installed through a ploughing method, shown in Figure 3.8, the increase in cost with close proximity is even more dramatic, tripling as the separation approaches 1 m (3 feet). Construction any closer than the rule of thumb distance of 1 m (3 feet) would require drastic measures such as placing the existing pipeline out of service, or taking major safety precautions such as evacuation of all residents within the potential zone of influence and hand or Hydrovac excavation and installation in the vicinity of the existing pipeline. In general, then, the usability of a significant strip on the right-of-way, approximately equal to twice the pipeline trench depth is significantly impaired through the presence of a high-pressure hydrocarbon pipeline.

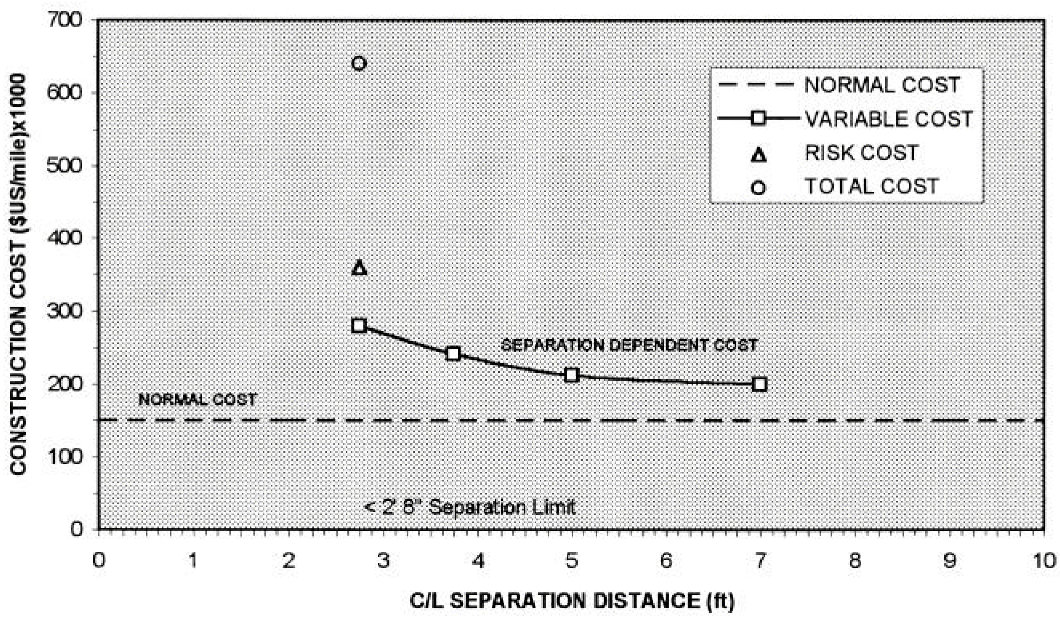
3.4.3 Health Impacts

Natural gas is composed primarily of methane. Methane is an invisible, odourless gas with a molecular weight of 16, which is just over one-half (0.55) the weight of air (molecular weight 29). Table 3.6 shows the typical constituent composition of sales natural gas – natural gas which has been prepared and processed so that it meets the specifications of natural gas residential and industrial users. None of its components are toxic. This is the type of natural gas that is the subject of the present study. In addition to the constituents listed there, the natural gas will contain less than 1/100th of 1% of an odourizing agent such as Mercaptan, which is added in order for people to be able to detect gas leaks (by smell) in commercial or residential situations.

No adverse health effects have been observed from many thousands of person years of exposure to low concentrations of natural gas in the air we breathe [13]. Thus, long-term adverse health effects are not a risk that needs to be considered. Naturally, because of its high flammability, or ability to ignite and burn vigorously, natural gas poses an acute risk which is the subject of Chapter 4.

It should be noted that certain types of raw gas, the gas as it comes from the reservoir, are highly toxic primarily because they contain hydrogen sulphide (H_2S). Even very low percentages of hydrogen sulphide, such as 1%, can be acutely toxic producing immediate discomfort, irritation, nausea, and in greater dosages, unconsciousness and death. No hydrogen sulphide is permitted in sales natural gas, which is carried by the pipelines studied here.





P/L TYPE: 20 IN. D
CONSTRUCTION: NORMAL ON S/P ROW
LOCATION: CALIFORNIA ZONE 3

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Figure 3.6
Pipeline Separation Construction Cost Variation – Rural

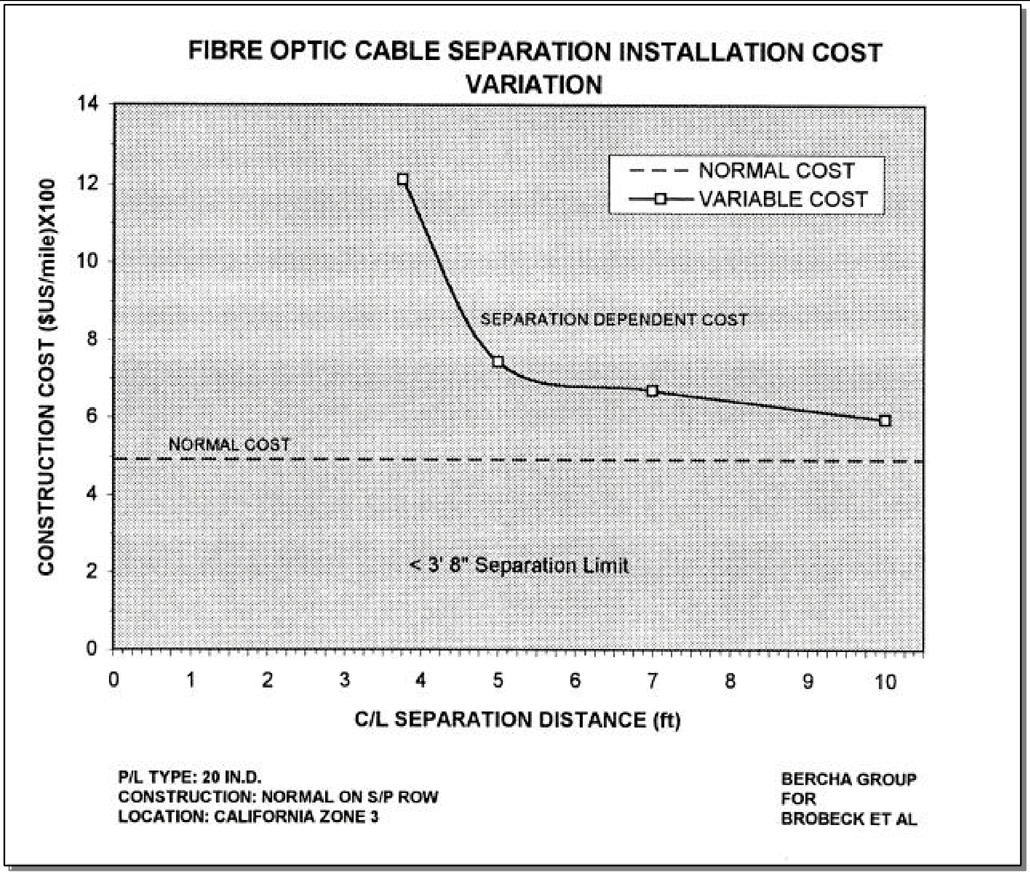


Figure 3.7
Fibre Optic Cable Separation Installation Cost Variation

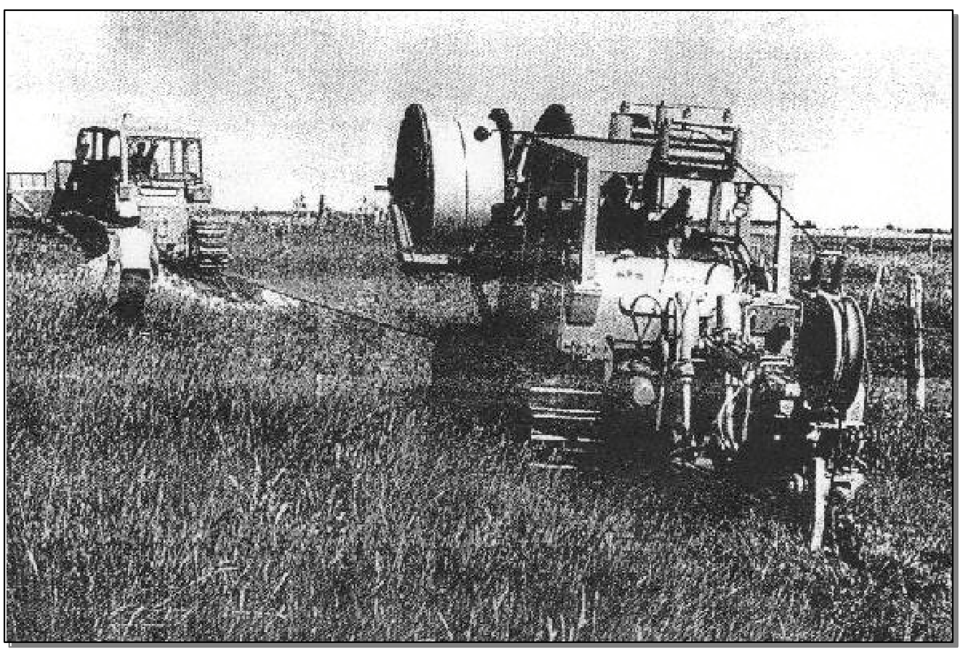


Figure 3.8
Typical Plough Method Installation for Fibre Optic Cable

Table 3.6
Typical Natural Gas Compositions

Substance Formula	%	Molecular Weight [gm/mol]
Methane CH_4	95.70	16.0
Ethane C_2H_6	1.75	30.1
Propane C_3H_8	0.04	44.1
Carbon Dioxide CO_2	0.87	44.0
Nitrogen N_2	1.64	28.0
Total	**100.00**	**16.7**

3.5 Economic and Operational Impact Ranking

Initially interviews with road maintenance contractors revealed that although the pipeline locations may impact on the level of effort needed for certain activities, some contractors said it is unlikely that they would make added cost provisions to cover such increases, in view of the competitive climate for road maintenance and construction contracts. Others maintained there would be real cost impacts. Road and pipeline construction contractors, however, maintained that costs would be inflated due primarily to the added safety measures needed to operate and construct in the vicinity of high-pressure natural gas pipelines. In the medium and long term, whether or not cost increases due to pipeline locations in the right-of-way are explicitly included in costs, cost increases will infiltrate private contractor and public budgets from effects of pipelines in road right-of-ways.

In any case, it is not always possible to quantify costs of activities. For activities where an increase in manpower, equipment, or operating time is effected, cost increments can be generated. However, for other activities such as road closure, it is difficult without specific inputs [43] to estimate the economic impact, and accordingly an attempt to estimate economic impacts of such effects is not made herein.

As shown in Table 3.1, the activities identified have been ranked according to severity. High and medium impact activities have been further investigated, and their impacts, where possible have been translated into cost increments.

3.5.1 Approaches to Quantification of Economic and Operational Impacts

As indicated in the introductory section to this chapter, a multi-phase approach to the ultimate quantification of significant economic and operational impacts has been used. First, all of the relevant road and pipeline activities and effects have been tabulated and classified, as given in Table 3.1, next, the activities have been reviewed with road and pipeline experts generally as described in Sections 3.2, 3.3, and 3.4, next the likelihood of impacts (and risks) was ascertained according to a broad ranking system of three ranks, low, medium, and high, and the associated road and pipeline location types were identified. Those activities or effects which had a medium or high ranking were chosen for further analysis and impact quantification.

Quantification of the cost increments of activities with and without consideration of an adjacent pipeline can only be done for some activities. When an increase in manpower, materials, equipment, or operating time is effected, cost increments can be generated. For other activities such as road closure, it is not possible to estimate cost impacts in a general way, and accordingly, no attempt to estimate economic impacts of such effects was made herein. The qualitative nature of impacts can be subdivided into ones that are essentially inconsequential, ones where the activity could be affected depending on the pipeline location, and others where the activity could affect the pipeline, and therefore create risks. As an example of these three categories, Table 3.7 summarizes relevant maintenance activities in each category. Some activities appear in more than one category as they change with site-specific details.

Based on qualitative reasoning similar to that exemplified in Table 3.7, all of the activities listed in Table 3.1 and discussed above in detail have been ranked for both operational and economic impact and risk. Those ranking medium or high were selected for further analysis of operational and economic impacts as described below, and for further risk assessment as described in Chapter 4.

3.5.2 Methodology Used to Quantify Economic Impacts

A direct estimating procedure for specified scenarios was utilized to quantify economic impacts. First, a base price, or a price for the activity or installation without the pipeline in any of the three right-of-way locations was carried out. This was based either on direct estimating through inquiry and experience or through utilization of a facility construction and cost data Means Manual [45]. Next, the procedure that would have to be followed, including manpower, excavation, and material quantities with the pipeline in each of the three locations was defined and costed, for those locations which would have an influence on the activity. The difference between the base cost and the cost considering the pipeline in each location is the incremental cost brought on by the pipeline.

Table 3.7
Pipeline Impacts on Highway Maintenance Activities

A. Inconsequential Impacts

Most of the following highway maintenance activities are affected only by potential conflicts resulting from two different contractors trying to carry out work at the same location. Generally the highway maintenance contractor would avoid the area where the pipeline contractor is working.

- Litter pickup
- Cleaning signs and guide posts
- Straightening signs posts and guide posts
- Erosion Control/Repairs
- Brushing
- Chemical Vegetation Control
- Culvert Maintenance
- Installation of Snow Fencing
- Installation of Livestock Guards
- Mowing
- Hand Trimming
- Drainage Maintenance/Improvements
- Removal and/or Installation of Culverts
- Installation of Minor Signs (single post)
- Installation of Major Signs (cluster frames, concrete bases, breakaway posts)
- Installation of Guide Posts
- Installation of Guardrail
- Installation/Repair of Fencing

B. Activities Impacted by Pipeline

The following highway maintenance activities could be affected by a pipeline, after it has been installed in the highway R/W (depending on whether the pipeline has been installed under the road shoulder, under the ditch, or along the edge of the R/W boundary):

- Installation of Livestock Guards
- Mowing
- Hand Trimming
- Drainage Maintenance/Improvements
- Removal and/or Installation of Culverts
- Installation of Minor Signs (single post)
- Installation of Major Signs (cluster frames, concrete bases, breakaway posts)
- Installation of Guide Posts
- Installation of Guardrail
- Installation/Repair of Fencing

C. Activities Impacting the Pipeline

The following highway maintenance items could affect the pipeline in some way, after it has been installed in the highway R/W (depending on whether the pipeline has been installed under the road shoulder, under the ditch, or along the edge of the R/W boundary). The pipeline could be affected by potential damage due to contact with the maintenance contractors mechanical equipment, or loss of cover.

- Installation of Livestock Guards
- Mowing
- Drainage Maintenance/Improvements
- Removal and/or Installation of Culverts
- Installation of Minor Signs (single post)
- Installation of Major Signs (cluster frames, concrete bases, breakaway posts)
- Installation of Guide Posts
- Installation of Guardrail
- Installation/Repair of Fencing
- Snow Plowing

The initial estimate was done based on Alberta manpower, material, and contract rates. These are the prices and price increments that are given in the summary table of impacts, described in the next section. Then, for other geographical areas, such as those associated with the two case studies, a geographical location factor was applied to the estimate in order to reflect the geographical variations in the estimate component unit costs. Table 3.8 summarizes these location factors based on the Means Manual [45].

Table 3.8
Canadian Regional Location Factors

LOCATION	FACTOR (%)
Alberta	100.0
British Columbia	109.6
Manitoba	100.2
New Brunswick	95.8
Newfoundland	97.4
Northwest Territories	94.2
Nova Scotia	98.7
Ontario	111.9
Prince Edward Island	93.8
Quebec	106.6
Saskatchewan	95.2
Yukon Territory	94.4

3.5.3 Summary of Economic and Operational Impacts

Table 3.9 gives the resultant summary of the economic and operational impacts (in Alberta costs) for the activities that have been screened for economic and operational impact analysis. As can be seen, this table repeats the applicable activity, the road types to which impacts are applicable, associated pipeline locations, impact severity, a brief description of the type and quantity of the impact, the units, and base, extra, and total cost estimates for those items which can be economically quantified.

Pipeline relocation costs are not given. In general, when a pipeline is relocated, the old pipeline is purged with nitrogen, sealed, and left in place. Costs of the relocation, then, are primarily those of building a new pipeline including new pipe, and can typically range as follows per kilometre:

- NPS 6 - $60,000 to $100,000
- NPS 8 - $75,000 to $120,000
- NPS 12 - $100,000 to $180,000

Table 3.9
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading - Continuous - with Backhoe	ALL	2	M-H	Use hydrovac or hand excavation - per CPEP	m3	6.00	114.00	120.00	1900
B.5.12 M	Ditch Grading - Continuous - with Grader	ALL	2	M	Use caution over p/l	1m^3	7.00	0.50	7.50	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock Scaling	ALL	ALL	H	Additional nets, p/l protection	day	1200.00	800.00	2000.00	67
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R, 4R Projects)***									
C.1.2	Major Section Repair, Excavation of Embankment	ALL	1&2	M	CPEP and Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add Climbing/Passing Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.12	Blasting for Wider Road Surface	ALL	ALL	M	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading; 3m3 CPEP	ea	2869.00	870.00	3739.00	30
			2	H	CPEP and 2m3 Hydrovac	ea	2869.00	231.00	3100.00	8
		GH	1	H	CPEP Drop invert .5m, 30m3 extra grading; 3m3 hand excav	ea	1189.00	935.00	2124.00	79
			2	H	CPEP and 2m3 Hydrovac	ea	1189.00	319.00	1508.00	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2342.00	440.00	2782.00	19
			2		25m culvert; locate p/l	ea	2342.00	219.00	2561.00	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench; daylight p/l CPEP		1959.00	2200.00	4159.00	112
C.2.4	New Utility II	ALL	1&2	H	Assume 32-inch separation new NPS 12 p/l per Fig. 3.6	m	140.00	121.00	261.00	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km, total 100, scan p/l and hydrovac 100 holes	100	23045.00	5115.00	28160.00	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	66550.00	8250.00	74800.00	12
C.2.7	New Overhead Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	80000.00	5000.00	85000.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	250000.00	10000.00	260000.00	4
C.2.9	New Power Poles	ALL	3	M	3km, 100 std. wood posts at 30m; locate p/l and hydrovac holes	100	39050.00	14850.00	53900.00	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					
C.2.11	New Guard Rail	ALL	1	M	1 km,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	74681.00	13770.00	88451.00	18
C.2.12	New Driveway - Gravel	ALL	ALL	M	Locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1155.00	560.00	1715.00	48
C.2.13	New Road Bridge	ALL	ALL	M	Design to suit; locate p/l hydrovac 5m3	ea	250000.00	2000.00	252000.00	1

Table 3.9
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
C.2.14	Borrow Pit Access Driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1155.00	760.00	1915.00	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline Failure	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
D.3	Suspected Pipeline Damage	ALL	ALL	H	Road closure - 2-8 hr and lane closure TTC 8-24 hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline Repair (Major)	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (new parallel pipeline) -10 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 2-4 wks					H
F.2	Tap with Lateral Directed away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.3	Tap with Lateral Directed under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.6	Section Replacement -1 km	ALL	ALL	M	Road closure - 4-12 hr and lane closure TTC 1-2 wk					H
F.7	Lateral away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.8	Lateral under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic Protection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					H
F.10	Instrument Installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for New Trench	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.13	New Pipeline Construction - 25km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 1-2 months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1 - Settlement; Yr 2-3 - Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

***Note re CPEP:* If excavation more than 0.3 m deep planned:**

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

Clearly, given the choice, the pipeline operator will prefer to leave the pipeline in place. Construction of roads over existing pipelines is occasionally done using the following general procedures:

- Direct supervision by pipeline owner representative.
- Limited excavation and backfill, with excavation limited to depth of 0.3 metres, assuming 1.2 metre original pipeline cover.
- Static compaction only within 3 metres either side of pipeline.

To complete the possibilities, it should be mentioned that pipelines are also occasionally constructed (parallel to the road centreline) under the existing road pavement. The following general procedure is followed:

- Pavement is cut with a dual saw, and the trench is excavated.
- The assembled pipeline is lowered into the trench bottom bed.
- The trench is filled with Fillcrete, a bulk concrete with low strength properties.
- The location is paved over.

Fillcrete is a low strength bulk concrete manufactured by LaFarge. Its principal component, in addition to cement, is flyash. Fillcrete prevents trench backfill settlement and therefore could also be used as a measure to reduce settlement and increase road structure integrity, for some of the pipeline locations outside of the pavement considered in this study.

Because of its unitized nature, the applicability of Table 3.9 is not restricted by any particular scenario; rather, it can be applied to any specific scenario if the annual or life cycle quantities for activities are known. The Regional Location Factors can be used for estimates for any region in Canada, and additional factors for U.S. regions can be obtained from the Means Manual [45]. Naturally, impact quantities may need to be varied with differences in terrain, and site-specific requirements; these, however, should be easily definable by a road engineering or construction technician based on the guidelines set out in Table 3.9 and the location factors from Table 3.8.

Finally, it should be noted that the operational and economic impacts of high-pressure natural gas pipelines must be planned for and safety measures implemented to ensure safety of the public and workers on the road system. They are not just measures of convenience, rather, they are generally essential risk mitigation provisions which must be incorporated not just physically in the activities, but also psychologically, in the total attitude and culture to assure public and personnel safety within the road system occupied by high-pressure pipelines.

CHAPTER 4 – Public Risk Assessment

4.1 Introduction on Public Risk Assessment

The general purpose of public risk assessment is to gain an understanding of and assess the magnitude of risks to individual members and groups of the public from a specific project. In this case, the risk source is the pipeline in each of the designated locations in the roadway system. Members of the public include users of the roadway system, workers, and nearby residents. In this chapter, following an introductory section giving background on risk analysis, measures of risk, and various risk acceptability guidelines, successive sections deal with each of the principal steps of the risk analysis process, culminating in the generation of a unified assessment of individual specific, collective, and relative risks.

A detailed description of risk analysis is given for the general case, where it is assumed that risks are mitigated using industry standard, regulated, and special safety practices for operations in the vicinity of high-pressure natural gas pipelines. For the case studies, results of both unmitigated and mitigated risks are given.

In the technical sections of this chapter on risk, only selected calculations and tabular data and results are given in order for readers and users to appreciate the nature, magnitude, and distribution of risks, with details of all the calculations left to Appendix C.

4.2 Risk Analysis Background

4.2.1 Objectives of Risk Assessment

The objectives of risk assessment may be summarized as follows:

- To provide an understanding of the nature and the extent of the risk and the factors that predominate the risk.
- To establish the level of risk posed by the subject.
- To compare the risks generated from the subject to other risks with which the reader is familiar.
- To identify ways of reducing the risk, particularly where the risks are high.

4.2.2 Risk Analysis Definitions and Methodology

What is risk? **Risk** is a compound measure of the probability and magnitude of adverse effect [39]. That is, risk is a description of the chances of something bad happening and how bad it will be. It is important to keep in mind that there are always these two elements of risk; namely, the probability or likelihood and the size or magnitude of the associated damage or loss. A typical risk is the probability of 1 in 1 million per year of a specific individual fatality.

Risk Analysis is an orderly process through which one can assess risk as well as methods of reducing the risk. When the risk analysis quantifies risks it is called Quantitative Risk Analysis (QRA). Methods of risk reduction are termed **Risk Mitigation**. The risk analysis process consists of three principal steps and various sub-steps illustrated in Figure 4.1. The three principal steps are **Hazard Analysis**, **Consequence Analysis**, and **Risk Assessment**.

In hazard analysis, essentially one determines the characteristics of the situation (**System Data**) which can pose a danger to the public, and how often it is likely to occur. This is called **Hazard Scenario Development** and **Frequency Analysis**. For example, for the case of a natural gas pipeline, in hazard analysis one would assess the ways in which the pipeline can fail, in this case considering the effects of the roadway, how much hazardous material could be released, and how often this is likely to happen.

In **Consequence Analysis**, one then models the evolution of consequences. First one finds the relative likelihood of different outcomes of the release, using event trees. This is called **Consequence Evolution**. That is, for the natural gas release what is the relative likelihood of ignition and non-ignition, and if there is ignition how likely is a jet fire, flash fire, or explosion? And if these happen, what are the **Damage Criteria**, or **Effect Footprints**. Next, one maps the zones in which damage to people or facilities could occur if they were present.

In the **Risk Assessment**, the results of the hazard analysis and the consequence analysis are melded, by considering the type of facilities and presence of personnel expected (**Receptors**) in areas where they could be damaged and at the times when such damaging events could occur. The results are then integrated into **Risk Assessment** to provide measures of risk. Measures of risk to people are primarily **Individual Risk** and **Collective Risk**. Measures of risk to facilities are generally expressed as **Facility Risk**. Both individual and facility risks are generally given as annual or per annum risks.

Finally, the proactive portion of the risk analysis is performed through the definition of ways of reducing the risks and assessing just how much risk reduction can be achieved if these different **Risk Mitigation** measures are applied. Following the definition of risk mitigation measures, and their effect on the unmitigated risk, the resultant or mitigated risk results for both individual and collective risk can be presented.

The risk analysis process described above typifies the steps in assessing acute risk; assessment of chronic or long-term cumulative risks follows a similar pattern but employs somewhat different terminology within a toxicological framework. Assessment of chronic risks is not within the scope of this QRA.

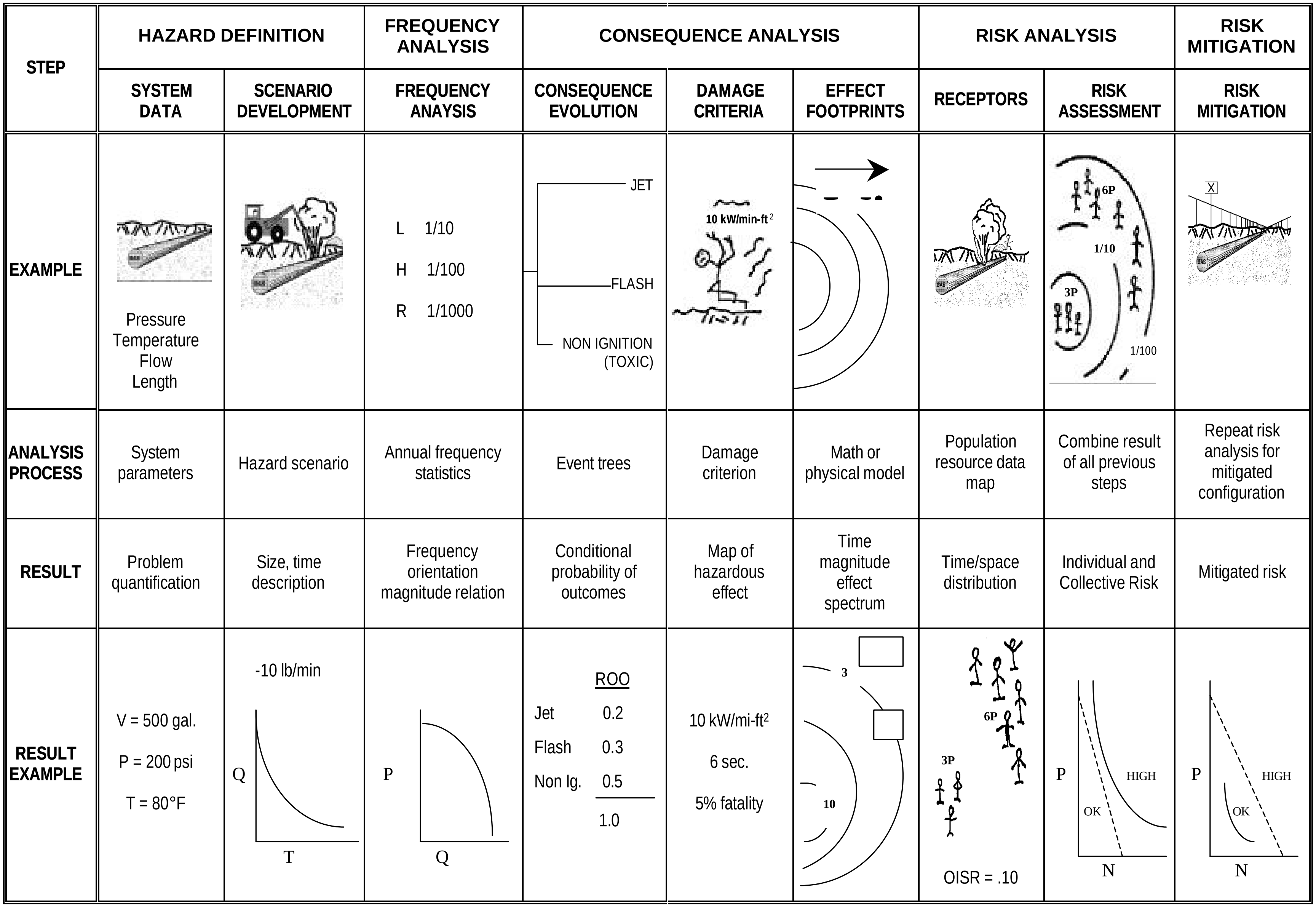


Figure 4.1
The Risk Analysis Process

4.2.3 Scope of Work of Typical Risk Analysis

A typical risk analysis consists of the following six tasks, interacting as shown in Figure 4.2:

Task 1	Data Assimilation and Analysis
Task 2	Hazard Scenario Definition
Task 3	Frequency Analysis
Task 4	Consequence Analysis
Task 5	Risk Assessment and Acceptability
Task 6	Risk Mitigation

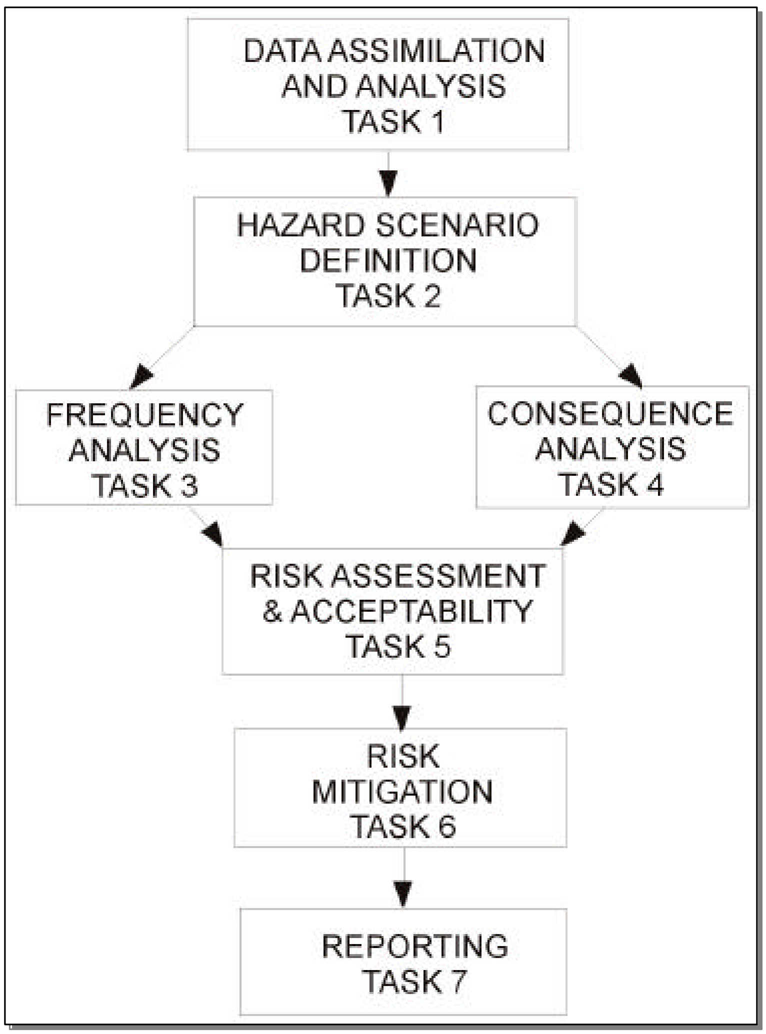


Figure 4.2
Risk Analysis Work Flow Diagram

4.2.4 Approaches to Risk Assessment

Results of Tasks 1, 2, 3, and 4 are integrated with an estimate of the likely population distribution to provide measures of public risk for the project. Measures of risk to be utilized are Individual Specific Risks (ISR) and Collective Risks (CR). Individual Specific Risks are the actual risks to a specific individual resulting from the project's operation over a one-year period. ISR takes into account both the amount of time the individual spends within the zone of influence of the project and the proportion that the individual is outdoors. Individual Specific Risks are expressed as risk transects or profiles giving the variation in ISR magnitude with distance from the pipeline. CR or societal risks are a measure of the variation in probability with different numbers of casualties. They are generally expressed as graphs giving the likelihood of different casualty levels, or risk spectra. Technically, a risk spectrum is a plot of the number of casualties and the probability of the occurrence of at least that number of casualties (probability of exceedance).

4.2.5 Individual and Societal Risk

4.2.5.1 Individual Risk

Individual Risk Field (IRF), also called Individual Risk Intensity (IRI), for a given location is defined as the probability that a normal adult individual will become a casualty if that individual remains outdoors continuously (24 hours a day, 365 days per year) at that location for one year. IRF, thus defined forms an upper bound to other measures of individual risk such as Individual Specific Risk (ISR) or Average Individual Risk (AIR). Any other measure of individual risk is likely to be lower due to the introduction of mitigating factors such as reduction in time spent at the location, sheltering through indoor time, use of protective gear, or evasive action. The upper bound Individual Risk Field quantified herein, has the advantage that it is a clearly defined quantity which can be used as a basis for computation of any other measure of specific individual risk without major factoring or manipulation**. Individual Specific Risk (ISR) for a given location is defined as the probability that a normal adult individual will become a casualty considering the actual proportion of time spent at the location and that proportion spent indoors and outdoors at this location.**

Computation of individual risk can be conducted for two different types of sources; namely, point sources and linear sources. In this study linear sources, such as pipelines, are the primary focus, but the theory for point sources is also introduced because it is used for pipeline collective risk evaluation.

For point sources, the Individual Risk Field (IRF) is computed as follows:

$$IRF_p = P_R \cdot P_S \cdot P_F \cdot P_D \qquad \textbf{(4.1)}$$

where

IRF_p = IRF for point source

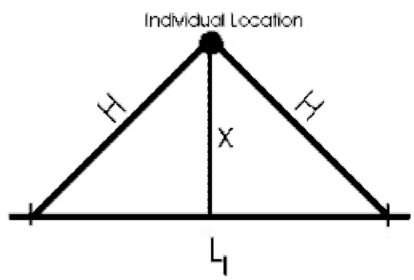
P_R = probability of release
P_S = conditional probability of scenario occurrence (ROO from event trees)
P_F = probability of fatality
P_D = probability of hazard occurring in direction D

For linear sources, pipelines, on the other hand, the Individual Risk Field (IRF) is computed by:

$$IRF_L = P_R \cdot P_S \cdot P_F \cdot P_D \cdot L_I \quad \textbf{(4.2)}$$

where, the Interaction Length, or length of pipeline from which hazards of length H can reach the individual, is given by:

$$L_I = 2\,(H^2 - X^2)^{1/2} \quad \textbf{(4.3)}$$



where,

IRF_L = Individual Risk Field for a linear source
P_R = linear failure rate per km year
P_S = conditional probability of scenario occurrence (ROO)
P_F = probability of fatality
P_D = probability of hazard in direction D
L_I = interaction length of pipeline
H = extent of hazard footprint from location of release at pipeline
X = distance to receptor, perpendicular to pipeline centreline

For either linear or point sources, the Individual Specific Risk, ISR, the actual risk to which a specific individual is subjected, is computed as follows:

$$ISR = IRF \cdot P_L \cdot P_E \quad \textbf{(4.4a)}$$
$$= IRF \cdot ISRF \quad \textbf{(4.4b)}$$

where,

P_L = Probability of being at location
P_E = Probability of being exposed
ISRF = Individual Specific Risk Factor

The above formulas are embedded in spreadsheets to generate base data for plotting individual risk transects. The spreadsheet approach, embedding Equation 4.2, is used for the computation of individual risk from linear sources. This facilitates calculation of individual risk at various distances for each of the consequence sub-scenarios. The appropriate representation of risk for a pipeline is a risk transect, showing the variation in ISR with the distance on either side of the pipeline, as illustrated in Figure 4.3. By contrast, for a point risk source, risk contours such as those illustrated in Figure 4.4 are used to represent ISR.

4.2.5.2 Societal Risk

The societal or group risk results are represented as risk spectra. A risk spectrum is a graph of the frequency of occurrence and the number of individuals involved in the occurrence, with the frequency given on the vertical axis and the number of individuals on the horizontal axis. Specifically, the graph represents the probability that N or more (or at least N) individuals will become casualties in any given situation.

The data for the construction of the risk spectrum is obtained by combining the iso-risk contours (risk isopleths) with actual population distributions together with their appropriate dwell time and outdoor exposure factors (combined as the OISR factors defined earlier). This applies to either linear or point sources. Essentially, to construct a risk spectrum each of the hazard footprints is analyzed to assess the number of individuals exposed within each successive contour, commencing with the outermost or lowest probability contour. These data are then sorted according to groups associated with the same number of individuals, their frequencies are added to give a summary frequency for each group of equal number, and the probabilities are cumulated beginning with the lowest probability associated with the greatest number of people.

4.2.6 Risk Acceptability Guidelines

Risk is a combined measure of the probability and magnitude of adverse effect. Risk thresholds are a term generally used to designate the levels of risk, which are acceptable in certain situations. Possible measures of risk include individual risk, risk expectations, and risk spectra. Individual specific risk is simply the probability that a given individual will become a casualty as a result of the project over a period of exposure of 1 year. Collective Risk expectation can be described by the use of a risk matrix which relates various discreet levels of likelihood of occurrence and severity of consequences. A more rigorous assessment of collective risk, a risk spectrum, gives a continuous relationship between the probability of occurrence and a quantitative measure of the severity of consequences, such as the number of people affected. Although it cannot be claimed that any specific risk thresholds have gained universal acceptability, a sufficient number of individual risk, risk matrix, and risk spectrum thresholds have been adopted by various jurisdictions to make it worthwhile to use some of these, at least as indicators of risk acceptability for the present project. Naturally, comparison of project risks with risks levels associated with known activities will also be used as an indicator of the severity of the risk.

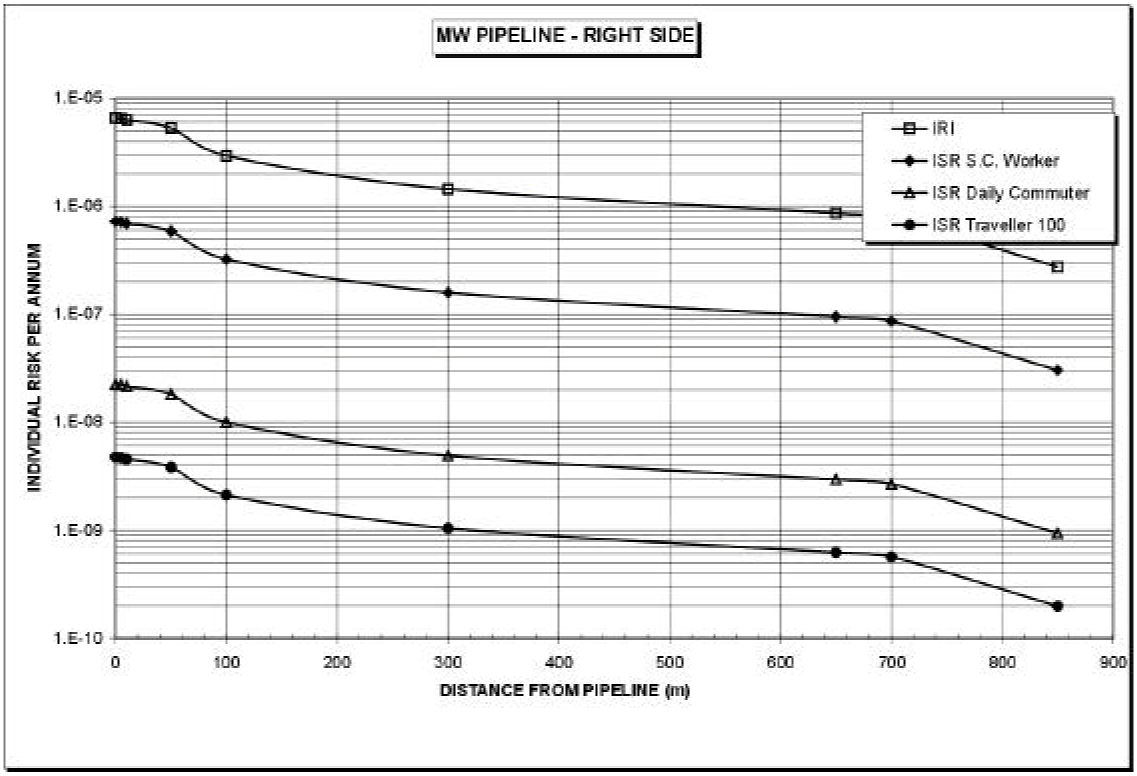


Figure 4.3
Example of Risk Transect for Linear Source

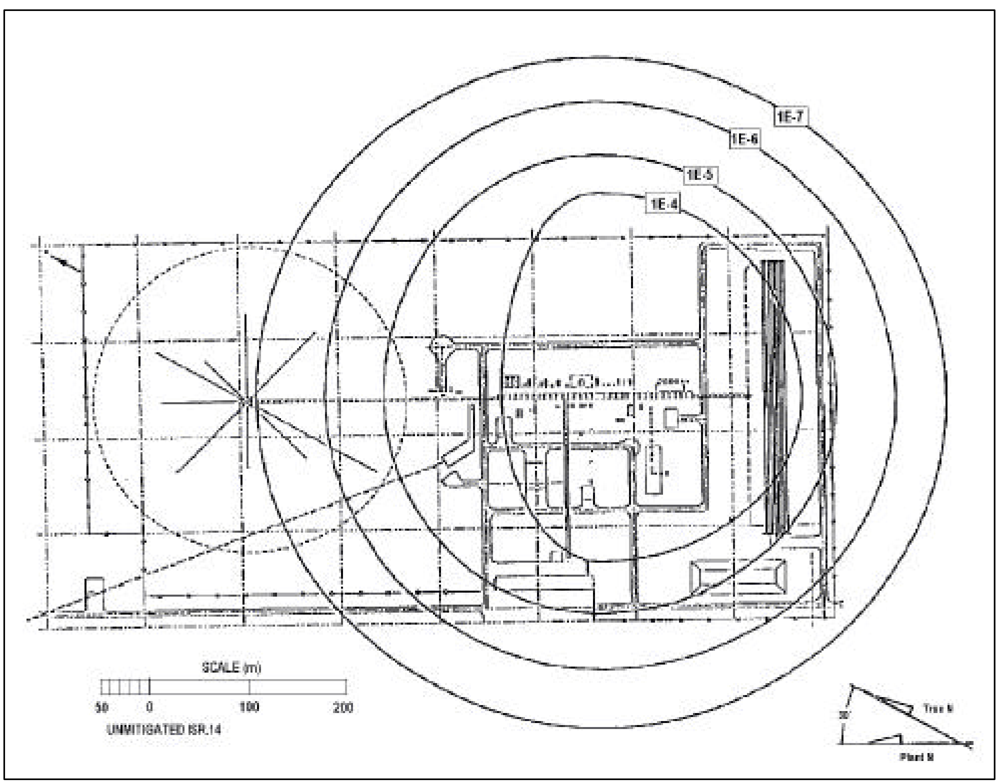


Figure 4.4
Example of Individual Risk Contours

4.2.6.1 Individual Specific Risk Thresholds

Risk acceptability criteria are often based on the premise that the risk being evaluated should not make a substantial addition to the existing risk of everyday life. An increase of 1% or less in the individual risk of death, due to a specific hazardous activity, is the basis of some [32] criteria of unacceptable or intolerable risk. Acceptable or tolerable risk criteria are a factor of 10 to 100 lower than those for unacceptable risks. In an area where risk lies between unacceptable and acceptable levels, risk reduction is desirable.

Table 4.1 shows a variety of urban Individual Specific Risks associated with common place activities. In addition, the highest levels of residential and commercial ISR for a typical 12" high-pressure natural gas pipeline are shown.

Individual risk is often expressed in terms of an annual probability of death for the exposed person or Individual Specific Risk (ISR). An annual probability (or chance) of death of 1 in 1,000,000 is often taken as a tolerable level [23, 28].

The (now defunct) Major Industrial Accident Council of Canada (MIACC) has proposed the risk acceptability criteria presented in Figure 4.5. These criteria are reflected in terms of allowable land-uses for specified levels of Individual Specific Risk. This approach implicitly provides a guideline for allowable risk in one simple, perhaps overly simple (see below), statement. An annual Individual Specific Risk of fatality of 1 in 10,000 (or 10^{-4}), from the presence of a facility is considered unacceptable for a member of the general public, and the area defined by ISR equals 10^{-4} contour is called the exclusion zone. As it is difficult to rationalize why office or low-density residential public should tolerate 10 times higher risks than high-density residential public, the MIACC criterion is somewhat impractical.

A more workable set of guidelines for individual risk thresholds are based on Individual Specific Risks (ISR) – the actual risks to which specific individuals are subjected [19, 32, 33]. Major oil and gas projects such as the Sable Offshore Energy Project (SOEP) under the jurisdiction of the Nova Scotia Petroleum Directorate [16], have adopted both ISR and CR thresholds. In both cases, there are three principal regions within which project risks are designated, depending on their level or intensity. The highest region is the intolerable region at which operations simply cannot proceed. The next region is the gray region, in the offshore industry termed the "as low as reasonably practicable" (ALARP) region, in which risks should be reduced in accordance with optimal cost beneficial activities until they are in the acceptable region. And finally, there exists the negligible risk region, in which risks are considered acceptable. The following hierarchy of Individual Specific Risk (ISR) levels is representative of that adopted by numerous Canadian oil and gas projects:

- Intolerable $ISR > 10^{-4}$ Unacceptable
- Gray $10^{-4} > ISR > 10^{-6}$ Unacceptable but mitigable
- Insignificant $ISR < 10^{-6}$ Acceptable

The above criteria will be used as a guide for assessing ISR acceptability in the present project.

Table 4.1
Comparative Urban Individual Background Risks of Fatality

CAUSE	INDIVIDUAL RISK PER MILLION PER YEAR
Motor Vehicle Accidents (Mexico)	750.0
Motor Vehicle Accidents (Canada) [67]	195.0
Home Accidents	110.0
Falls	62.0
Motor Vehicle Pedestrian Collisions	42.0
Drowning	36.0
Fires	28.0
Inhalation and Ingestion of Objects	15.0
Firearms	10.0
Accidental Poisoning: ♦ Gases and Vapours ♦ Solids and Liquids *(Not drugs or medicaments)*	 7.7 6.0
Electrocution	5.3
Tornadoes	0.6
Floods	0.6
Typical HP Natural Gas Pipeline - Residential	**0.5**
Extreme Weather	0.3
Bites and Stings by Venomous Animals and Insects	0.2
Typical HP Natural Gas Pipeline - Commercial	**0.2**

Note: *The above risks of fatality per year are based on Canadian national averages – except the first one.*

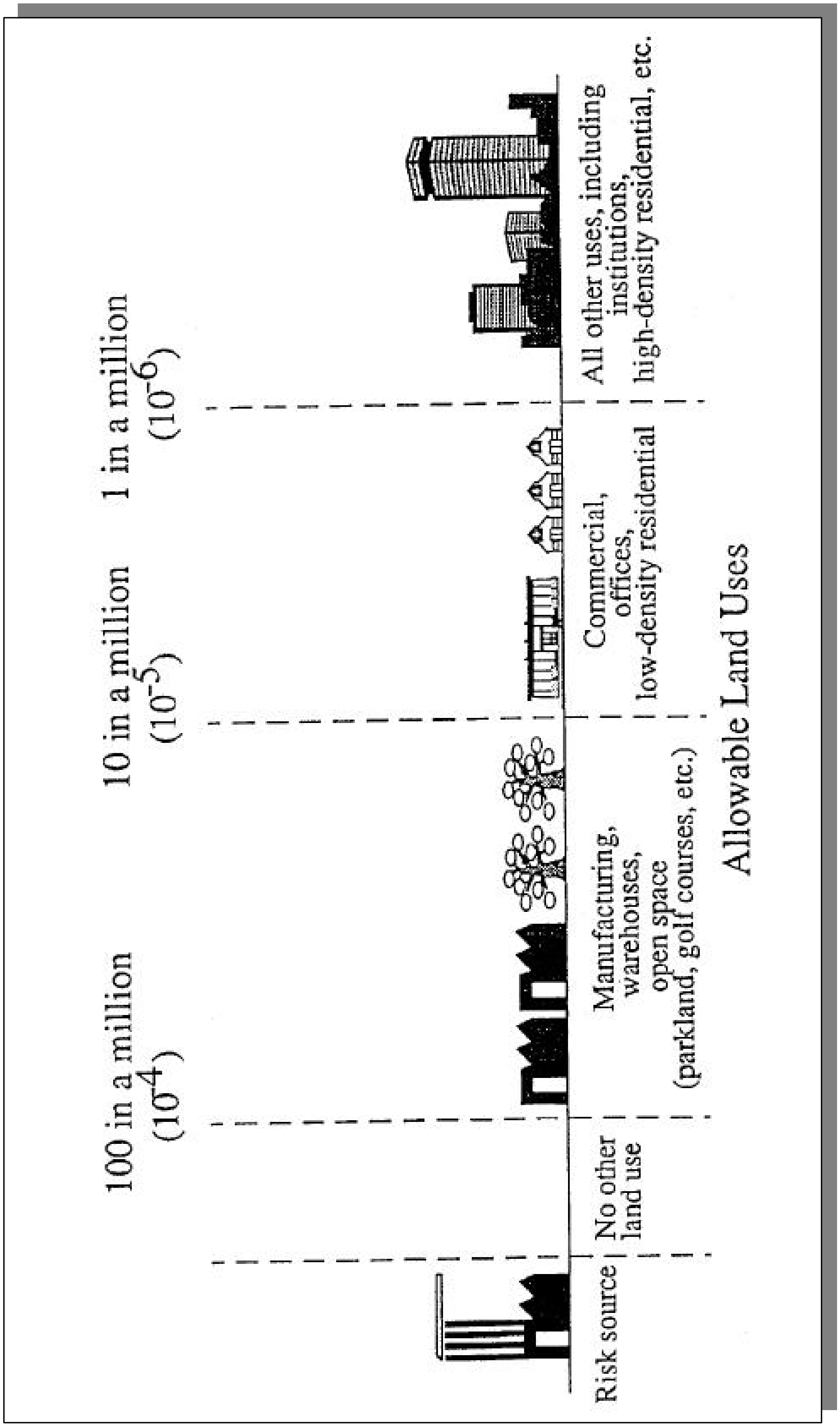


Figure 4.5
MIACC Individual Specific Risk Acceptability Criteria

The above classification of risks means that tolerable or acceptable risk levels will not vary with the benefits and costs. In between the unacceptable risk level and the acceptable risk level is the area where risks may or may not be tolerable depending on the situation. Risk in this in-between area is generally acceptable only if all reasonably practical measures have already been taken to reduce it.

The shortcoming of using solely individual risk as a simplified risk acceptability criterion is illustrated by the following application. Suppose a park is located next to a hazardous facility. During the day it is occupied by 400 people; at night by 2 people. According to the individual risk criterion, the risk is the same day and night.

4.2.6.2 Risk Matrix Criteria

Figure 4.6 illustrates a risk matrix adopted by the System Safety and Reliability Committee of the County of Santa Barbara prior to the implementation of risk spectrum thresholds [19, 28]. The risk matrix is a semi-quantitative display of the severity and likelihood of different adverse consequences. Increasingly more risky combinations of likelihood and severity of accidental events are reflected in increasing values of the integers designated in the squares of the matrix. A semi-quantitative description of each grade of likelihood and severity is given below the matrix. Thresholds may be defined according to increasing values of frequency and severity. For instance, in the above jurisdiction, matrix values of 5 to 7 are deemed to be in the gray region; values greater than 7 are in the intolerable region, and values less than 7 are deemed to be in the acceptable region. Because the risk matrix is considered to be a simplified (discretized) form of the risk spectrum used for semi-qualitative evaluations, it will not be explicitly used here.

4.2.6.3 Collective Risk Spectrum Thresholds

A risk spectrum, relating the probability to the associated expected number of fatalities, is often used as a measure of group risk. The risk spectrum is a convenient graphical display of the variation in probability with the magnitude of consequences for a given risk scenario. It is plotted on log-log paper with the vertical axis giving the probability and the horizontal axis, the associated **minimum** number of people affected; that is, the risk spectrum is a probability of exceedance graph giving the probability that *at least n people are at risk*.

Group or societal risk acceptability thresholds have been developed for public risks in the form of risk spectra based on the work by the U.K. Health and Safety Executive [32, 33] and the Dutch TNO [32]. Recently, the County of Santa Barbara has adopted these specific quantitative risk thresholds [28] based on an assessment of previous work in this area. These risk thresholds have also been adopted for projects such as the Sable Offshore Energy Project [16], and have been deemed acceptable by authorities having jurisdiction such as the Nova Scotia Offshore Petroleum Board. Figure 4.18 on page 4.40 shows the public risk of fatality thresholds on a risk spectrum as adopted in the County of Santa Barbara [19].

Likelihood					
5	5	8	9	10	12
4	4	7	8	9	10
3	3	6	7	8	9
2	2	4	6	7	8
1	1	2	3	4	5
	1	2	3	4	5
			Severity		

Likelihood	Severity
1. Extraordinary – less than one in one million years	1. Negligible – nuisance at worst, <10 bbl spill
2. Rare – 1/10,000yr – 1/1,000,000yr	2. Minor – several injuries, <200 bbl spill
3. Unlikely – 1/100yr – 1/10,000yr	3. Major -- <10 injuries, 200 – 2000 bbl spill, major eq. Damage
4. Likely 1/yr – 1/100yr	4. Severe -- <100 injuries, <10 fatalities, 2000 – 300,000 bbl spill, plant destruction
5. Frequent - >1/yr	5. Disastrous – 100+ severe injuries, 10+ fatalities, 300K+ bbl spill, plant write-off

Threshold Equivalence		
Red	=	8, 9, 10, 12
Amber	=	5, 6, 7
Green	=	1, 2, 3, 4

Figure 4.6
Risk Acceptability Matrix

The thresholds given are applicable to a maximum exposure population of 1,000 people. The registration of the risk spectrum (as shown by the ellipse) assessed for the subject project with respect to each of the above sets of risk thresholds is another indication of the level of acceptability of project risks.

4.3 Hazard Scenario Definition

4.3.1 General Approaches to Hazard Scenario Description

The first technical step in risk analysis is the definition of hazard scenarios. What can go wrong? Typical hazard scenarios include the release of a flammable natural gas due to the rupture of a pipeline, a traffic accident involving the uncontrolled impact of a tanker truck against or by another vehicle, or a spill of gasoline or crude oil at a loading terminal due to the accidental severance of a loading hose. Many of these hazard scenarios can be characterized by the initial conditions of the accident including the impact energy or amount of fluid released and the duration of the release. The characterization of hazard scenarios is a semi-quantitative step involving the qualitative description of the hazard scenario or initiating accident and a quantitative characterization of its most important parameters such as impact energy, amount of fluid released, and duration. *All of the hazard scenarios postulated for the general case include the basic assumption that all industry standard and other appropriate safety measures have been incorporated.*

4.3.2 Hazard Scenario Characteristics

At the outset of the risk assessment, it is necessary to characterize the hazard scenarios. In accordance with previous experience, representative release sizes and segment isolation times have been estimated. Release sizes are apertures corresponding to leaks (0.5 cm), holes (10-cm diameter), ruptures (full bore), and double ruptures (where two relatively long segments are both discharging in opposite directions due to a full diameter severance of the pipe). In addition, the time taken to blowdown the gas from the 25-km pipeline segment, together with the amount of time that gas continues to flow until the segment is being isolated must be estimated. Clearly, the time to isolation is going to vary dramatically with the pipeline isolation valve controls, and can range from a few seconds from automatic shutdown, to a few hours. Larger times are needed where the operator needs to travel to the valve location from a remote control centre, and manually shut the valve down. For the purposes of the present assessment, an additional 50% of gas volume is assumed to enter the segment while it is being isolated. The resultant calculation gives a release rate such as that shown in Figure 4.7, for the high pressure NPS 12 pipeline. The steady state flow rate for such a pipeline is between 10 and 20 kg/sec, fairly close to the curve's asymptote.

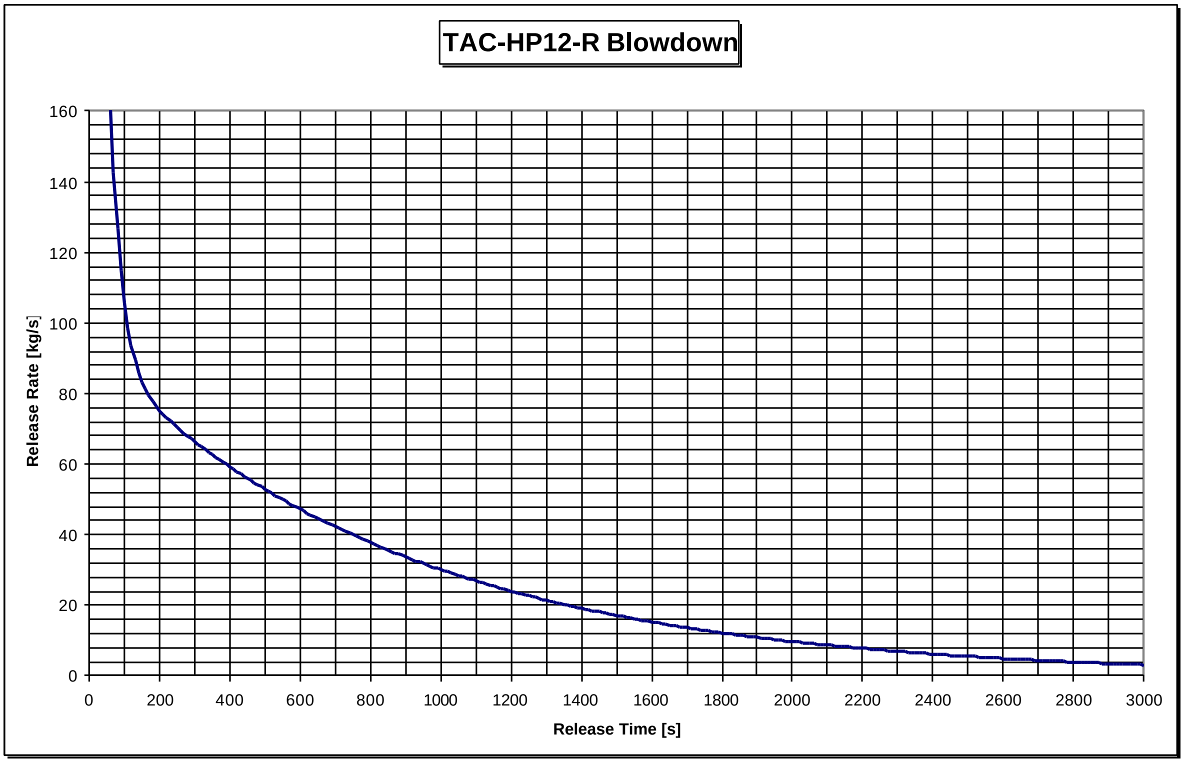


Figure 4.7
Rupture Blowdown for HP12

4.4 Frequency Analysis

4.4.1 General Description of Frequency Analysis

When will it happen? How often? The next step of the risk analysis, the frequency analysis, involves an estimation of the likelihood of occurrence of each of the different types of hazard scenarios identified. In risk analysis, it is customary to characterize frequencies of occurrence either on an annual basis, or on an incident basis. An example of an annual frequency of occurrence is 10 major spills per 100 years or one pipeline rupture per year per one million pipeline kilometers. An example of an event frequency of occurrence is that in 10% of tanker traffic accidents, a spill of the cargo fluid occurs. These frequencies of occurrence are generally based on empirical data available to the risk analyst and, generally, to the public. Empirical data sources on accident or accidental release frequencies include industry sources [21], public sources [30, 33, 69], and results of other risk analyses in the public domain [12, 16, 17].

When the frequency for the type of event being studied is not directly available from the data, it can be obtained utilizing analytical techniques such as fault tree analysis [1, 12]. In fault tree analysis, the frequency of occurrence of an event under study can be derived by considering the probabilistic relationships of more basic events that lead to its occurrence. For the current analysis, failure probabilities for different locations considering effects of the road system have to be assessed using fault trees. Naturally, the frequencies available from databases have to be adapted to the specific conditions and configurations of facilities under study. For example, although unit (per km-year) failure frequencies for each type of pipeline are available, they still need to be adapted to each segment length and condition. The frequency evaluation process based on public available data as well as that based on fault tree analysis will be described and documented in the latter portion of this chapter.

4.4.2 Base Pipeline Failure Data

The principal database for natural gas pipeline failure data utilized is that from the Alberta Energy and Utilities Board (AEUB) [30]. This data is multi-year (1980 – 1998) and gives the best description and quantitative categorization of different failure causes which are important to complete the subject risk assessment. Table 4.2 displays the high pressure NPS 12 rupture failure rate data from the AEUB, together with the conversion for the application of these data to natural gas pipelines with NPS 12 diameters. The reduction factors for third party damage, shown as a percentage in the third numerical column, were derived from US DOT data [69], which gives a better representation of the diameter related variation of this failure cause as illustrated in Figure 4.8.

4.4.3 Pipeline Failure Rates Considering Effect of Pipeline Locations

With the definition of the principal impact factors for the failure rate road-pipeline synergy utilizing the screening process described in Chapter 3, the quantification to assess their incremental effect on the base failure rate was conducted. Table 4.3 shows the quantification for the incremental failure rate (failure rate change) due to the factors identified so far. As can be seen from Table 4.3, reading from left to right, the following columns are defined:

- ***Location (Loc)*** – 1, 2, and 3 (4 is not considered to be affected by the roadway system).
- ***Classification*** – Of the failure cause.
- ***Hazard to the Pipeline*** – From activity or event which threatens pipeline integrity.
- ***Return Period*** – The time in years between hazard occurrences.
- ***Base Pipeline Length*** – In generic case, a 25-km segment between isolation valves in accordance with Class 2 CSA Z662 code regulation.
- ***Hazard Quantity*** – In terms of either the number of operations or their linear distance along the 25-km road segment.
- ***Pipeline Damage Probability*** – The probability of damaging the pipeline if the activity/event occurs, per unit, and per 25-km segment (total).
- ***Failure Rate Change*** – The increment to the per kilometre-year failure rate attributable to this event/activity. Note that the failure rate in this column means damage to the pipeline corresponding to a 50% probability of immediate loss of containment.

Table 4.2
TAC-HP12 Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP12 DISTRIBUTION (%)	PL HP12 FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**4.1**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	1.1	1.78E-06
External	3.2	9.50E-06	50.0	1.6	3.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**52.5**	**38.0**	**71.0**	**1.13E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	9.5	1.51E-05
Third Party Damage	70.1	2.08E-04	60.0	28.0	52.3	8.32E-05
Earth Movement	4.9	1.46E-05	0.0	4.9	9.2	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**5.0**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	2.2	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	2.8	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**2.2**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.9	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.4	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**17.6**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	8.2	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	3.6	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.4	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	3.6	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.9	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**46.5**	**53.5**	**100.0**	**1.59E-04**

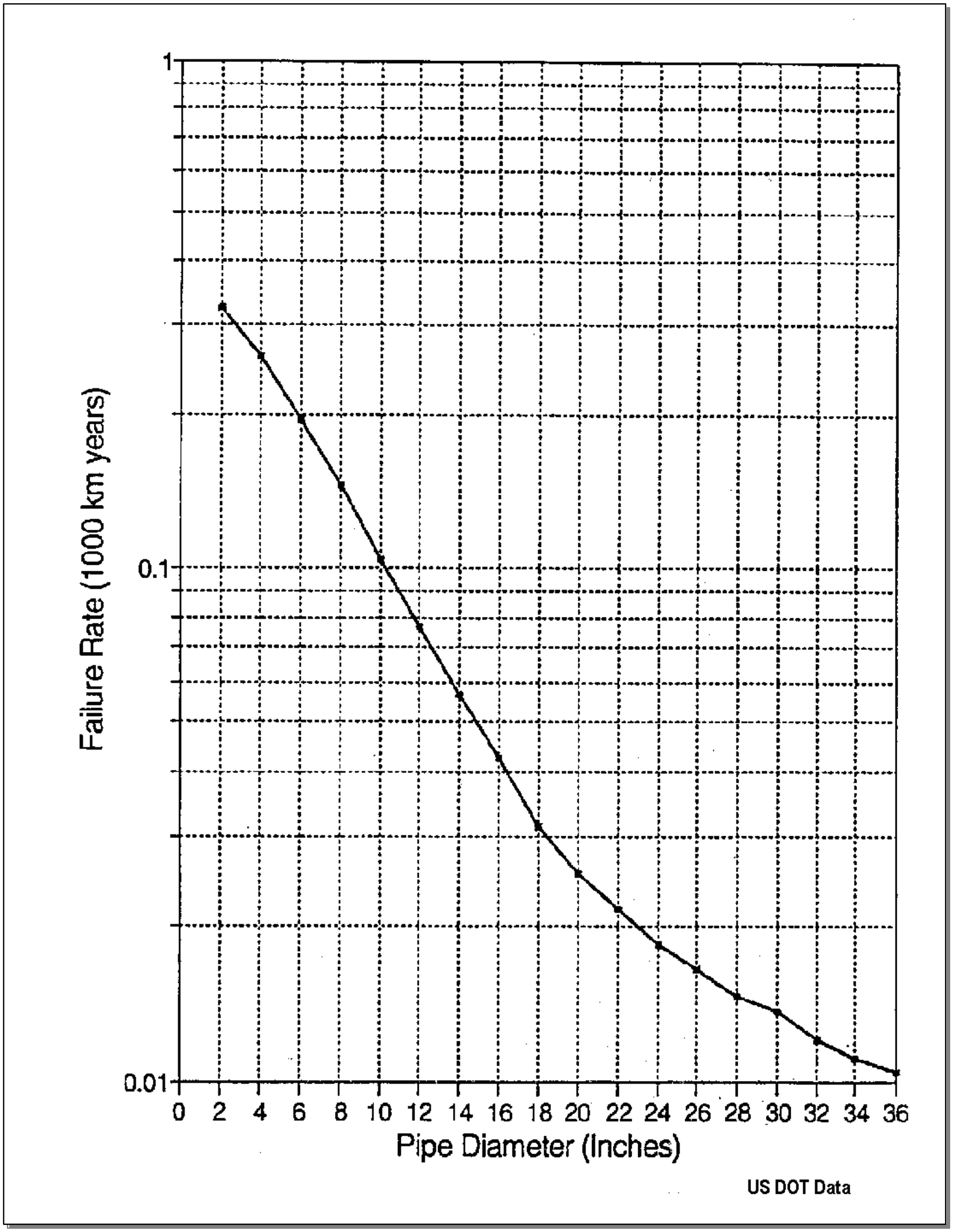


Figure 4.8
External Impact Failure Frequency as a Function of Pipe Diameter

Table 4.3
Roadway Effects on Pipeline Failure Rate (Mitigated)

ROAD TYPE B, C, E, H									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing - Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Replacement Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading - Continuous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	.1	25	25	km	1.00E-06	2.50E-04	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Roadbed	10	25	0.5	km	1.00E-05	5.00E-05	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party Damage Total							**7.94E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							1.04E-05
		Unknown Total							**1.04E-05**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading - Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Replacement Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading - Continuous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05

Table 4.3
Roadway Effects on Pipeline Failure Rate (Mitigated)

ROAD TYPE B, C, E, H									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		Snow Ploughing	.1	25	25	km	1.00E-06	2.50E-04	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Roadbed	10	25	0.5	km	1.00E-05	5.00E-05	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party Damage Total							**5.92E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							8.36E-06
		Unknown Total							**8.36E-06**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Replacement Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**9.25E-06**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							3.36E-06
		Unknown Total							**3.36E-06**

Next, the total failure rate increment for each cause is added to the base failure rate (from Table 4.2) for the pipeline specified (NPS 12 here) for each location as shown in Table 4.4.

Finally, the total failure rate corresponding to each of the four causes affected by the pipeline (external corrosion, third party damage, earth movement, unknown) and combined with the balance of the causes (weld failure, joint failure, surface equipment failures (none), and other failures) to obtain the total failure rate for each pipeline type and location is shown for the NPS 12 line in Table 4.5.

Then, based on the historical data, the failure rate is distributed according to the hazard scenario aperture sizes, as shown in Table 4.6.

The resultant variation in failure rate by location for NPS 12 pipeline thus derived is shown in the fault tree in Figure 4.9. Similar computations, fault trees, for variation in failure rate by pipeline and road type and location are given in Appendix C.

4.5 Consequence Analysis

4.5.1 General Description of Consequence Analysis

What happens after the initial accidental release? What consequences evolve? Fire, explosions, toxic clouds? What are their relative chances of occurrence? These questions are answered through consequence analysis.

The primary components in consequence analysis are consequence evolution, source and dispersion, fire and explosion, and effect or damage models. Consequence evolution models give the relative likelihood of different consequences (fires, explosions, unignited dispersion) resulting. Source and dispersion models provide quantitative information on release rates and vapor cloud concentrations or spill characteristics and geometries. Fire and explosion models convert the geometric and concentration data into hazard potentials such as thermal radiation and explosion overpressure levels. Effect or damage criteria are applied to incident-specific results to estimate effects on people (injury or fatality) and property or environment. Additional accuracy can be added by including consideration of mitigating factors such as sheltering (in houses or vehicles), evacuation, protective gear, which reduce the magnitude of potential effects for the incidents considered.

4.5.2 Fire and Explosion Damage Criteria

Fires and explosions can result if the accidental natural gas release is ignited. Fire effects were considered for either direct contact with the flame or exposure to injurious levels of thermal radiation. Direct contact with a fire, for example inside a vapor cloud, will often result in fatality. The vapor cloud lower flammability limit [1] was used to define the fatality location extent.

Table 4.4
Roadway Effects on Pipeline Failure Rate (NPS 12)

ROAD TYPE B, C, E, H Pipeline 12									
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	3.97E-05	1.51E-04	135.6
		Leak	2.83E-05	Leak	36	2.86E-05	5.69E-05	201.1
		Rupture	8.32E-05	Rupture	14	1.11E-05	9.43E-05	113.4
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.19E-06	3.14E-05	119.8
		Leak	2.33E-05	Leak	36	3.74E-06	2.70E-05	116.1
		Rupture	2.97E-06	Rupture	14	1.45E-06	4.42E-06	148.9
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	2.96E-05	1.41E-04	126.6
		Leak	2.83E-05	Leak	36	2.13E-05	4.96E-05	175.4
		Rupture	8.32E-05	Rupture	14	8.29E-06	9.15E-05	110.0
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	4.18E-06	3.04E-05	115.9
		Leak	2.33E-05	Leak	36	3.01E-06	2.63E-05	112.9
		Rupture	2.97E-06	Rupture	14	1.17E-06	4.14E-06	139.4
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	4.62E-06	1.16E-04	104.1
		Leak	2.83E-05	Leak	36	3.33E-06	3.16E-05	111.8
		Rupture	8.32E-05	Rupture	14	1.29E-06	8.45E-05	101.6
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.68E-06	2.79E-05	106.4
		Leak	2.33E-05	Leak	36	1.21E-06	2.45E-05	105.2
		Rupture	2.97E-06	Rupture	14	4.71E-07	3.44E-06	115.9

Note: NLC means damage with No Loss of Containment.

Table 4.5
Failure Rate Calculation Leak and Rupture (NPS 12)

LEAK CAUSE CLASSIFICATION	PL 12 FAILURE RATE [per km- yr]	ROAD TYPE B, C, E, H Failure Rate [per km - yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**4.43E-05**	**8.13E-05**	**7.40E-05**	**5.60E-05**	**4.43E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	2.83E-05	5.69E-05	4.96E-05	3.16E-05	2.83E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FAILURE	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.45E-05**	**9.37E-05**	**9.20E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	2.63E-05	2.45E-05	2.33E-05
TOTALS	**4.26E-04**	**4.67E-04**	**4.59E-04**	**4.39E-04**	**4.26E-04**
RUPTURE CAUSE CLASSIFICATION	**PL 12 FAILURE RATE [per km- yr]**	**ROAD TYPE B, C, E, H Failure Rate [per km - yr]**			
		Loc 1	**Loc 2**	**Loc 3**	**Loc 4**
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.13E-04**	**1.27E-04**	**1.24E-04**	**1.17E-04**	**1.13E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	8.32E-05	9.43E-05	9.15E-05	8.45E-05	8.32E-05
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FAILURE	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**2.91E-05**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.42E-06	4.14E-06	3.44E-06	2.97E-06
TOTALS	**1.59E-04**	**1.75E-04**	**1.72E-04**	**1.64E-04**	**1.59E-04**

Table 4.6
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	ROAD TYPE B, C, E, H							
	Pipeline 08(06)"							
Base Leak	73.0%	**4.92E-04**	73.0%	**4.84E-04**	73.0%	**4.64E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**2.48E-04**	27.0%	**2.45E-04**	27.0%	**2.37E-04**	27.0%	**2.32E-04**
Leak	73.0%	4.92E-04	73.0%	4.84E-04	73.0%	4.64E-04	73.0%	4.51E-04
Hole	20.0%	1.84E-04	20.0%	1.81E-04	20.0%	1.76E-04	20.0%	1.72E-04
Rupture	4.6%	4.22E-05	4.6%	4.17E-05	4.6%	4.04E-05	4.6%	3.95E-05
D Rupture	2.4%	2.20E-05	2.4%	2.18E-05	2.4%	2.11E-05	2.4%	2.06E-05
	Pipeline 12"							
Base Leak	73.0%	**4.67E-04**	73.0%	**4.59E-04**	73.0%	**4.39E-04**	73.0%	**4.26E-04**
Base Rupture	27.0%	**1.75E-04**	27.0%	**1.72E-04**	27.0%	**1.64E-04**	27.0%	**1.59E-04**
Leak	73.0%	4.67E-04	73.0%	4.59E-04	73.0%	4.39E-04	73.0%	4.26E-04
Hole	20.0%	1.30E-04	20.0%	1.27E-04	20.0%	1.22E-04	20.0%	1.18E-04
Rupture	4.6%	2.98E-05	4.6%	2.93E-05	4.6%	2.80E-05	4.6%	2.71E-05
D Rupture	2.4%	1.55E-05	2.4%	1.53E-05	2.4%	1.46E-05	2.4%	1.41E-05

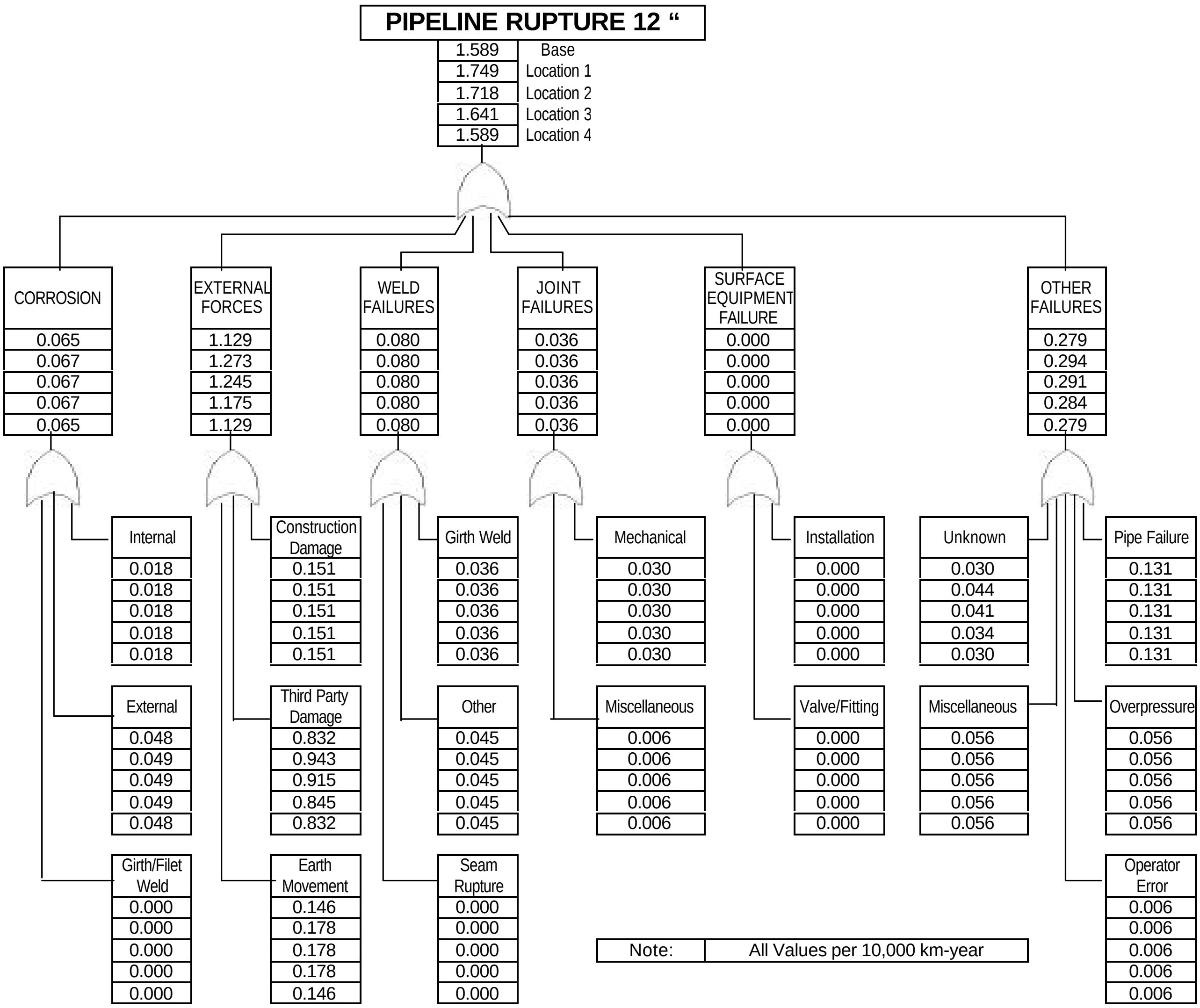


Figure 4.9
Pipeline Rupture Rate Variation Fault Tree by Location (NPS 12)

Thermal radiation hazards vary with distance near a jet fire. A summary of selected effects of thermal radiation is given in Table 4.7 from [1]. Experimental data on thermal radiation hazards show that a thermal radiation level of 37.5 kW/m^2 is sufficient to cause 50% fatality within 60 seconds.

Explosion effects on people involve either direct exposure to overpressures or impact by missiles or collapsing objects resulting from the explosion. Empirical data on blast overpressure damage is used to estimate human effect criteria for vapor cloud explosions. A summary of effects for explosion overpressures from [1] is given in Table 4.8. 10% fatality may be expected from direct human exposure to 35 kPa (5 psi) blast overpressures. Buildings, however, will be damaged if exposed to 20 kPa (2.8 psi) overpressures and therefore people inside such buildings could be injured as a result of structural collapse.

4.5.3 Consequence Evolution Analysis

Of all the factors influencing the public and personnel risk from pipeline accidents adjacent to roadway systems, the increase in ignition probability due to ignition sources (vehicles) on the roadway, appears to be the predominant one. Figure 4.10 shows an event tree, which describes the evolution of hazardous (and non-hazardous) consequences of a pipeline release, in this case, for Location 1 adjacent to a freeway. From left to right, the event tree models the likelihood of occurrence of different scenarios once a release has occurred. For example, for the rupture, there is a probability of 0.59 or 60% that ignition will occur if an accidental release occurs. This probability is of paramount importance in the final risk assessment – if no ignition were to occur, then, for natural gas (which is not toxic), there would be no possibility of acute damage such as injury or fatality. For the control location, Location 4, in the countryside away from population centres and transportation routes, the corresponding probability of ignition is 0.15 for ruptures, primarily associated with auto-ignition from the occurrence of the rupture itself. Following ignition definition, the event tree then gives the relative likelihood of the timing of the ignition, which is instrumental in determining whether there will only be a jet fire, or if there is potential for a flash fire or explosion as shown next in the event tree. Finally, the event tree gives the Ratio of Occurrence of the different possible outcomes of the accidental release. Detailed ignition probability calculations, event tree inputs and event trees are given in Appendix C (Table C.2.1) for all road types, pipeline types, and locations.

Table 4.7
Effects of Thermal Radiation

RADIATION INTENSITY		OBSERVED EFFECT	% CASUALTIES	
(kW/m^2)	(BTU/ft^{2}hr)		Fatalities	Injuries
1.9	600	Will cause no discomfort for long exposure.	0	0
6.3	2000	Sufficient to cause pain to personnel if unable to reach cover within 20 s; however blistering of the skin (second degree burns) is likely; 0% lethality.	0	0
9.5	3000	Pain threshold reached after 8 s; second degree burns after 20 s; 1% lethality after 60 seconds	1	10
12.5	3960	Melting of plastic tubing. 10% fatality after 60 seconds.	10	100
25	7925	Minimum energy required to ignite wood. 50% fatality after 60 seconds	50	100
37.5	11887	Sufficient to cause damage to process equipment. 100% fatality after 60 seconds.	100	100

Table 4.8
Effects from Explosion Overpressures

OVERPRESSURE			OBSERVED EFFECT	% CASULATIES	
(Bars)	(kPa)	(psi)		Fatalities	Injuries
.02	2	.3	Typical pressure for 10% glass failure. Safe distance.	0	0
.07	7	1.0	Damage to houses; 100% glass breakage	0	0
.2	20	2.8	Non-reinforced concrete or cinder block walls destroyed. (1% fatality); wood frame partial collapse	1	10
.25	25	3.5	Steel buildings collapse (90% eardrum rupture) (5% fatality)	5	50
.35	35	5.0	Wooden utility poles snapped; buildings destroyed (10% fatality)	10	100
1.0	100	15.0	100% fatalities among exposed populations due to direct blast effects.	100	100

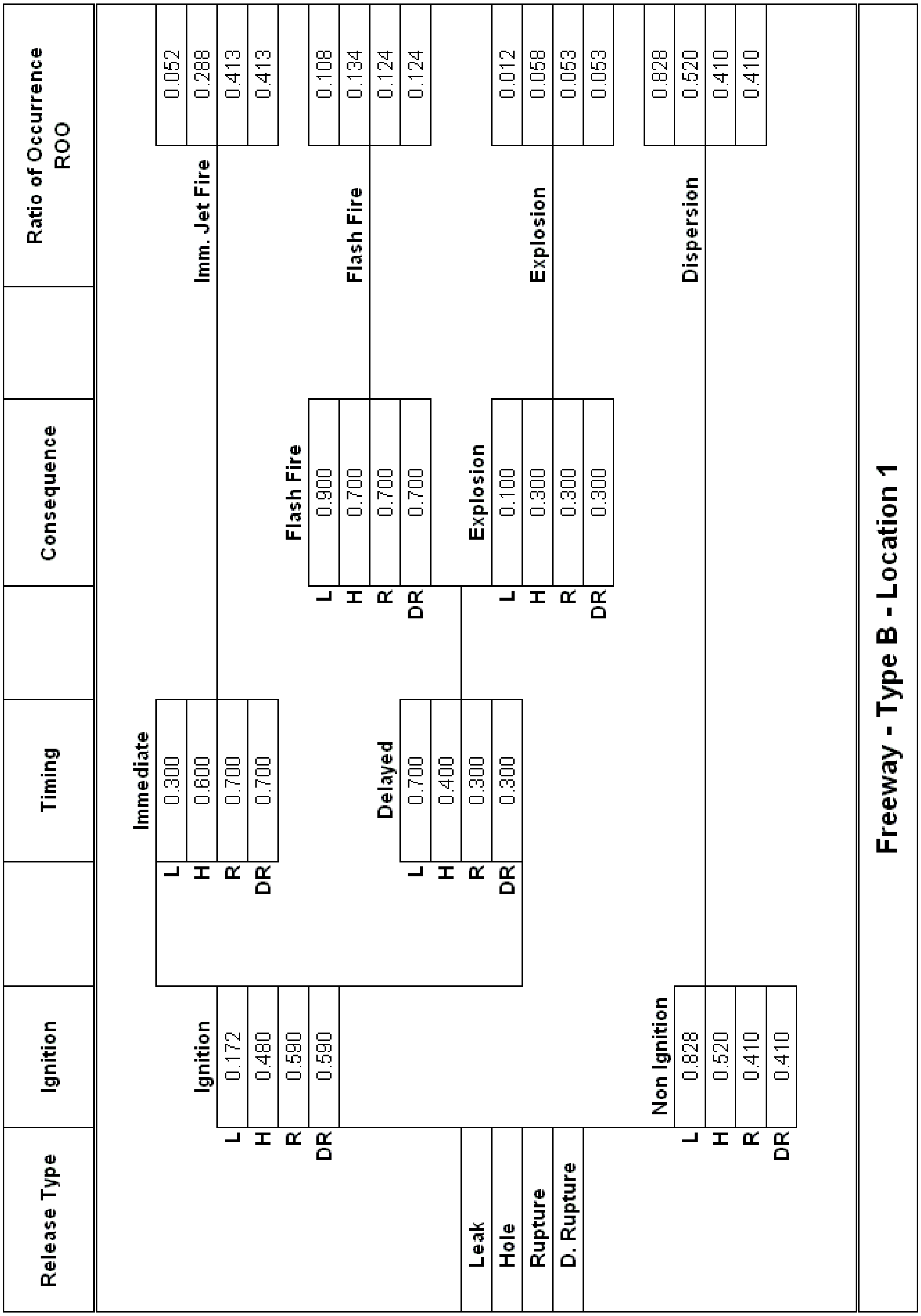


Figure 4.10
Event Tree Freeway Location 1

4.5.4 Consequence Analysis

A multipurpose consequence analysis model [59] was used to assess the spatial and temporal distribution of hazard zones corresponding to different release and atmospheric conditions. Table 4.9 gives the hazard distances for the NPS 12 pipeline for each of the principal hazard types, the flash fire, the jet fire, and the uncontained vapour cloud explosion, associated with accidental natural gas releases. Again, results for each of the three pressure classes and for aperture sizes for corresponding results for NPS 8 and NPS 6 pipelines are given in Appendix C. As the dispersion characteristics of the release vary with atmospheric conditions, different meteorological classes have been used together with a weighted average. Those chosen here correspond to a central Canadian location (Southern Ontario). The isopleths pertain to levels associated with different likelihoods of lethality for exposed persons, for the two primary hazards, thermal radiation and explosion overpressure. The length and width characterize the hazard footprint, for which typical graphic printouts of the program are shown in Figure 4.11. Thus, the hazard distances can be used as input to the risk calculation program to calculate the risks, or likelihoods of fatality at different locations relative to the pipeline.

4.6 Risk Analysis

4.6.1 Description of Approaches to Risk Analysis

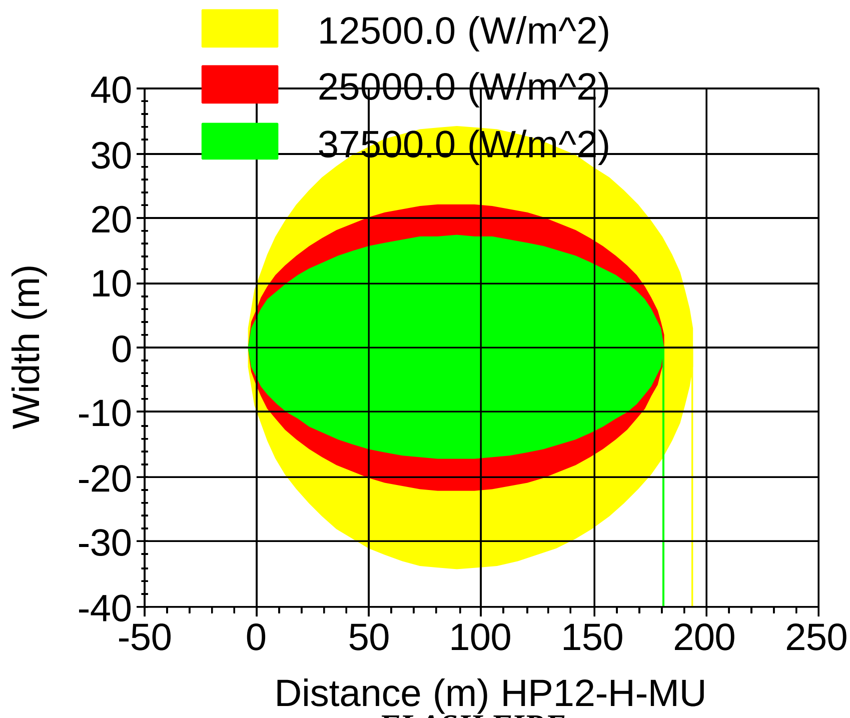
In the previous sections, the assessment of consequences including the hazard footprints associated with different possibilities of lethality have been completed. This work has been done without regard to specific population distributions. In this section, the results of the analysis described above will be integrated with an estimate of the likely population distribution to provide measures of public risk for the project. Measures of risk to be utilized will be Individual Specific Risks (ISR) and Collective Risks (CR). Individual Specific Risks are the actual risks to a specific individual resulting from the project's operation over a one-year period. ISR takes into account both the amount of time the individual spends within the zone of influence within the project and the proportion that the individual is outdoors. Individual Specific Risks are expressed as risk isopleths giving the variation in ISR magnitude with distance from the pipeline. CR or societal risks are a measure of the variation in probability with different numbers of fatalities. They are generally expressed as frequency-number curves or risk spectra. A risk spectrum is a graph of the number of fatalities (on the horizontal axis) and the probability of the occurrence of at least that number of fatalities (probability of exceedance) on the vertical axis.

4.6.2 Public and Personnel Exposure Factors

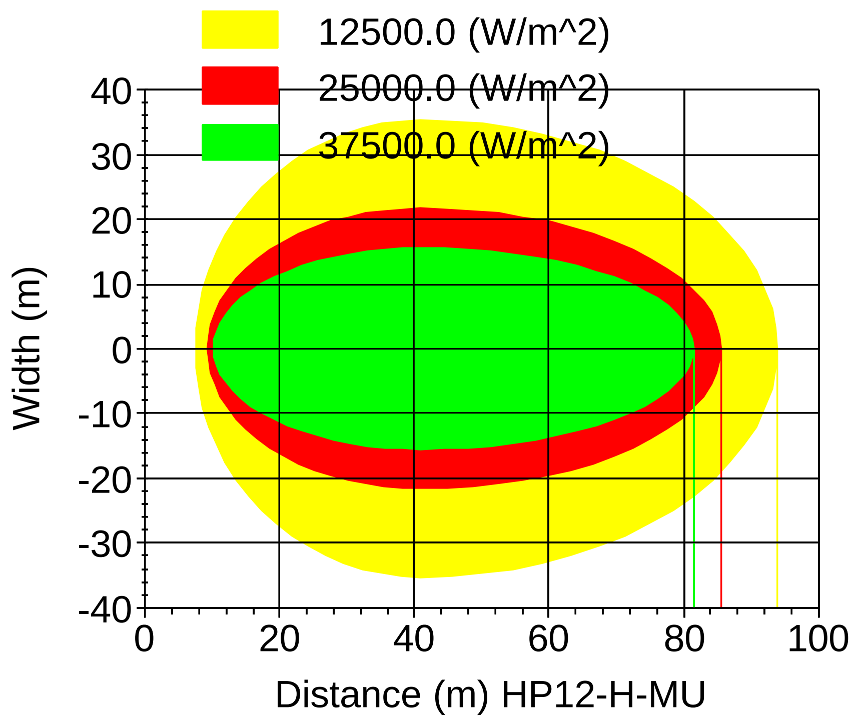
As described in Section 4.2, the amount of time and degree of exposure by members of the public or the work force is needed in order to assess their individual specific or collective risks. In the individual specific risk assessment, we have selected five categories of personnel together with the rates of exposures for them described in Table 4.10:

Table 4.9 – 12" Pipeline Consequence Modeling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m] Flash Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Jet Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Explosion Overpressure [Pa]		
							12500		25000		37500		12500		25000		37500		6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-LP12-L-MU	Leak .5 cm Dia	44763	0.05	A,B,C	15.9	0.9	0.3	0.4	0.2	0.3	0.2	4.0	1.2	3.6	0.6	3.4	0.5	0	0	0
2	TAC-LP12-L-MN				D	53.9	2.9	0.6	1.4	0.6	0.9	0.6	3.2	1.2	2.9	0.6	2.8	0.5	0	0	0
3	TAC-LP12-L-MS				E,F	30.2	13.8	3.2	13.8	2.0	13.8	1.5	4.5	1.1	4.1	0.6	3.9	0.5	0	0	0
4	TAC-LP12-L-MA				**Average**	**100**	**6**	**1**	**5**	**1**	**5**	**1**	**4**	**1**	**3**	**1**	**3**	**1**	**0**	**0**	**0**
5	TAC-LP12-H-MU	Hole 10 cm Dia	112	19.6	A,B,C	15.9	152	28	151	18	150	14	64	24	59	14	56	10	334	103	61
6	TAC-LP12-H-MN				D	53.9	209	20	207	10	208	10	58	25	52	15	50	10	334	103	61
7	TAC-LP12-H-MS				E,F	30.2	139	32	114	20	108	16	70	22	65	11	62	9	334	103	61
8	TAC-LP12-H-MA				**Average**	**100**	**179**	**25**	**170**	**14**	**169**	**12**	**63**	**24**	**57**	**14**	**55**	**10**	**334**	**103**	**61**
9	TAC-LP12-R-MU	Rupture 30 cm Dia	12.4	176	A,B,C	15.9	280	70	225	50	198	40	171	70	155	40	147	30	684	212	126
10	TAC-LP12-R-MN				D	53.9	347	60	297	40	273	35	156	70	140	45	132	30	202	63	37
11	TAC-LP12-R-MS				E,F	30.2	218	50	187	40	172	40	189	70	173	40	165	30	121	37	22
12	TAC-LP12-R-MA				**Average**	**100**	**297**	**59**	**252**	**42**	**231**	**37**	**168**	**70**	**152**	**43**	**144**	**30**	**254**	**79**	**47**
13	TAC-LP12-DR-MU	Double Rupture 43 cm Equ. Dia	6.1	363	A,B,C	15.9	329	70	292	60	276	60	235	100	214	60	203	40	841	260	154
14	TAC-LP12-DR-MN				D	53.9	404	70	339	50	228	50	214	100	192	70	182	50	841	260	154
15	TAC-LP12-DR-MS				E,F	30.2	243	60	205	40	187	40	261	90	239	60	228	40	143	44	26
16	TAC-LP12-DR-MA				**Average**	**100**	**343**	**67**	**291**	**49**	**223**	**49**	**232**	**97**	**210**	**65**	**199**	**45**	**630**	**195**	**115**
17	TAC-HP12-L-MU	Leak .5 cm Dia	56491	0.1	A,B,C	15.9	13.0	3.0	13.0	1.5	13.0	1.5	5.4	1.6	5.0	0.9	4.7	0.6	0	0	0
18	TAC-HP12-L-MN				D	53.9	1.1	0.6	0.8	0.5	0.6	0.4	4.6	1.6	3.9	1.0	3.8	0.6	0	0	0
19	TAC-HP12-L-MS				E,F	30.2	22.0	0.6	22.0	0.3	22.0	0.3	6.1	1.6	5.6	0.8	5.3	0.6	0	0	0
20	TAC-HP12-L-MA				**Average**	**100**	**9**	**1**	**9**	**1**	**9**	**1**	**5**	**2**	**5**	**1**	**4**	**1**	**0**	**0**	**0**
21	TAC-HP12-H-MU	Hole 10 cm Dia	141	47	A,B,C	15.9	205	42	182	29	181	25	94	35	86	22	82	16	447	138	82
22	TAC-HP12-H-MN				D	53.9	247	32	247	20	247	16	85	36	77	24	73	16	447	138	82
23	TAC-HP12-H-MS				E,F	30.2	167	36	149	29	140	27	103	34	94	20	90	15	447	138	82
24	TAC-HP12-H-MA				**Average**	**100**	**216**	**35**	**207**	**24**	**204**	**21**	**92**	**35**	**84**	**22**	**80**	**16**	**447**	**138**	**82**
25	TAC-HP12-R-MU	Rupture 30 cm Dia	15.7	423	A,B,C	15.9	351	75	309	60	288	60	252	100	229	70	217	50	921	285	169
26	TAC-HP12-R-MN				D	53.9	413	80	354	60	353	50	227	110	204	70	192	50	921	285	169
27	TAC-HP12-R-MS				E,F	30.2	249	60	210	45	191	45	276	100	252	60	240	40	921	285	169
28	TAC-HP12-R-MA				**Average**	**100**	**354**	**73**	**303**	**55**	**294**	**50**	**246**	**105**	**222**	**67**	**210**	**47**	**921**	**285**	**169**
29	TAC-HP12-DR-MU	Double Rupture 43 cm Equ. Dia	7.6	870	A,B,C	15.9	410	100	353	70	324	60	348	150	315	90	299	60	1134	351	208
30	TAC-HP12-DR-MN				D	53.9	463	100	394	70	394	60	313	150	280	100	264	80	1134	351	208
31	TAC-HP12-DR-MS				E,F	30.2	280	70	232	50	208	50	381	140	347	80	331	60	1134	351	208
32	TAC-HP12-DR-MA				**Average**	**100**	**399**	**91**	**339**	**64**	**327**	**57**	**339**	**147**	**306**	**92**	**290**	**71**	**1134**	**351**	**208**
33	TAC-VP12-L-MU	Leak .5 cm Dia	64422	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
34	TAC-VP12-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
35	TAC-VP12-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
36	TAC-VP12-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
37	TAC-VP12-H-MU	Hole 10 cm Dia	161	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	541	168	99
38	TAC-VP12-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	541	168	99
39	TAC-VP12-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
40	TAC-VP12-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**541**	**168**	**99**
41	TAC-VP12-R-MU	Rupture 30 cm Dia	17.9	752	A,B,C	15.9	520	190	424	160	375	160	324	140	294	80	279	60	311	96	57
42	TAC-VP12-R-MN				D	53.9	576	160	447	140	408	120	291	140	261	90	246	60	542	168	99
43	TAC-VP12-R-MS				E,F	30.2	525	210	413	180	355	180	354	120	323	80	308	60	291	90	53
44	TAC-VP12-R-MA				**Average**	**100**	**552**	**180**	**433**	**155**	**387**	**144**	**315**	**134**	**285**	**85**	**270**	**60**	**429**	**133**	**78**
45	TAC-VP12-DR-MU	Double Rupture 43 cm Equ. Dia	3.9	1545	A,B,C	15.9	642	240	512	210	447	210	447	200	404	120	384	100	367	114	68
46	TAC-VP12-DR-MN				D	53.9	695	210	571	180	508	180	402	200	359	130	339	100	427	132	78
47	TAC-VP12-DR-MS				E,F	30.2	674	300	525	250	448	250	489	190	445	120	424	90	355	110	65
48	TAC-VP12-DR-MA				**Average**	**100**	**680**	**242**	**548**	**206**	**480**	**206**	**435**	**197**	**392**	**125**	**372**	**97**	**396**	**122**	**72**



FLASH FIRE



JET FIRE

Figure 4.11
Thermal Isopleths

Table 4.10
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E h/day	Nt trip/day	Nd days/week	Nw weeks/year	L km/trip	V km/h	LISRF	IF	OF	Sfi	Sfo	ISRF
1	Freeway Type B	1	Daily Commuter	n/a	2	5	48	25	90	0.0153	0.95	0.05	0.1	1.0	0.00221
		2	Weekly Commuter	n/a	2	1	48	25	90	0.0031	0.90	0.10	0.1	1.0	0.00058
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
2	Arterial Type C,D	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.00199
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.00052
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
3	Collector Type E,F	1	Daily Commuter	n/a	2	5	48	15	70	0.0118	0.95	0.05	0.1	1.0	0.00171
		2	Weekly Commuter	n/a	2	1	48	15	70	0.0024	0.90	0.10	0.1	1.0	0.00045
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
4	Local Type G,H,I,J	1	Daily Commuter	n/a	2	5	48	10	50	0.0110	0.95	0.05	0.1	1.0	0.00159
		2	Weekly Commuter	n/a	2	1	48	10	50	0.0022	0.90	0.10	0.1	1.0	0.00042
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833

- ***Daily commuters*** – Are people traveling along the relevant segment twice per day, five days per week.
- ***Weekly commuters*** – Are individuals traveling along the segment twice in one week.
- ***Workers*** – Individuals who spend time working adjacent to the segment 8 hours per day, 5 days per week.
- ***Residents*** – Those who spend time in nearby residences 12 hours a day, 7 days per week.
- ***Generic road users*** – Any road users, who are any persons spending time adjacent to the segment, but cannot be deemed to be specific individuals for the purposes of Individual Specific Risk computations.

The first 10 columns essentially present the above data in quantitative form, resulting in a factor called ISRF, the Individual Specific Risk Factor. Because whether a person is outdoors or indoors affects their likelihood of being injured by a pipeline accident, their indoor proportional factors (IF) and outdoor proportional factors (OF) are also estimated, together with the effective amount of exposure indoors and outdoors. The combined Individual Specific Risk Factor is given in the final column of Table 4.10.

Table 4.11 deals with the estimation of the probable number of cars and corresponding people that are likely to be exposed at any one time in a pipeline hazard footprint. Naturally, the hazard footprints as described under Section 4.5.4 had to be first estimated, and then, based on the ADDT and lower end of the design speed, the car spacing was estimated and finally the number of people likely to be exposed, inside vehicles, was estimated. These estimates are used for the collective risk evaluations.

4.6.3 Individual Specific Risks from Pipelines in Locations 1, 2, and 3

Individual Specific Risk (ISR) from the pipeline is best expressed as a risk transect. A risk transect gives the value of ISR as a function of horizontal distance from and perpendicular to the pipeline centreline (and hence also perpendicular to the road centreline). The following risk transects are given here to illustrate the risk values and trends:

- Figure 4.12 – Freeway, HP 12, Location 1
- Figure 4.13 – Freeway, HP 12, Location 2
- Figure 4.14 – Freeway, HP 12, Location 3
- Figure 4.15 – Arterial, HP 12, Location 1
- Figure 4.16 – Collector, HP 12, Location 1
- Figure 4.17 – Local, HP 12, Location 1

Each of the transects also gives the control or base case, Location 4, to allow comparisons (for residential exposure). The transect shown is for only one side of the road; due to assumption of equiprobable wind direction, a mirror image transect governs the opposite side. Maximum risks (at pipeline centre line) from the above transects as well as those given for other pipeline categories in Appendix C are tabulated in Table 4.12.

Table 4.11
Collective Risk Exposure Numbers

Nr	Road Type	ADDT cars/day max	Hazard m	V km/h min	Spacing m	N Cars	N People
1	Freeway Type B	10000	400	90	216	1.85	4
2	Arterial Type C,D	5000	400	80	384	1.04	2
3	Collector Type E,F	3000	400	70	560	0.71	2
4	Local Type G,H,I,J	300	400	50	4000	0.10	1

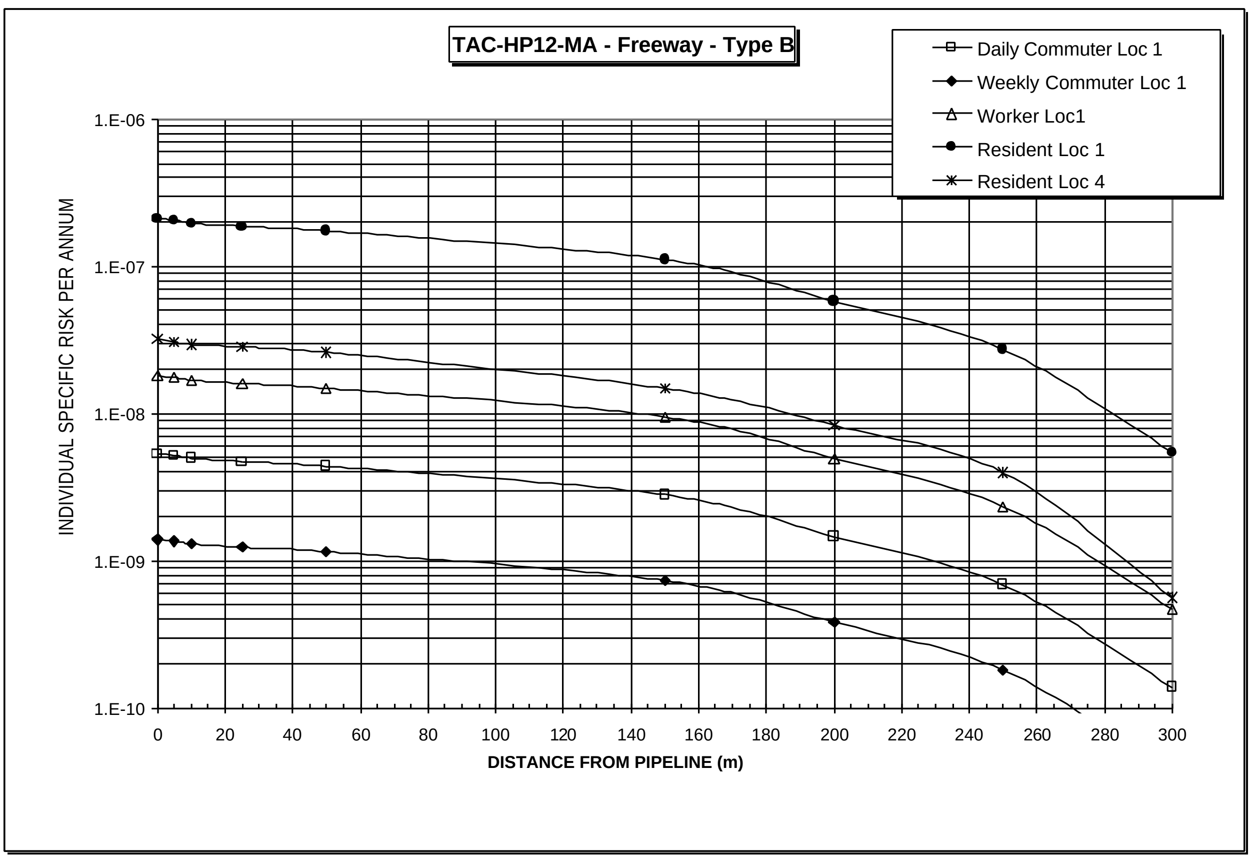


Figure 4.12
Transects – Freeway HP12 – Location 1

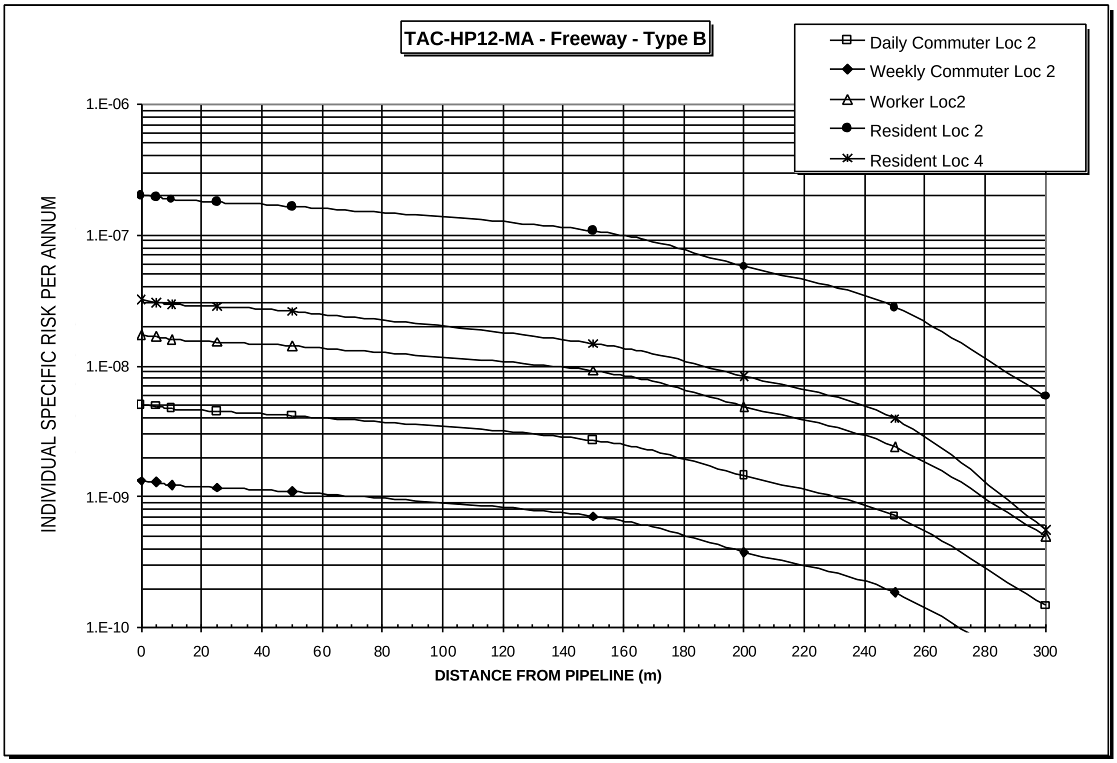


Figure 4.13
Transects – Freeway HP12 – Location 2

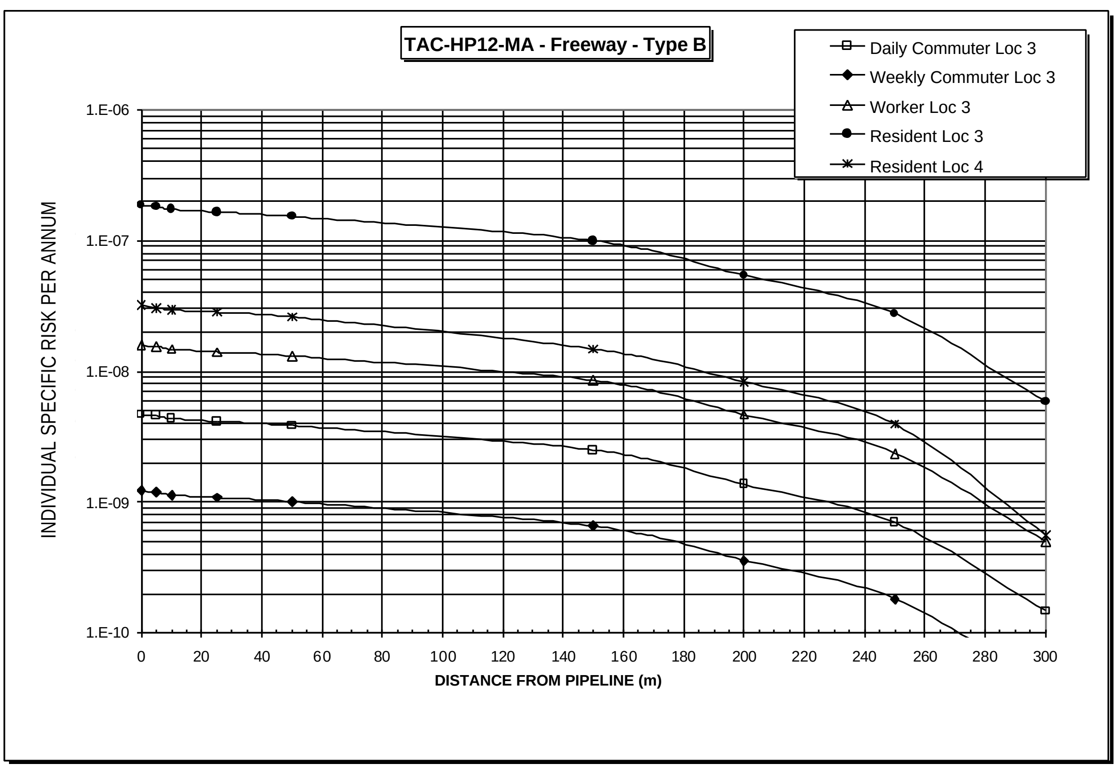


Figure 4.14
Transects – Freeway HP12 – Location 3

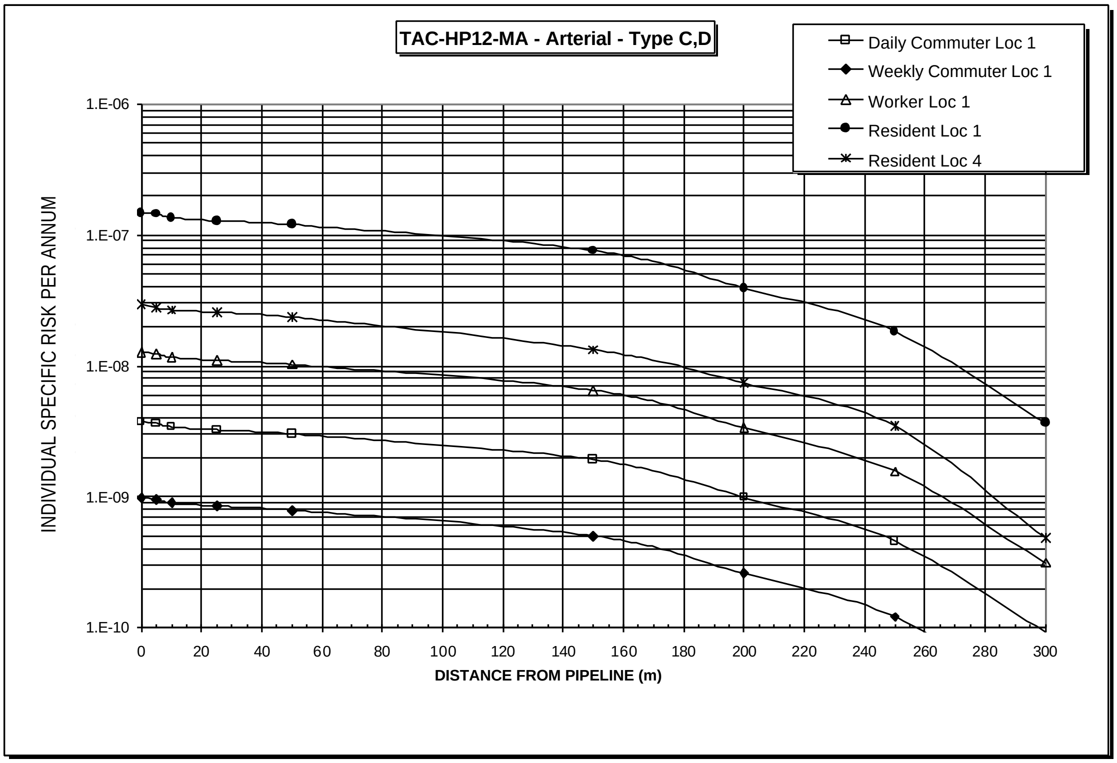


Figure 4.15
Transects – Arterial HP12 – Location 1

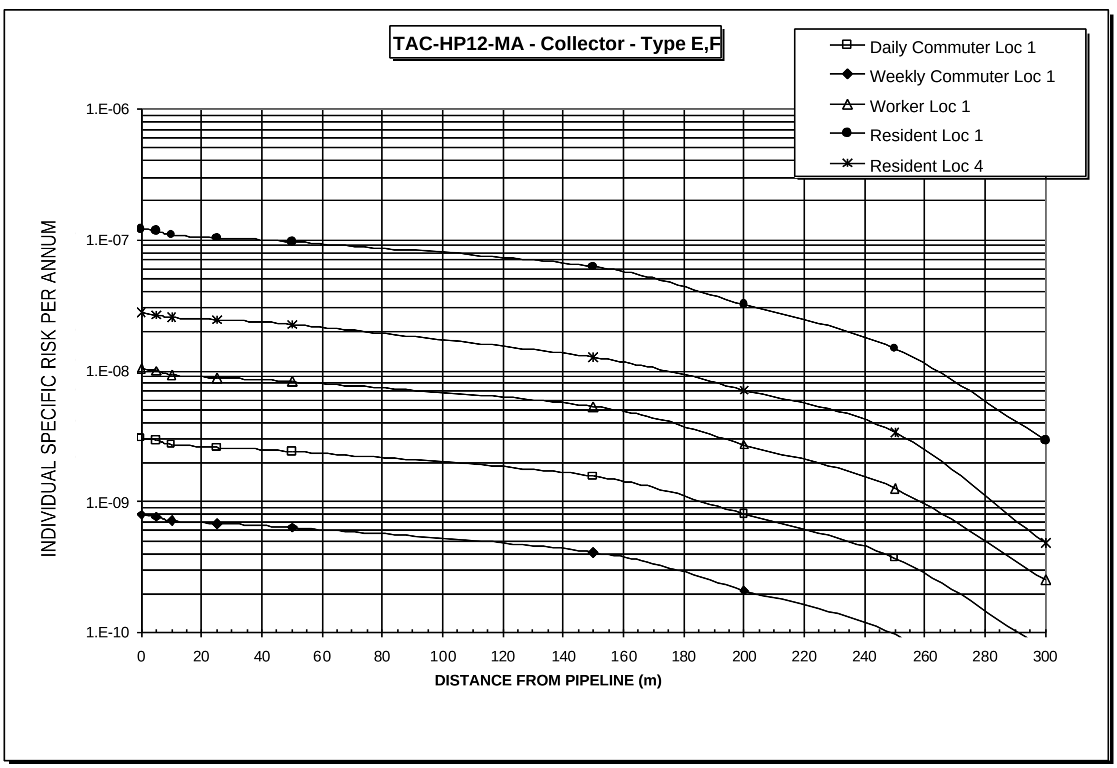


Figure 4.16
Transects – Collector HP12 – Location 1

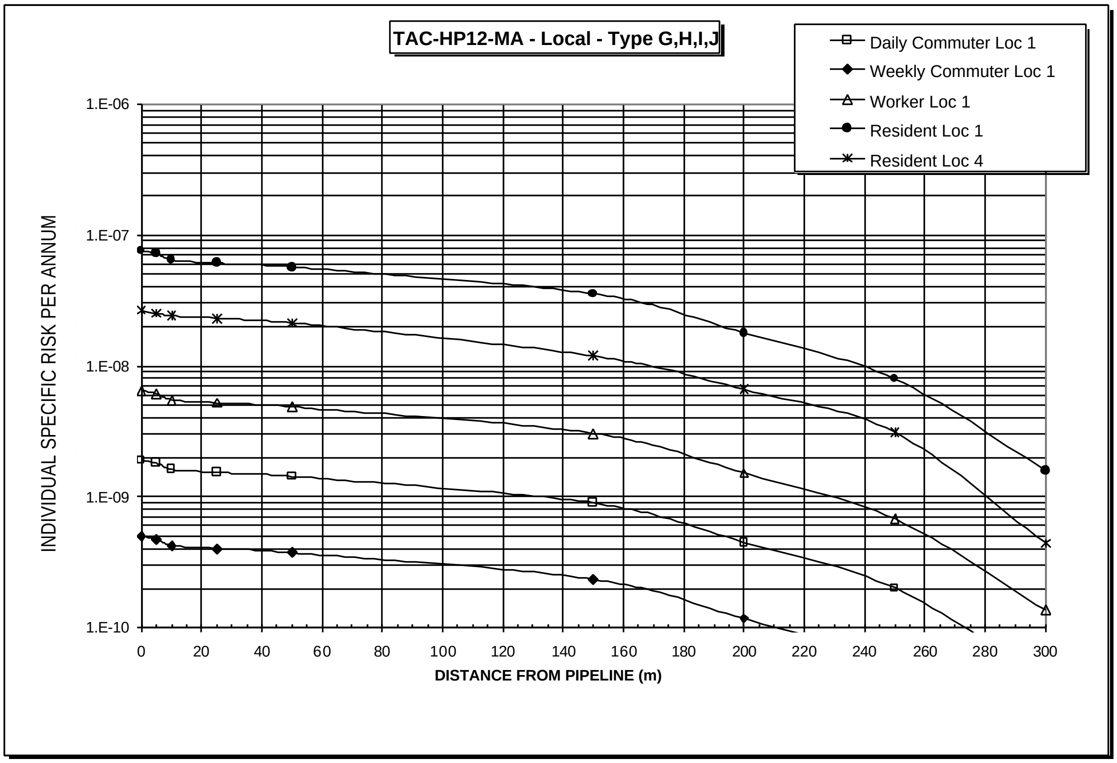


Figure 4.17
Transects – Local HP12 – Location 1

Table 4.12
Variations in Risk with Road and Pipeline Parameters

Road Type	HP P/L TYPE (inches)	MAXIMUM RESIDENT RISK (CHANCES OF FATALITY PER MILLION YEARS)			
		Loc. 1	Loc. 2	Loc. 3	Loc. 4
Freeway	12	0.21	0.20	0.18	0.03
	8	0.27	0.25	0.23	0.04
Arterial	12	0.16	0.15	0.14	0.03
	8	0.20	0.18	0.17	0.04
Collector	12	0.12	0.11	0.10	0.03
	8	0.15	0.14	0.12	0.04
Local	12	0.08	0.07	0.06	0.03
	8	0.10	0.09	0.08	0.04

The following observations on individual specific risk (ISR) trends can be made from the risk transects and Table 4.12:

- All ISR values are below 1 in 1 million.
- The freeway type gives the maximum risks, which are approximately seven times greater than the control Location 4 risks.
- Local roads give the smallest risks, at a level of approximately three times that of the control location.
- The NPS 8 (and 6) pipeline gives somewhat higher risks due to the larger base failure rate associated with smaller pipelines.
- Location 1 risks are highest, with Location 2 next, and Location 3 risks are the lowest, but still higher than Location 4.
- From all the transects, it can be seen that risks fall off rapidly with distance from the pipeline, reducing by a factor of 10 within approximately 200 m. This is most relevant for the Residential ISR.
- Road users are expected only within a short distance from the pipeline, and hence only the maximum risks were tabulated. However, if there were a parallel road with similar ADDT at some distance from the pipeline, the more distant portions of the transect would apply.

4.6.4 Representative Collective Risks

The societal or group risk results are represented as risk spectra. A risk spectrum is a graph of the frequency of occurrence and the number of individuals involved in the occurrence, with the frequency given on the vertical axis and the number of individuals on the horizontal axis. Specifically, the graph represents the probability that N or more (or at least N) individuals will become fatalities in any given situation.

The data for the construction of the risk spectrum is obtained by combining the iso-risk contours (risk isopleths) with actual population distributions together with their appropriate dwell time and outdoor exposure factors (combined as the ISR factors defined earlier). This applies to either linear or point sources. Essentially, to construct a risk spectrum each of the hazard footprints is analyzed to assess the number of individuals exposed within each successive contour, commencing with the outermost or lowest probability contour. These data are then sorted according to groups associated with the same number of individuals, their frequencies are added to give a summary frequency for each group of equal number, and the probabilities are cumulated beginning with the lowest probability associated with the greatest number of people.

The collective risks associated with the generic NPS 12 pipeline segment adjacent to a freeway were computed based on the detailed calculations given in Appendix C. Figure 4.18 shows the resultant collective risks, with the trend line connecting the actual points calculated as described in Appendix C, and the large ellipse showing the region in which this collective risk would be expected to vary with variations of the speed, ADDT, and occupant parameters assumed in the calculation. As can be seen, all parts of the expected collective risk zone are within the insignificant collective risk area according to the spectrum shown.

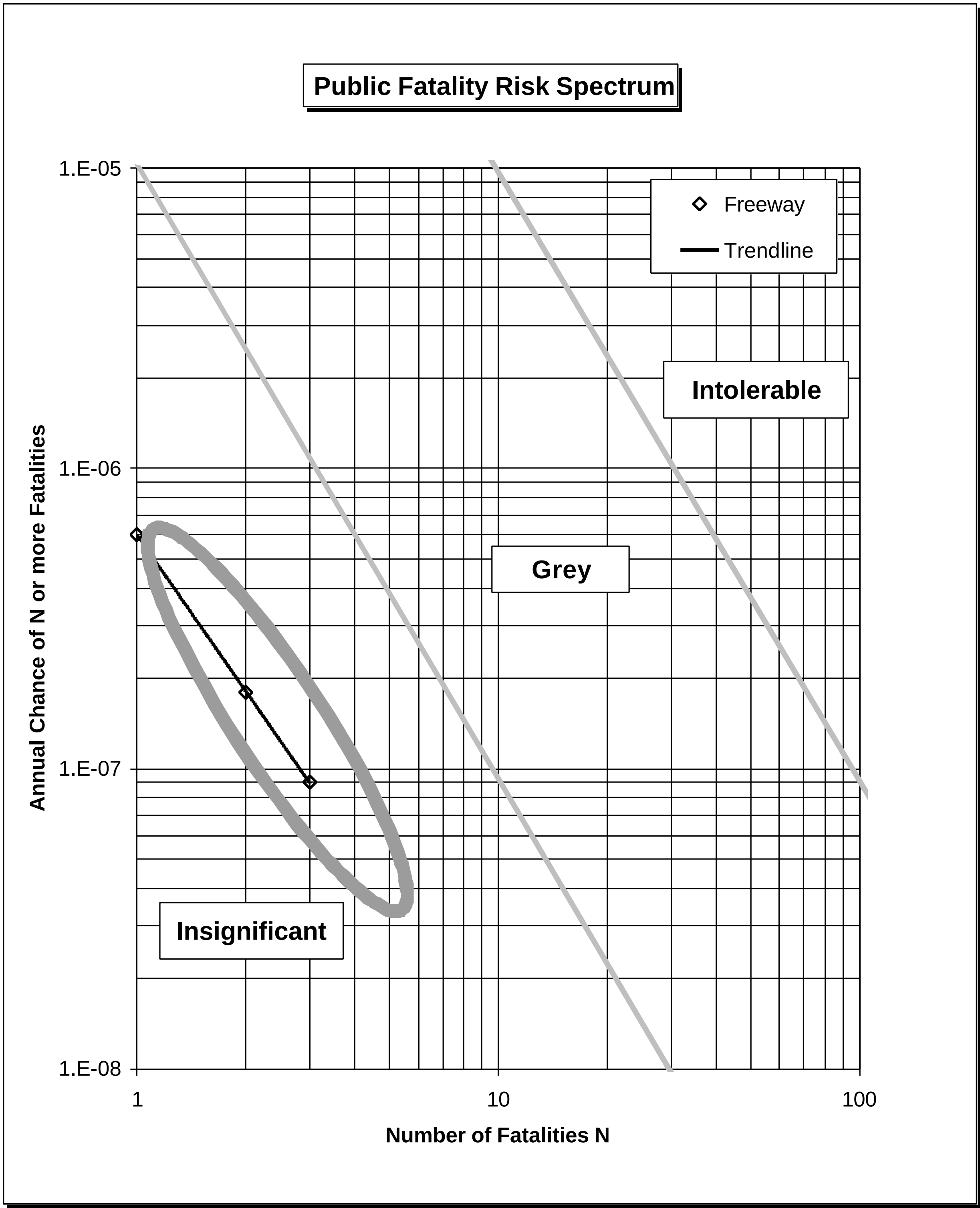


Figure 4.18
Collective Risk for Freeway

CHAPTER 5 – Risk and Impact Mitigation

5.1 General Approaches to Risk and Impact Mitigation

The objective of impact or risk mitigation is to reduce the ultimate impact or risk of a system to a level as low as reasonably practicable, while still permitting it to operate in a productive and cost-effective manner.

Risk mitigation can be addressed on two principal levels; namely, at the source and at the effect level. That is, we can reduce the frequency and volume of hydrocarbon releases and we can reduce the probability and magnitude of adverse consequences. Examples of pipeline source (or hazard) risk reduction include control of use and access to the right-of-way (R.O.W.) to help prevent third party damage, use of pipe with greater wall thickness to reduce corrosive and mechanical defect ruptures, or installation of a better system of line isolation valves to reduce accidental release volumes. Examples of consequence risk mitigation measures include pipeline route selection to minimize public exposure to accidental releases, enactment of land use zoning ordinances to restrict development in areas exposed to high consequence potential, and preparation and availability of appropriate emergency response measures to reduce accident effects. In [46] Muhlbauer lists a variety of pipeline risk factors and provides a risk ranking scheme for pipelines.

Both these levels of safety enhancement can be further classified under the general headings of strategic or tactical. Strategic measures are ones designed to avoid accidents. Tactical measures are ones designed to minimize the adverse effect of an accident if it does take place. Thus, R.O.W. control, extra engineering and construction measures, and zoning regulations would be considered as strategic, while measures such as pipeline segment isolation, automatic shutdown, or emergency response, are tactical measures. Similarly, impact mitigation can be addressed on corresponding levels, aimed at minimizing the occurrence or opportunity for impacts and reducing impact magnitudes if impacts do take place.

In this chapter, following this introductory section and Section 5.2, Section 5.3 describes in detail generic as well as specific pipeline risk mitigation measures, while Section 5.4 describes the impact mitigation process, and gives specific impact mitigation measures for the impacts identified as a result of the installation of pipelines in various locations in the road right-of-way.

Figure 5.1 summarizes the principal levels and types of risk mitigation measures in block diagram form, under the general categories introduced above and utilized in the balance of the discussion in this chapter. Further, the type of risk mitigation measures identified in the balance of this chapter by letter combinations "F" for Failure, "C" for Consequence, "S" for Strategic, and "T" for Tactical. For example, a Failure-Tactical measure such as automatic line isolation valves would be referred to as "F-T".

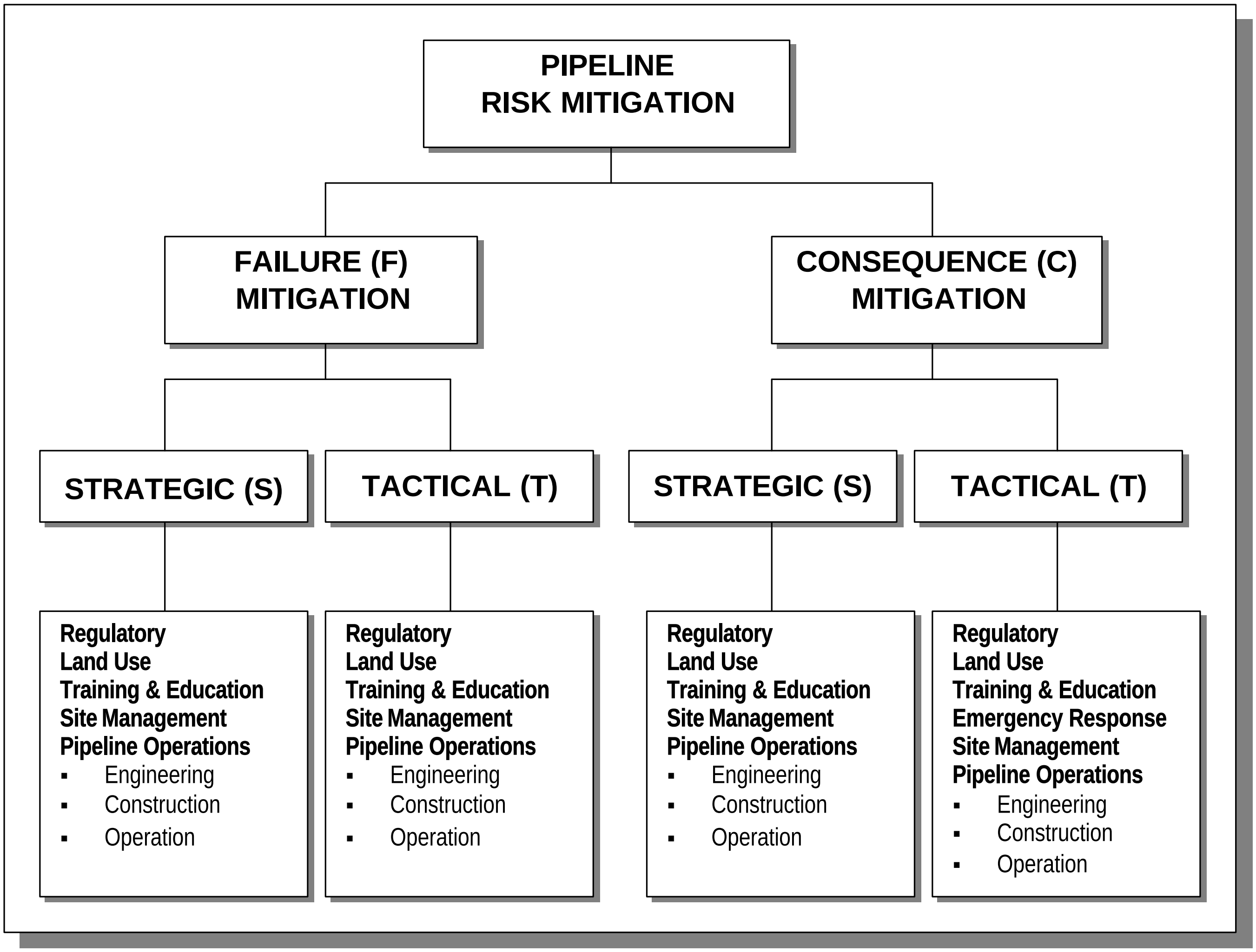


Figure 5.1
Schematic of Risk Mitigation Measures

5.2 Risk Mitigation Process

Once the risk and consequences of a particular system have been evaluated, the analysis conducted can be used as a basis for the development and selection of optimal risk mitigation measures. First, principal causes of rupture and major consequence factors are identified. For example, the leading cause of natural gas pipeline rupture is third party damages.

Consequences are intrinsically dependent on proximity and density of population. Clearly, a candidate for mitigation measures of ruptures and consequences are, respectively, reduction of third party damage and avoidance of high population density areas, respectively. Practical ways of achieving these mitigation measures are then developed. For example, third-party damage to pipelines can be reduced by R.O.W. signs, public education, mandatory excavation permits and proof of compliance, restrictive R.O.W. access, and excavation warning measures. Similarly, consequences to densely populated areas can be reduced by proper route selection and building setbacks for new pipelines. The effect on the risk of incorporation of each of the measures, individually, as well as in feasible combinations, is then conducted utilizing the procedures set out in Chapter 4; namely, hazard, frequency, consequences, and risk analysis. As will be seen, mitigated and unmitigated risks were assessed for each of the two case studies reported in Chapters 6 and 7, while only mitigated risks, assuming appropriate risk mitigation measures, were assessed for the general case described in Chapter 4.

In the present chapter, however, the treatment of risk mitigation measures is restricted to a qualitative presentation and discussion of regulated, special, and common industry practices for mitigating pipeline risks. In Chapters 6 and 7, dealing with the case studies, both unmitigated and mitigated risks are given, illustrating a more rigorous approach to the risk mitigation process.

5.3 Pipeline Risk Mitigation

5.3.1 General Discussion of Pipeline Failure Risk Mitigation

Pipeline rupture probability can be reduced in a variety of ways, ranging from relatively subtle provisions such as changes in design codes, development guidelines, or educational programs, to very direct measures such as restricting access to pipeline right-of-ways or increasing pipeline wall thickness or burial depth. The spectrum of risk mitigation measures, summarized under its principal classifications in Table 5.1 will be discussed in the balance of this section.

A one call system, development referral prior to approval, and certain land use controls constitute effective regulatory risk mitigation measures. The one call system is essentially one whereby a single phone number will provide information on pipeline locations for numerous different operators as well as receive information on intended excavations.

Table 5.1
Pipeline Failure Risk Mitigation Measures

MEASURE	STRATEGIC (S) TACTICAL (T)	DESCRIPTION
Regulatory	S	Design and construction codes and standards
	S/T	Public awareness program requirements
	S	Accident reporting
	S	One call system mandatory
	S	Proof of communication for R.O.W. excavation permit
Land Use	S	Design and develop to maximum practical setback
	S	Application referral system
	S	Future planning consider development, roadway expansion, and pipeline facilities
	S	Setbacks to avoid R.O.W. third-party damage
Training & Education	S/T	Train operator personnel in risk mitigation and pipeline operation
	S/T	Train road maintenance and construction personnel in pipeline safety and emergency response.
	S/T	Inform public of safety measures regularly
R.O.W. Management	S	Review easement agreements
	S	Prevent or remove encroachments
	S	Restrict third party access
	T	Have good access for emergency vehicles by locating pipelines and valves in unobstructed locations.
	S	Post signs on R.O.W.
	T/S	Regular surveillance and monitoring
	S	One call system participation
Engineering	S	Pipeline location selection to avoid hazards to pipeline.
	S/T	Low stress design
	S	Detailed stress analysis and flexibility analysis
	S	High quality external coating
	S	Appropriate material specifications

Table 5.1 - *Continued*
Pipeline Failure Risk Mitigation Measures

MEASURE	STRATEGIC (S) TACTICAL (T)	DESCRIPTION
Engineering *(continued)*	T	Valves optimal spacing
	S	Corrosion simulation analysis
	S	Cathodic protection system
	T	Automatic alarm and leak detection
	S	Greater burial depth
	S	Excavation warning, e.g., dye, tape, alarm
	S	Design for earthquake at fault intersections
	S	Design for expected floods, avalanches, or landslides including location, burial depth, and shielding and anchoring as necessary
Construction	S	Controlled burial temperature
	S	Stress relieve welds
	S	100% weld inspection; high quality radiography
	S	Pipeline out of service during pipeline or road construction
	S	Weld procedure strict
	S	Caliper pigs and magnetic logging
Operations	S	Low % of Maximum Operating Pressure
	S	Corrosion inhibitors
	S	Regular leak and cathodic system inspections
	S	Smart Pigging regularly and following any incident
	S	Elimination of free water
	S	Improved training, maintenance
	S	Control R.O.W. access by third-party
	T	Automatic leak detection, alarm, and shutdown system
	T	Emergency measures in place

Land use controls are generally exercised primarily by the local government. An application referral system requiring approval of an application by all parties including relevant pipeline operators facilitates risk mitigation. Future planning and zoning must consider both development and existing and potential pipeline facilities. Finally, setbacks to avoid right-of-way encroachments which could lead to third-party damage of pipelines should be utilized.

Training and education are probably among the most cost-effective mitigation measures possible. Cost of additional training for road or pipeline operating personnel is quickly recovered if only one major pipeline accident caused by operator error can be avoided as a result of that training. Likewise, specialized emergency training within the context of specific systems and their surroundings is important. Public awareness programs for residents can be conducted effectively and inexpensively through the regular mail-out of a brochure describing the pipeline facility, potential consequences of accidents, and ways in which the public can help avoid such accidents. In addition, such brochures can contain guidelines for emergency response by the public, referred to in the next section. However, the material must be presented in a manner that will not provoke unnecessary fear or panic which could impair understanding of the concepts and procedures. The public too has a responsibility, particularly when information sessions with voluntary attendance are made available in communities by operators or governments.

A properly coordinated right-of-way management program instituted by the operator can add significant risk mitigation at relatively low cost. Easement agreements to determine encroachments should be reviewed periodically, R.O.W.s inspected for encroachments, any encroachments found should be removed, and an on-going surveillance and monitoring program for the right-of-way should be conducted. Protection of right-of-ways can range from posting of warning and information signs to the erection of protective fencing and even pipeline shielding. Participation in a multi-operator one call system, as mentioned earlier, is another cost-effective right-of-way management risk mitigation measure.

The way in which the pipeline itself is designed, constructed, and operated has a significant impact on its probability of failure. A large number of pipeline operational risk mitigation measures have been identified, analyzed, publicly debated and implemented in various projects. The measures given in Table 5.1 under Pipeline Engineering, Construction, and Operations are a summary of strategic and tactical measures in each of the operation categories which can be implemented to reduce risk.

5.3.2 Pipeline Failure Consequence Mitigation

Consequence risk mitigation measures are divided into the same general categories as those pertaining to rupture risk mitigation. Consequence risk mitigation measures have the objective of reducing the adverse effects of a loss of containment if it does happen. They are directed at reducing the number of people exposed, at emergency response efficiency, at minimizing the amount of fluid leaked, and at avoiding public exposure through proper planning. The principal consequence risk mitigation measures applicable to natural gas pipelines are summarized in Table 5.2. Many of the measures are tactical because they are designed to reduce consequences once the accident has happened.

Principal regulatory measures, which can mitigate consequences, relate primarily to the requirements for emergency response plans and coordination of emergency response agencies. Local governments can strategically influence pipeline safety enhancement with appropriate land use control, separating commercial and residential development as much as possible from pipelines and pipeline right-of-ways. In particular, emergency facilities and high population density public facilities such as schools should be set back from pipelines at distances dictated by risk criteria.

Availability of all relevant information to the emergency response team, including both road and pipeline expertise, is essential for reducing accident consequences. Thus, the location of valve stations, emergency facilities, secondary hazard locations, right-of-way access routes, and demographic distributions are important data that should be maintained by both local governments and their emergency response agencies and operators in a readily accessible form. The level of awareness of the public is particularly important in an emergency response situation.

The information provided to the public (residents) and roadwork personnel by the pipeline operator in regard to evacuation plans, evasive tactics such as seeking shelter indoors, and other tactical actions may be very significant in reducing consequences in an emergency situation. Also, by keeping pipeline right-of-ways clear of any (except for pipeline markers) encumbrances, public awareness of the pipeline presence is increased. Further, local governments and local emergency agencies such as fire and police departments and hospitals should obtain all pertinent information on the facilities and possible emergency situations from the operator. Special assistance may be required from more senior levels of government with the provision of specialized training or high technology equipment necessary for handling certain emergencies.

The development and implementation of an emergency response plan is an essential element for successful tactical pipeline failure consequence reduction. Planning, establishment of a team and equipment, drills and training, and a high level of public awareness constitutes the basis for a successful emergency response capability. Right-of-way management procedures include maintenance of emergency access routes to the right-of-way and remote monitoring which could assist in minimizing the impact of a rupture by early detection, isolation, and quick deployment of a repair crew.

Optimal route or location selection is an effective means for reducing consequence risk. Whenever feasible, an effort should be made to minimize public exposure through routing to avoid high-density population distributions within the zone of influence of the pipeline. Failsafe isolation valves, their location and spacing, fully redundant emergency power and control backup systems, and leak detection and monitoring equipment, are other engineering measures used to reduce consequence potential. Operational measures relate primarily to generating a capability for an effective and immediate response to an emergency. This involves both operator and emergency agency response as well as public readiness through appropriate awareness programs.

Table 5.2
Pipeline Failure Consequence Risk Mitigation Measures

MEASURE	STRATEGIC/ TACTICAL	DESCRIPTION
Regulatory	T	Requirement for emergency response plan
	T	Public and personnel education
	S	Accident reporting
	T	Coordination of emergency response agencies
	S	Coordination between pipeline and road operators
Land Use	S	Land use control
	S	Setbacks for buildings and emergency facilities
	S	Site development to minimize exposure
	S	Require adequate setback
	S	Future planning for road expansion, zoning, and pipelines
Training & Education	S/T	Operator personnel training in emergency procedures
	S/T	Information to public on emergency procedures
	S/T	Coordination and training of emergency agencies
R.O.W. Management	T	Maintain emergency access routes and TTC readiness
	T	Surveillance and monitoring - early leak detection
Emergency Response	T	Emergency response plan
	T	Emergency response team and equipment
	T	Emergency training and drills
	S	ERP coordinated among road and pipeline operators and emergency agencies
	S	Clean chain of command on road and/or pipeline closure
	T	Public awareness of emergency response by evasion, evacuation, and tight shelter (applies to residents and road workers)
Engineering	S	Route selection to avoid exposed population
	T	Automatic shutdown and segment depressurisation to flare
	T	Failsafe isolation and block valves
	T	Plant isolation valves (at end of pipeline)
	T	Optimal isolation valve location & spacing
	T	Full emergency power & control backup systems
	T	Automatic leak detection
Operation	T	Emergency response plans in place
	S/T	Public awareness program
	T	Early warning system
	T	Emergency response team on call

5.3.3 Specific Risk Mitigation Measures for Pipelines in Road Right-of-Way

Based on the generic risk mitigation measures, mitigation of the specific hazards identified in the risk assessment is addressed. Table 5.3 shows these hazards, and suggests risk mitigation measures which can be utilized to reduce their effect on either failure frequency or consequence. In Table 5.3, several mitigation measures have been listed for some of the events. Only some of these measures may be most relevant. Clearly, for example, in the case of “rock scaling”, if the last (fourth) mitigation measure listed is implemented “avoid rock scaling area with pipeline route”, the other mitigation measures are no longer relevant.

In general, specific risk mitigation measures for any particular project are arrived at through a risk- and cost-benefit analysis. Depending on the level of risk posed, the optimal risk mitigation measure can be determined. For example, if risks are found to be in the intolerable region, then severe measures such as re-routing the pipeline should be considered. On the other hand, if risks are in the insignificant region, only due diligence in reducing them should be applied. If risks are found to be in the gray region, then, the most cost beneficial and effective risk mitigation measures should be developed through an optimization process.

5.3.4 Mitigation of Risks from Ground Disturbance in the Vicinity of Pipelines

The primary cause (roughly 70%) of natural gas pipeline ruptures is third party impact. Because pipelines in any of the road adjacent locations are exposed to an increased number of third party ground disturbance activities, risk mitigation of these activities is essential for the safety of the public and workers.

Although various guidelines and regulations exist to mitigate these risks [6, 47, 48], those proposed by the Edmonton Area Pipeline and Utility Operators Committee (EAPUOC) [29] are described here as they are among the most stringent of those reviewed, and are based on a good deal of experience. The procedure is illustrated in Figure 5.2 and summarized as follows for the rural case:

- All rural transmission pipelines are protected by a 30-metre control strip on each side of the pipelines.
- No excavation deeper than 0.3 metres may occur within 30 meters of the pipeline until the surface location of the line is marked by the owner/operator of the facility (see below). Once the surface location is marked, mechanical excavation is permitted to within 5 metres of the pipelines.
- No mechanical evacuation is allowed within 5 metres of the pipeline until the line has been hand exposed and positively identified. Hand exposure or excavation can be done with approved water or air jet or vacuum (Hydrovac) tools.
- Once the pipeline has been hand exposed and identified, mechanical excavation is permitted to within 60 cm (2 feet) of the pipeline. Mechanical excavation within 60 cm (2 feet) of the pipeline may only take place when the excavating is directly supervised by the pipeline owner/operator or their representative.

Table 5.3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
External Corrosion				
	Percolation	ALL	ALL	1-Ensure adequate protective coating for expected soil ph/moisture conditions
				2-Ensure adequate drainage control
				3-Conduct regular inspection pigging to detect incipient corrosion and permit repairs
	EMF	ALL	ALL	1-Ensure adequate Cathodic protection system and check regularly
				3-Conduct regular inspection pigging to detect incipient corrosion and permit repairs
	Salt Effects	ALL	ALL	1-Ensure adequate protective coating for expected salt concentrations
				2-Ensure adequate drainage control to minimize road salt drainage to p/l
				3-Conduct regular inspection pigging to detect incipient corrosion and permit repairs
Third Party Damage				
	Roadway Clearing - Debris, Rockfall	ALL	ALL	1-Identify pipeline locations from p/l markers if grading to max .3m ok
				2-Use care with excavators or loaders CPEP within 30m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Culvert Maintenance	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Supply, Remove, & Install Minor Culverts	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Minor Signs (Single Post)	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Major Signs	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Guide Posts	ALL	ALL	1-Locate p/l and use CPEP
				2-Ensure guide post holes do not exceed .5m depth if within 3m
	Installation of Extra or Repl. Power Poles	ALL	ALL	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Ditch Grading- Continous, Grader	ALL	2	1-Locate p/l and use CPEP
				2-Conduct depth of cover survey prior to commencement of grading of ditches
	Ditch Grading- Continous, Excavator	ALL	2	1-Ditch grading with excavator not permitted if p/l installed less than 2m below ditch invert
				2-Install p/l in alternate location
				3-Develop safe ditch grading procedure and p/l installation method
	Snow Ploughing	1	ALL	1-Locate p/l (from markers) and use care if over p/l
	Rock Scaling	1	ALL	1-Avoid locating p/l in frequent (<20yr) rock fall locations
				2-Use nets/deflectors to deflect rockfalls from p/l locations
				3-Protect p/l with grade surface protectors -slabs, plates adequate to absorb rock fall impacts
				4-Design and install p/l for maximum rock fall impact resistance
	Mud Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Land Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Washout Repairs	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Major Section Repair, Excavation of Embankment	5	ALL	1-Locate p/l and use CPEP

Table 5.3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
Third Party Damage - *Continued*				
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
				5-Conduct full scale p/l resistance/integrity tests for expected dynamic compaction methods
				6. P/l should be located at depth where it is safe from heavy equipment/vibratory compaction
	New Culvert X	1	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Culvert II	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Utility X (e.g., FOC)	ALL	ALL	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
	New Utility II	ALL	1,2	1-Locate p/l
				2-Use CPEP within 2m of p/l
	New Minor Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Major Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Power Line	ALL	ALL	1-Locate p/l and use CPEP
	New Ditch	ALL	1	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
			2	1-No new ditch over 1.2m cover p/l location
				2-Relocate p/l to alternate location
	New Guard Rail (Unmitigated)	ALL	ALL	1-Locate p/l and use CPEP
				2-Plan ahead and install p/l in location 3 or 4 where guardrail work expected
	New Guard Rail (Mitigated)	ALL	1,2	1-Locate p/l and use CPEP
	New Driveway	ALL	ALL	1-Locate p/l
				1-Locate p/l and use CPEP
				3-Plan ahead-Install new access grade at time of p/l installation
	Railway Crossing Accident Derailment	ALL	ALL	1-Install p/l as far as possible from railroad, preferred >20m to avoid derailed train impact
				2-Implement derailment ERP, including immediate p/l shut in and blowdown
Earth Movement				
	Vibration from Traffic	1	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Conduct regular inspection pigging to detect incipient damage and permit repairs
	Frost Heave	3	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Drainage control to avoid water/ice buildup in vicinity of p/l
	Landslide	5	ALL	1-Locate outside landslide zone
				2-If in landslide zone design and install p/l for maximum landslide survival
				3-Shut in and blowdown if landslide warning red alert
	Flood	10	ALL	1-Locate outside flood zone
				2-If on flood plain design/install to maintain integrity in max flood
				3-Shut in and blowdown if flood buildup predicted and underway

Note re CPEP: ***If excavation more than 0.3 m deep planned:***

1. Within 30 m of p/l, contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

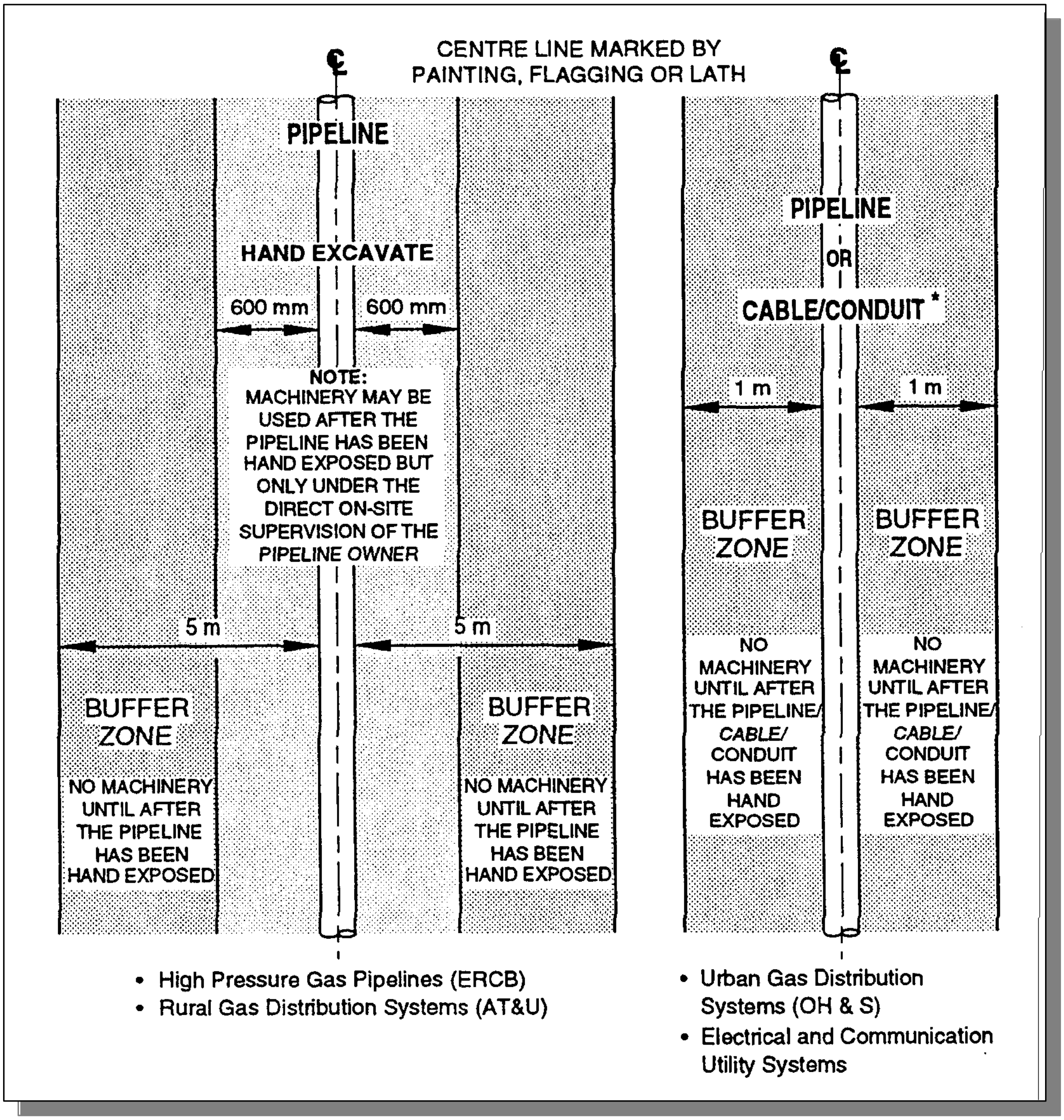


Figure 5.2
Schematic of Ground Disturbance Risk Mitigation Measures or CPEP

- The pipeline owner/operator may choose to exceed the above mentioned minimum standards, and if that is the case pipeline and road workers are expected to adopt the higher standards

The following applies to locating and exposing the pipeline specifically in Alberta:

- Before any work begins within 30 metres of the pipeline, it must be properly located. First contact should be Alberta 1st Call, the primary organization regarding underground installations in the province (or its counterpart elsewhere). If installations are not covered by Alberta 1st Call, contact the respective utility company at least 48 hours (2 working days) before starting construction and arrange to have their facilities located. All other facilities that may be affected by a ground disturbance must also be accurately located.
- To avoid unnecessary expenditures, the person making the contact must distinguish between a "rush" job and an emergency. Construction cannot start until all utilities have been located, so locating work should be planned and coordinated to avoid delays in the actual start of construction.
- Underground facilities must be located by a person designated or approved by the owner. This individual must be trained in the proper use of location equipment. Location technique includes the use of plot plans, the 'conductive mode' of pipe locating, and visual evidence.

5.4 Impact Mitigation

5.4.1 Impact Mitigation Process

The impact mitigation process is analogous to the risk mitigation process, and can be qualitatively described through virtually the same concepts. Essentially, once impacts have been identified, as was done in Chapter 3, the optimal impact reduction measure should be developed. Where impacts are intolerable, consideration should be given to altering the project configuration, in this case, the pipeline location. Where impacts are low or moderate only, adjustments to further reduce them either through reconfiguring the pipeline installation or through adjusting the operation or activity should be considered. Once the adjusted or mitigated configuration has been defined, a re-evaluation of the impact should be carried out to assess the benefit from the reconfiguration or mitigative measure. Clearly such a detailed iterative process on a generic level would loose some significance here, and in any case lies well beyond the intended scope of work.

5.4.2 Specific Impact Mitigation for Pipelines Located in the Right-of-Way

Table 5.4 summarizes specific suggestions for mitigating the impacts which were screened out for impact evaluation as described in Chapter 3. The mitigation measures suggested in general are intended to be practical recommendations on possible ways, often more than one, for reducing either the economic or operational impact of the activity/pipeline synergy that had been identified earlier. As for the risk mitigation measures, the impact measures to be defined ultimately depend on the specific situation and should include consideration of the actual amount of impact to be reduced, the flexibility of the road system on the one hand and the pipeline installation and operation on the other, and the resultant cumulative benefit to be gained through mitigation.

Table 5.4
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
	ROAD ACTIVITIES			
A	**NORMAL ROAD OPERATION**			
		ALL	ALL	None
B	**ROAD MAINTENANCE**			
B.1	***Routine Maintenance***	ALL	ALL	None
B.2	***Road Surface Maintenance***	ALL	ALL	None
B.3	***Roadside Maintenance***	ALL	ALL	None
B.5	***Roadside Repairs and Installations***			
B.5.1	Supply, Remove, & Install Culverts-x	ALL	1.2	1-Use of culvert liner inside existing culvert would require no additional mitigation
		ALL	1,2	2-If culvert replaced, locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within .6m of p/l, use CPEP
		ALL	1,2	3-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	4-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
B.5.1	Supply, Remove, & Install Culverts-II	ALL	1,2	1-Use of culvert liner inside existing culvert would require no additional mitigation
		ALL	1,2	2-If culvert replaced, locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within .6m of p/l; use CPEP
		ALL	1,2	3-Plan ahead - locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	4-Avoid p/l in loc 2 if culvert replacement anticipated
B.5.2	Installation of Minor Signs (single post)	ALL	1	1-Locate p/l min 2m from minor sign location (ie 6.5 m from edge of road); adopt CPEP
B.5.3	Installation of Major Signs	ALL	1	1-Locate p/l min 2m beyond outside post of major sign; adopt CPEP
B.5.6	Installation of Guard Rail	ALL	1	1-Locate p/l min 2m beyond guardrail post outside face; adopt CPEP
		ALL	1	2-Increase p/l cover to be min .5 m below bottom of post and conduct cover survey (daylight) before drilling and use auger depth governor when drilling
				3-Use CPEP
B.5.12	Ditch Grading – Continuous - Backhoe	ALL	2	1-Avoid ditch location 1 for p/l where ditch grading anticipated
		ALL	2	2-Locate top of p/l in loc 2 min 2m below ditch invert and conduct cover survey before grading
B.5.11	Installation of Extra or Replacement Power Poles	ALL	ALL	1-Locate p/l min 5m from existing power line, use CPEP
B.6	***Winter Operations***			
B.6.2	Snow Ploughing	ALL	1,2	None
B.7	***Mountain Operations***			
B.7.1	Rock Scaling	ALL	ALL	1-Avoid locating p/l in continuous rock fall locations
				2-Design and install pipeline to withstand maximum rock drop impact
C	**ROAD CONSTRUCTION**			
C.1	***Road Surface***			Mitigation depends on extent of 3R/4R programme
C.1.2	Major Section Repair/Resurfacing	ALL	1,2	1-Locate p/l in location 3
C.1.3	Add Climbing/Passing Lane	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.4	Add Turn Lane	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.

Table 5.4
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
C.1.5	Widen Road	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.6	Pave Shoulder	ALL	1	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.7	New Exit/Entry	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.8	New Overpass	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.9	New Underpass	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
C.1.12	Blasting for Wider Road Surface	ALL	ALL	1-Use blast mats and take p/l out of service during blasting operations
C.2	***ROW (Off Surface)***			
C.2.1	New Culvert X	ALL	1,2	1-Locate new culvert invert .5m minimum from top (or bottom) of p/l and use CPEP
		ALL	1,2	2-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	3-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
C.2.2	New Culvert II	ALL	1,2	1-Locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within 2m of p/l
		ALL	1,2	2-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	3-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
C.2.3	New Utility X (e.g., FOC)	ALL	1,2	1-Plan ahead-install x utility conduits during p/l construction
				2-Install p/l with sufficient depth to clear future utility by .5m vertical and use CPEP
C.2.4	New Utility II	ALL	1,2	1-Install new utility in common trench during p/l construction; use CPEP
C.2.5	New Minor Sign	ALL	1,2	1-Locate p/l min 2m from minor sign location (ie 6.5 m from edge of road); use CPEP
C.2.6	New Major Sign	ALL	1,2	1-Locate p/l min 2m beyond outside post of major sign; use CPEP
C.2.7	New O/H Sign Bridge	ALL	1,2	1-Locate footings min 2m from p/l; use CPEP
C.2.9	New Power Line	ALL	1,2	1-Locate new power line min 2m from p/l; use CPEP
C.2.10	New Ditch	ALL	1,2	1-Avoid ditch location 1 for p/l where new ditch anticipated
C.2.11	New Guard Rail	ALL	1	1-Locate p/l min .6m beyond guardrail post outside face; use CPEP
		ALL	1	2-Increase p/l cover to be min .5 m below bottom of post and conduct daylighting cover survey before drilling survey and use auger depth governor when drilling
C.2.12	New Driveway/Access road	ALL	1,2	1-Plan ahead-locate p/l for min 1.2 m clearance below max excavation depth
				2-Reinforce p/l backfill and bedding to accept localized paving
				3-Design driveway/ access to give 2m clearance from grade to top of p/l
	PIPELINE ACTIVITIES			
D	**NORMAL PIPELINE OPERATION**			
D.1	Pipeline Remotely Operated	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
D.2	Pipeline Failure	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
D.3	Suspected Pipeline Damage	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
E	**PIPELINE MAINTENANCE**			
E.1	Pipeline Repair (Major)	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F	**PIPELINE CONSTRUCTION**			
F.13	New Pipeline Construction	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.1	Looping	ALL	ALL	1-Follow Temporary Traffic Control Guidelines

Table 5.4
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
F.2	Tap Away from Road	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.3	Tap Across Road	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
		ALL	ALL	2-Use boring rather than open trench
F.4	New Valve	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.5	Valve Replacement	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.6	P/l Section Replacement	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.7	Lateral Away from Road	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.8	Lateral Under Road	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
				2-Use boring rather than open trench
F.9	New Cathodic Protection	ALL		1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.10	Instrument Installation	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.11	Blasting for New Trench	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.12	Hydrotesting	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
G	**LONG TERM**			
G.1	ROW Usability			1-Install any parallel utilities in common trench at time of p/l construction
G.2	Road System Structural Integrity			1-Assure optimal backfill/compaction procedure in p/l trench
				2-Conduct geotechnical investigation prior to p/l installation to avoid integrity problems

<u>Note re CPEP:</u> If excavation more than 0.3 m deep planned:

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

CHAPTER 6 – Case Study #1 – Nova Scotia

6.1 General Description of Case Study #1

Sempra Atlantic Gas (Sempra) proposes to install a natural gas distribution system in Pictou County, Nova Scotia, generally as located in Figure 6.1. Currently Sempra proposes to locate the majority of the high-pressure distribution lines within the road shoulders of provincial roads and highways. As a basis for this case study, the proposed route from the Maritimes & Northeast Pipeline (M&NP) Lateral along Highway #4 toward Trenton and New Glasgow has been analyzed. Figure 6.2 shows a more detailed drawing of a typical alignment showing the pipeline in Locations 1 and 2.

A risk and impact assessment was carried out on the basis of the NPS 6 (very-high pressure) pipeline generally distributed between two segments, with one segment approximately 13.6 km and the second segment 2.6 km as described in the natural gas distribution system drawings series PI-101 [61] and PI-201 [61]. Road characteristics were obtained from road section details transmitted by NSTPW. It should be noted that data were not available on isolation valve location, leak detection systems, response time, and general design information as would appear in a design basis memorandum, as well as risk and impact mitigation measures in the form of emergency response plans, pipeline protection, and other details. However, the results given here for both impact and risks are expected to give a good indication of qualitative and quantitative trends in these two areas, and should form a good foundation for risk and impact management and decision making in regard to the proposed project.

The following principal parameters characterize the case study and were used as a basis for the impact and risk assessment:

- Pipelines are proposed in Locations 1 and 2.
- Pipelines will be NPS 6, Class 2 construction, with a maximum allowable operating pressure of 6,900 kPa or 1,000 psi.
- The AADT of the road system can be expected to be in the order of 5,000 vehicles per day.
- The length of the pipeline as proposed is approximately 13.6 km for one segment described in drawings PI-101 and 2.6 km for those in PI-201.

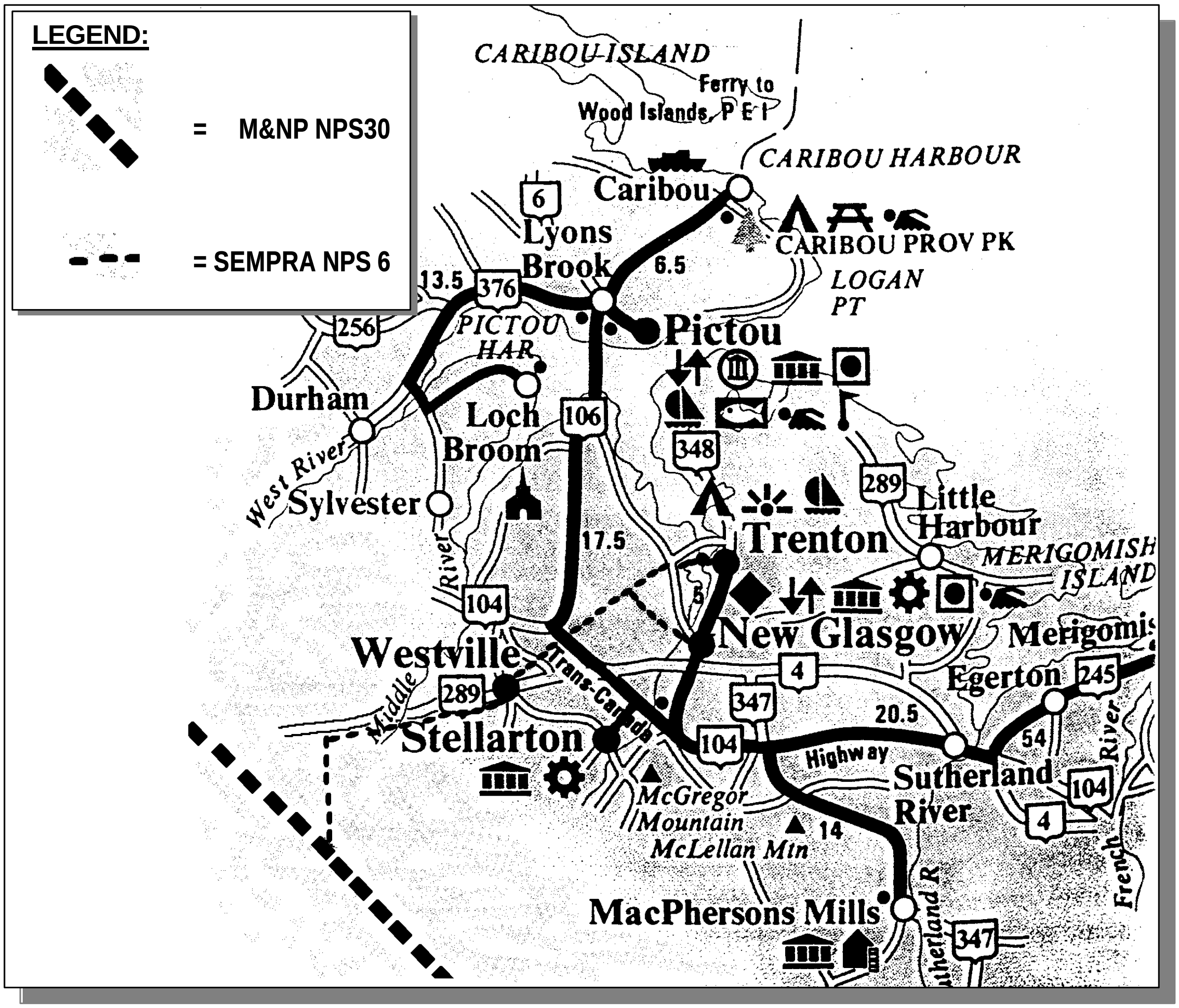


Figure 6.1
General Location

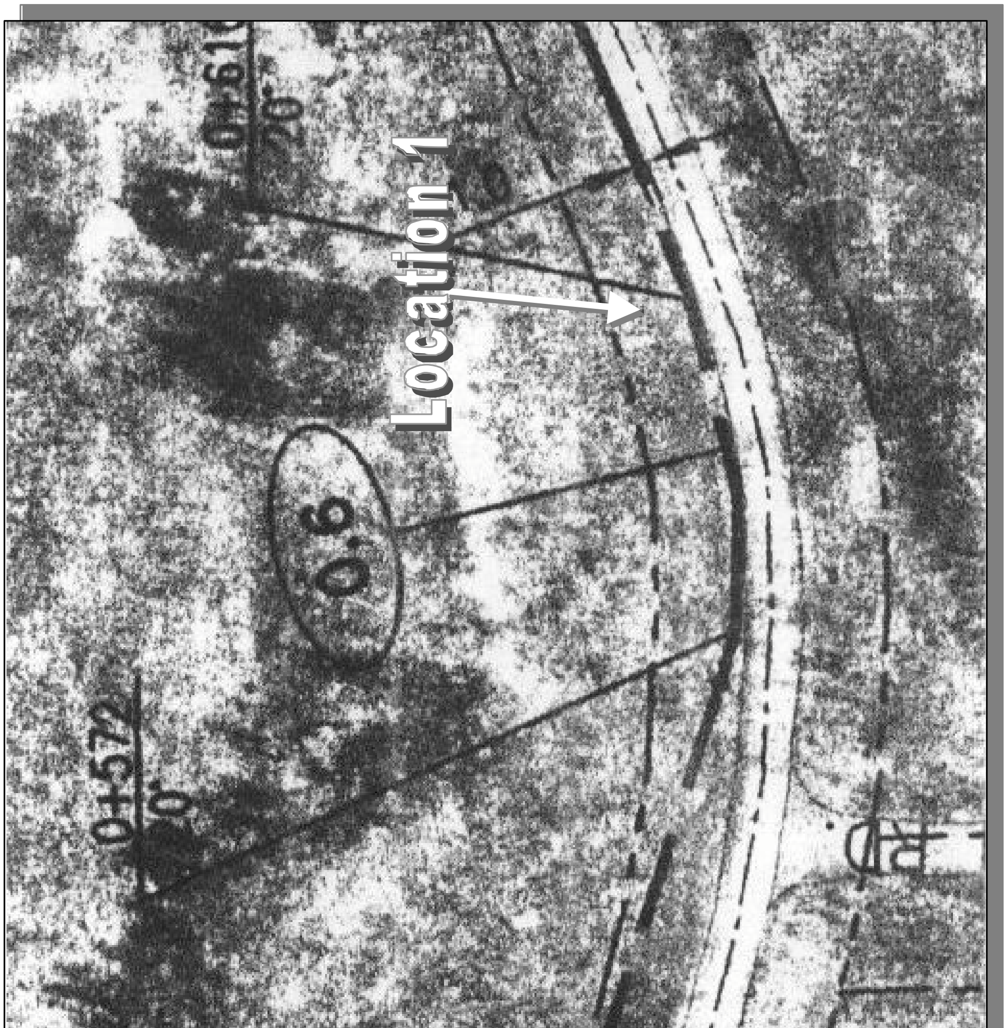


Figure 6.2
Typical Location 2 and 1 Alignment

6.2 Operational and Economic Impacts

6.2.1 Quantification of Impacts

As was described in Chapter 3, a screening analysis of impacts of the pipeline location on road activities was first carried out. This detailed screening analysis is given in Appendix B. Again, as was done previously, only the impacts which were ranked high or medium were subjected to more detailed quantitative assessment, with cost estimates where applicable. Table 6.1 gives the results of this assessment. The assessment was based on the cross section shown in Figure 6.3, with selected variations in order to reduce economic impacts.

To reduce economic impacts, the following items apply for this case study:

- In the installation of new guard rail (C.2.11), estimates were carried out both for the scenario shown in Figure 6.3, with a 0.4 m separation, as well as for a mitigated situation where the guard rail is located more than 2.0 m from the pipeline. It is understood that the latter configuration simply may not be feasible due to the restricted width of the shoulder, but this would have to be verified through a site visit or detailed investigation of the road cross section and its variation over the alignment.
- Similarly, activity C.1.2, major section repair which was initially assessed to be of high impact due to the requirement for static compaction only, has been downgraded to medium impact with dynamic compaction allowed to within 2 metres of the pipeline, and static only allowed in the 4 metre zone straddling the pipeline.
- Another major potential impact is ditch grading (B.5.12), which is normally done with a backhoe in Nova Scotia. As will be seen from the risk assessment, this activity as currently done, for Location 2 with 1.2 metre cover, would result in excessively high risks. Other than not locating the pipeline in Location 2, where ditch grading may be anticipated, it was estimated that the use of a Hydrovac or air tool for the ditch grading would be necessary with the pipeline in that location, resulting in significant economic impact (1,900% increase). However, more feasible conditions of pipeline cover (2 metres) and ditching procedure may be possible.

Finally, economic impact to the pipeline operator would undoubtedly result from the proposed pipeline installation. However, there would be both benefits and liabilities, and their exact nature is not possible to estimate without a detailed site-specific assessment. The following factors would generally benefit the pipeline costing:

- The availability of a long, continuous unencumbered easement as opposed to the need to assemble the right-of-way from a mixture of private and public land ownership.
- Easy access for inspection, maintenance and repairs.

Table 6.1
Pipeline Location Cost Impact Case Study #1

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	NS		RLF	0.987
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading - Continuous - with Backhoe	ALL	2	M-H	Use hydrovac or hand excavation	1m3	5.92	112.52	118.44	1900
B.5.12M	Ditch Grading - Continuous - with Grader	ALL	2	M	Use caution over p/l	1m3	6.91	0.49	7.40	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***				None					
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R,4R Projects)***									
C.1.2	Major Section Repair, Excavation of Embankment	ALL	1&2	M	CPEP Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add Climbing/Passing Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.12	Blasting for Wider Road Surface	ALL	ALL	M	Pipeline relocation borne by p/l operator					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading; 3m3 CPEP;	ea	2831.70	858.69	3690.39	30
			2	H	2m3 CPEP	ea	2831.70	228.00	3059.70	8
		GH	1	H	Drop invert .5m, 30m3 extra grading; 3m3 CPEP;	ea	1173.54	922.85	2096.39	79
			2	H	2m3 CPEP	ea	1173.54	314.85	1488.40	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2311.55	434.28	2745.83	19
			2		25m culvert; locate p/l	ea	2311.55	216.15	2527.71	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench;daylight p/l CPEP		1933.53	2171.40	4104.93	112
C.2.4	New Utility II	ALL	1&2	H	Assume im separation new NPS 12 p/l per Fig. 3.6	m	138.18	119.43	257.61	86
C.2.5	New Minor Sign	ALL	1&2	M	4 signs/km, total 100, scan p/l and hydrovac 100 holes	100	22745.42	5048.51	27793.92	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	65684.85	8142.75	73827.60	12
C.2.7	New O/H Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	78960.00	4935.00	83895.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	246750.00	9870.00	256620.00	4
C.2.9	New Power Poles	ALL	3	M	3km, 100 std. wood posts at 30m; locate p/l and hydrovac holes	100	38542.35	14656.95	53199.30	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by					0

Table 6.1
Pipeline Location Cost Impact Case Study #1

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	NS		RLF	0.987
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
					p/l operator					
C.2.11	New Guard Rail	ALL	1	M	1 km,10 sections @ 100m over 25km; loc p/l and hydrovac holes	1km	73710.15	13590.99	87301.14	18
C.2.12	New Driveway - Gravel	ALL	ALL	M	Locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1139.99	552.72	1692.71	48
C.2.13	New Road Bridge	ALL	ALL	M	Design to suit; locate p/l hydrovac 5m3	ea	246750.00	1974.00	248724.00	1
C.2.14	Borrow Pit Access Driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1139.99	750.12	1890.11	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline Failure	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
D.3	Suspeected Pipeline Damage	ALL	ALL	H	Road closure-2-8hr and lane closure TTC 8-24hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline Repair (Major)	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure - TTC-8-24 hrs					M
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (New Parallel Pipeline) - 10 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 2-4 wks					H
F.2	Tap with Lateral Directed Away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.3	Tap with Lateral Directed Under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.6	Section Replacement - 1 km	ALL	ALL	M	Road closure - 4-12 hr and lane closure TTC 1-2wk					H
F.7	Lateral Away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.8	Lateral Under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic protection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					H
F.10	Instrument Installation	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.11	Blasting for New Trench	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.13	New Pipeline Construction - 25 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 1-2 months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1 - Settlement; Yr 2-3 - Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

Note re CPEP: ***If excavation more than 0.3 m deep planned:***

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

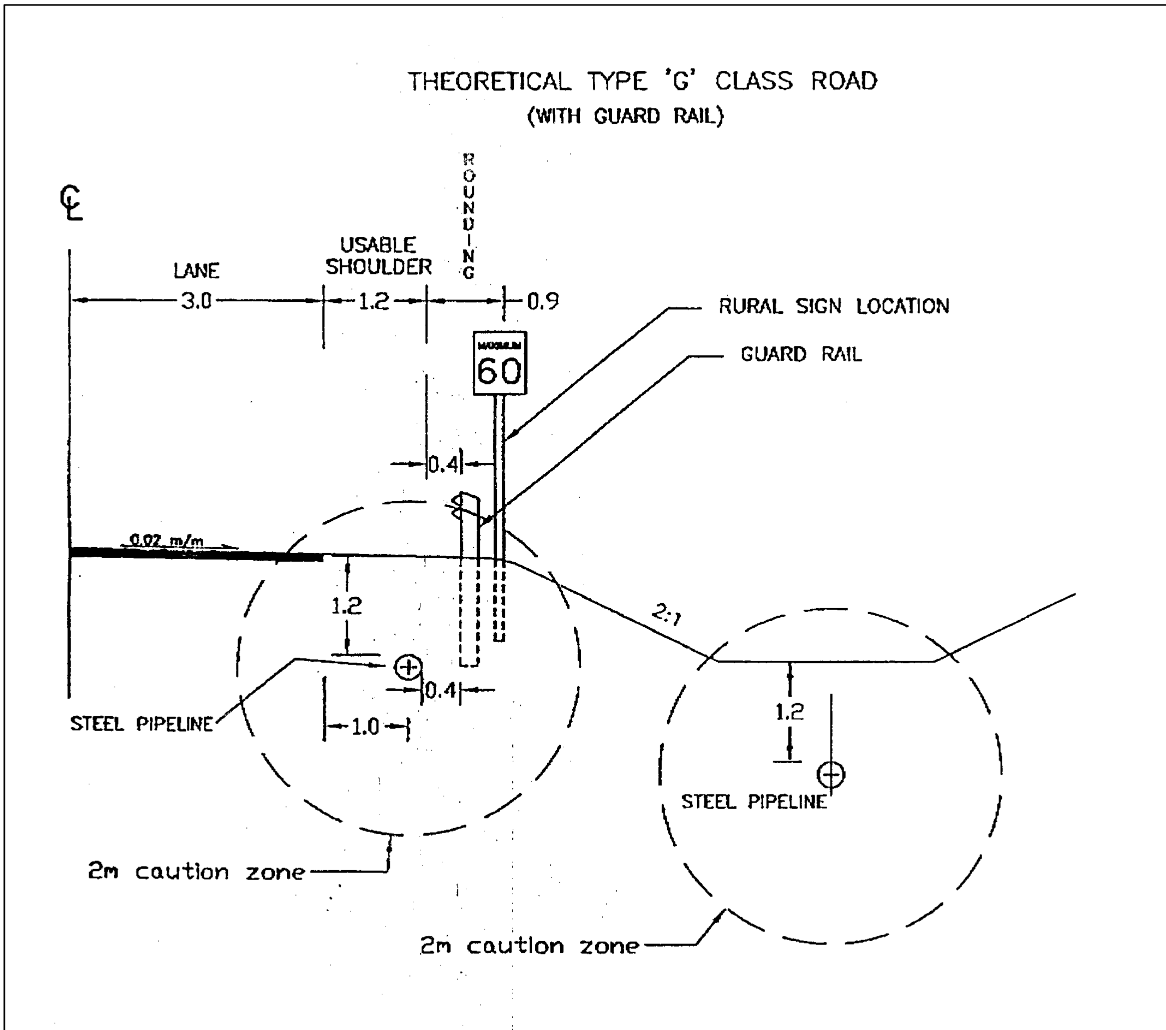


Figure 6.3
Typical Construction Showing Locations 1 and 2

- Easy surveillance conditions.
- Uniform soil properties, generally on disturbed, properly graded and compacted soil.

The following are likely to be liabilities:

- Costs of easement and easement maintenance to the pipeline operator levied by the right-of-way owner.
- Constrained initial construction or reconstruction due to the narrowness of the right-of-way and potential interference with road operations.
- Relocation of pipeline if road widening or reconstruction is required.
- Potential liability for public and property damage in case of a pipeline accident.

6.3 Public Risk Assessment

6.3.1 Unmitigated Risk Assessment

For Case Study #1, both a mitigated and an unmitigated risk assessment was carried out. This section describes the unmitigated risk assessment. In the unmitigated risk assessment, the predominant risk source was the continuous ditch grading utilizing a backhoe, with the pipeline located in Location 2, under the ditch. Table 6.2 summarizes the roadway effects on the pipeline failure rate. As can be seen under Location 2, the third party damage “ditch grading – continuous” and for Location 1 “New Guardrail” result in a noticably high contribution, orders of magnitude higher than the other activities. This high contribution is based on the input of pipeline damage probability of 0.5 or 50% per kilometre year for ditch grading and 10% per kilometre for new guardrail installation. The ditch grading damage probability was arrived at in discussions with NSTPW personnel. Figure 6.4 graphically depicts the effect of this input on the rupture rate variation for Location 2.

In order to adequately characterize the risks to appropriate individuals from these ditching operations, an additional type of individual for risk evaluation, the “ditcher operator” has been introduced with the exposure as shown in Table 6.3.

Conduct of the usual computations based on the above inputs to obtain risk transects results in a risk transect as shown in Figure 6.5. Clearly, the ditcher operator risks are quite high, at a value of approximately 3 in 100,000 per year, considerably in excess of the 1 in 1 million per year threshold identified earlier. In addition, risks to nearby residents exceed the threshold to approximately 230 m from the pipeline. Accordingly, the ditch grading operation, if unmitigated, exhibits high risks and requires risk mitigation and management.

The unmitigated risk assessment for Location 1 are similar to those for Location 2.

Table 6.2
Case Study #1 – Roadway Effects on Pipeline Failure Rate – Worst Case

CS1W ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris, Rockfall	2	25	1	km	1.00E-03	1.00E-03	2.00E-05
		Culvert Maintenance	2	25	10	item	1.00E-03	1.00E-02	2.00E-04
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-02	1.00E-01	8.00E-05
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Major Signs	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Ditch Grading - Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-03	2.00E-03	1.60E-06
		Major Section Repair, Excavation of Embankment	100	25	0.5	km	1.00E-02	5.00E-03	2.00E-06
		New Culvert X	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Culvert II	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility II	50	25	1	item	1.00E-01	1.00E-01	8.00E-05
		New Minor Sign	1	25	2	item	1.00E-02	2.00E-02	8.00E-04
		New Major Sign	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Ditch	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Guard Rail	5	25	5	km	5.00E-01	2.50E+00	2.00E-02
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**2.77E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							2.77E-03
		Unknown Total							**2.77E-03**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing - Debris, Rockfall	2	25	1	km	1.00E-03	1.00E-03	2.00E-05
		Culvert Maintenance	2	25	10	item	1.00E-03	1.00E-02	2.00E-04
		Ditch Grading - Localized	1	25	1	km	1.00E-02	1.00E-02	4.00E-04
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-02	1.00E-01	8.00E-05

Table 6.2
Case Study #1 – Roadway Effects on Pipeline Failure Rate – Worst Case

CS1W ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Major Signs	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Ditch Grading - Continous	10	25	25	km	5.00E-01	1.25E+01	5.00E-02
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-03	2.00E-03	1.60E-06
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		New Culvert X	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Culvert II	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility II	50	25	1	item	1.00E-02	1.00E-02	8.00E-06
		New Minor Sign	1	25	2	item	1.00E-02	2.00E-02	8.00E-04
		New Major Sign	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Ditch	10	25	5	km	1.00E-01	5.00E-01	2.00E-03
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**5.98E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							5.99E-03
		Unknown Total							**5.99E-03**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**7.06E-04**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05

Table 6.2
Case Study #1 – Roadway Effects on Pipeline Failure Rate – Worst Case

CS1W ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							7.30E-05
		Unknown Total							**7.30E-05**

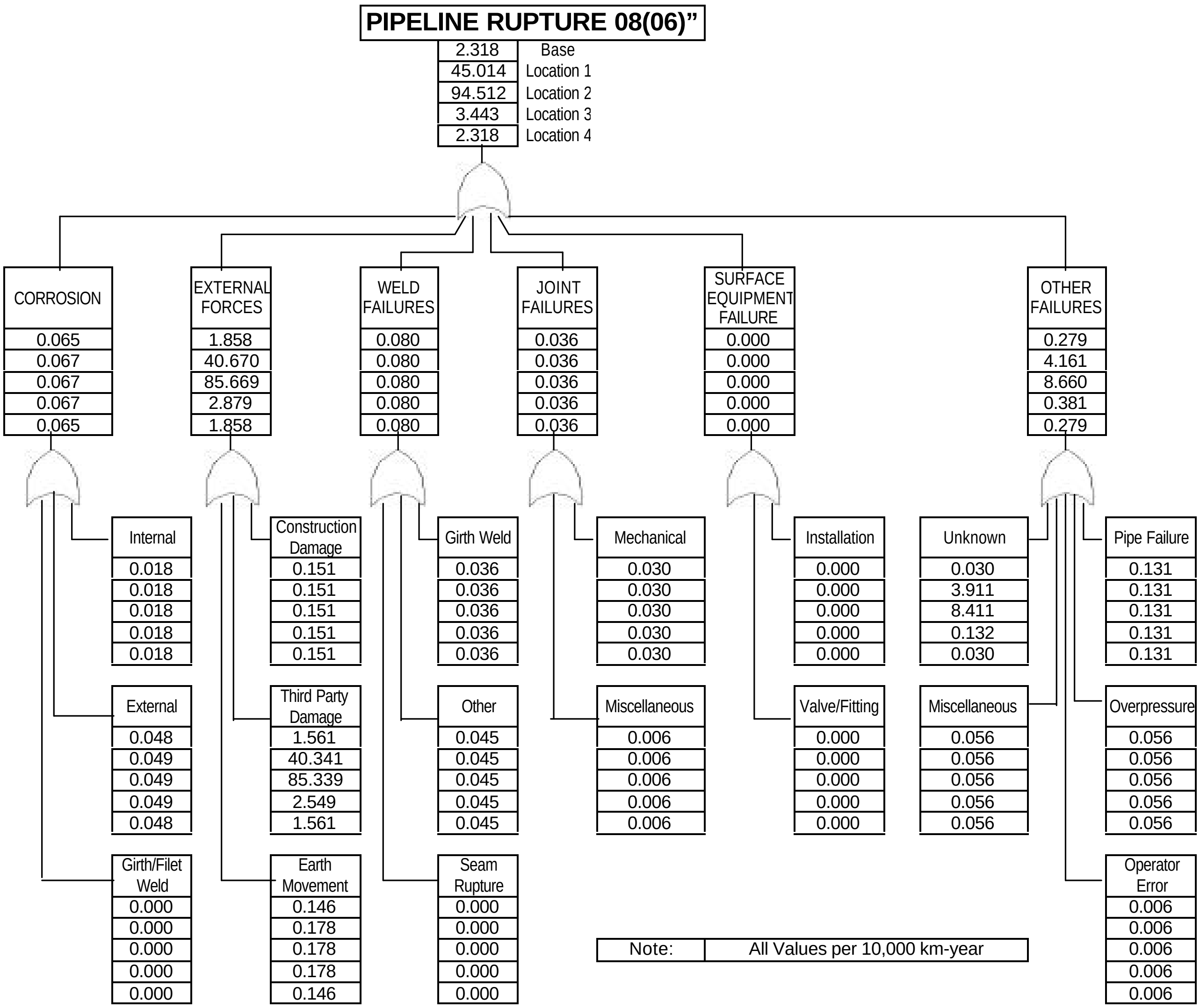


Figure 6.4
Pipeline Rupture Rate Variation Fault Tree by Location – 08(06)"

Table 6.3
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E	Nt	Nd	Nw	L	V	LISRF	IF	OF	Sfi	Sfo	ISRF
				h/day	trip/day	days/week	weeks/year	km/trip	km/h						
1	CS 1 Type G	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.0020
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.0005
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.0075
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.0877
		5	Ditcher Operator	10	n/a	5	50	n/a	n/a	0.2862	0.00	1.00	0.1	1.0	0.2862
		6	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.1583

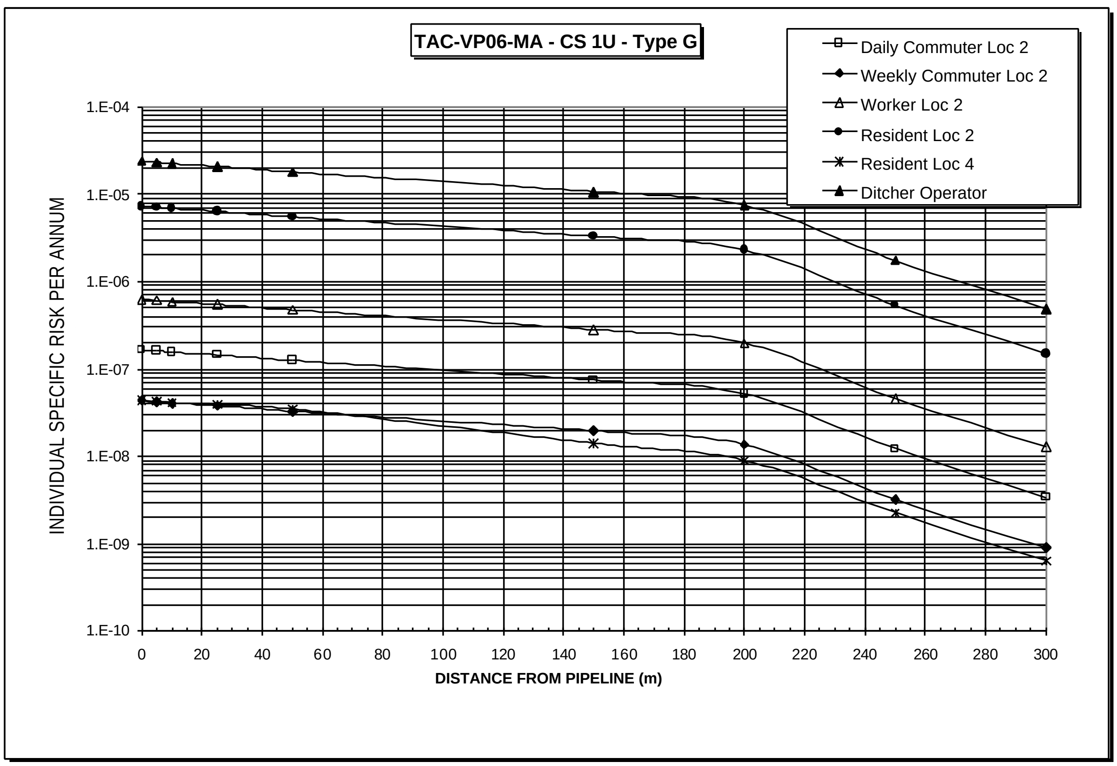


Figure 6.5
Unmitigated Transects CS1U VP06 – Location 2

6.3.2 Risk Mitigation

In general, the risk mitigation measures identified earlier in Chapter 5 would be applicable in order to reduce risks to as low a level as practicable.

The problem of ditching, however, requires special attention and must be mitigated. Possible ways of mitigating the ditching risk, other than the obvious one of not locating the pipeline below the ditch, may be as follows:

- A greater burial depth with two or more metres of cover.
- Protection of pipeline under ditch with casing, plate, or concrete slab to avoid impact from trenching machine.
- Modification of ditch grading procedure to use air or Hydrovac tools as costed in operational impacts Section 6.2.

6.3.3 Mitigated Risk Assessment

In the mitigated risk assessment, all pipeline damage probabilities have been reduced to a level which can be achieved if industry standard risk mitigation measures as well as other appropriate measures for operation and construction in the vicinity of high-pressure natural gas pipelines are implemented and effectively utilized throughout the lifecycle of the pipeline installation and associated road operation.

Figure 6.6 gives the mitigated ISR transects for Location 1, the pipeline location in the shoulder. Again, Individual Specific Risks are given for the complete range of categories of public affected. Figure 6.7 gives the mitigated Individual Specific Risk transects for Location 2, the location under the pipeline. As can be seen, if appropriate mitigation measures are taken for the two locations, risks are generally in the insignificant category.

6.3.4 Collective Risks

Figure 6.8 gives the risk spectrum for both the mitigated and unmitigated situation for Case Study #1. For the unmitigated risks, the risk region is located entirely in the gray or cost-benefit area indicating a need to reduce risks. For the mitigated case, risks are in the insignificant area.

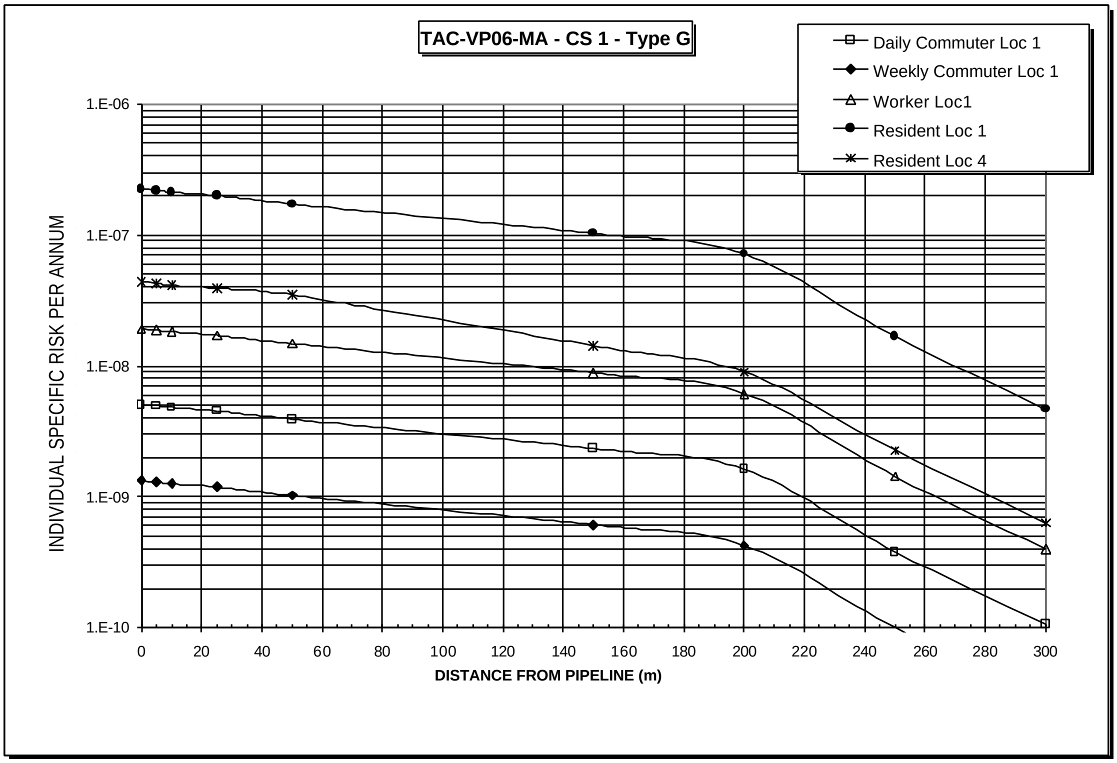


Figure 6.6
Mitigated Transects CS1 VP06 - Location 1

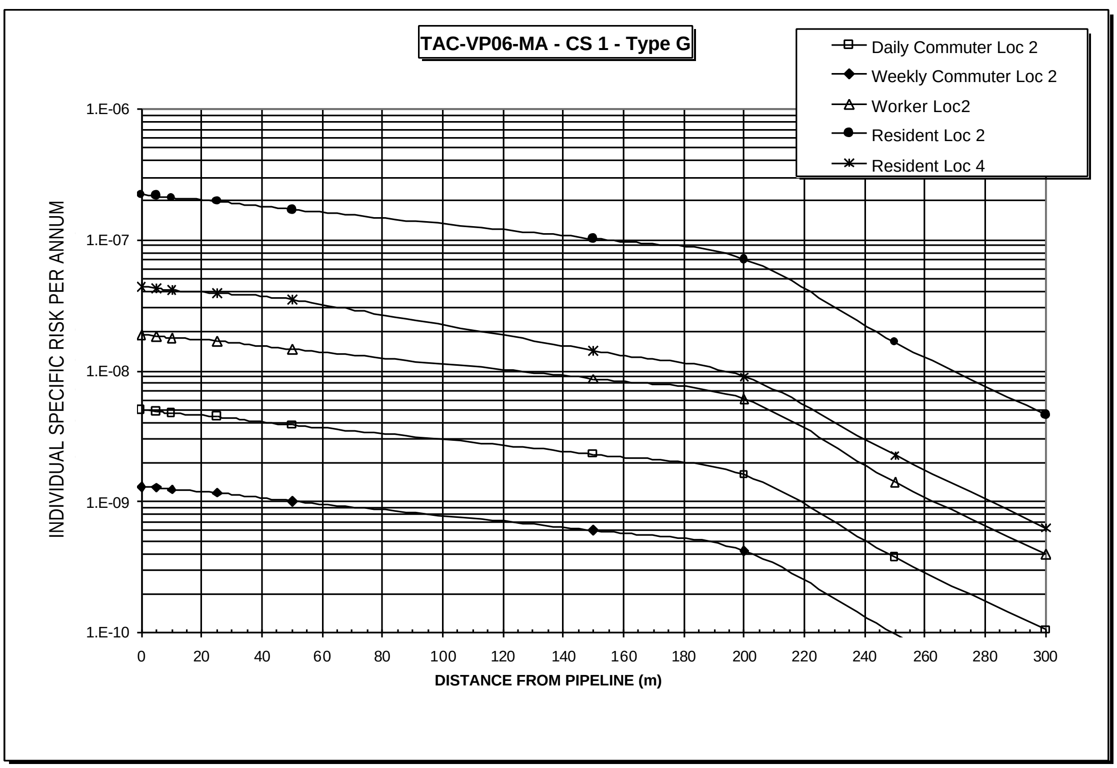


Figure 6.7
Mitigated Transects CS1F VP06 - Location 2

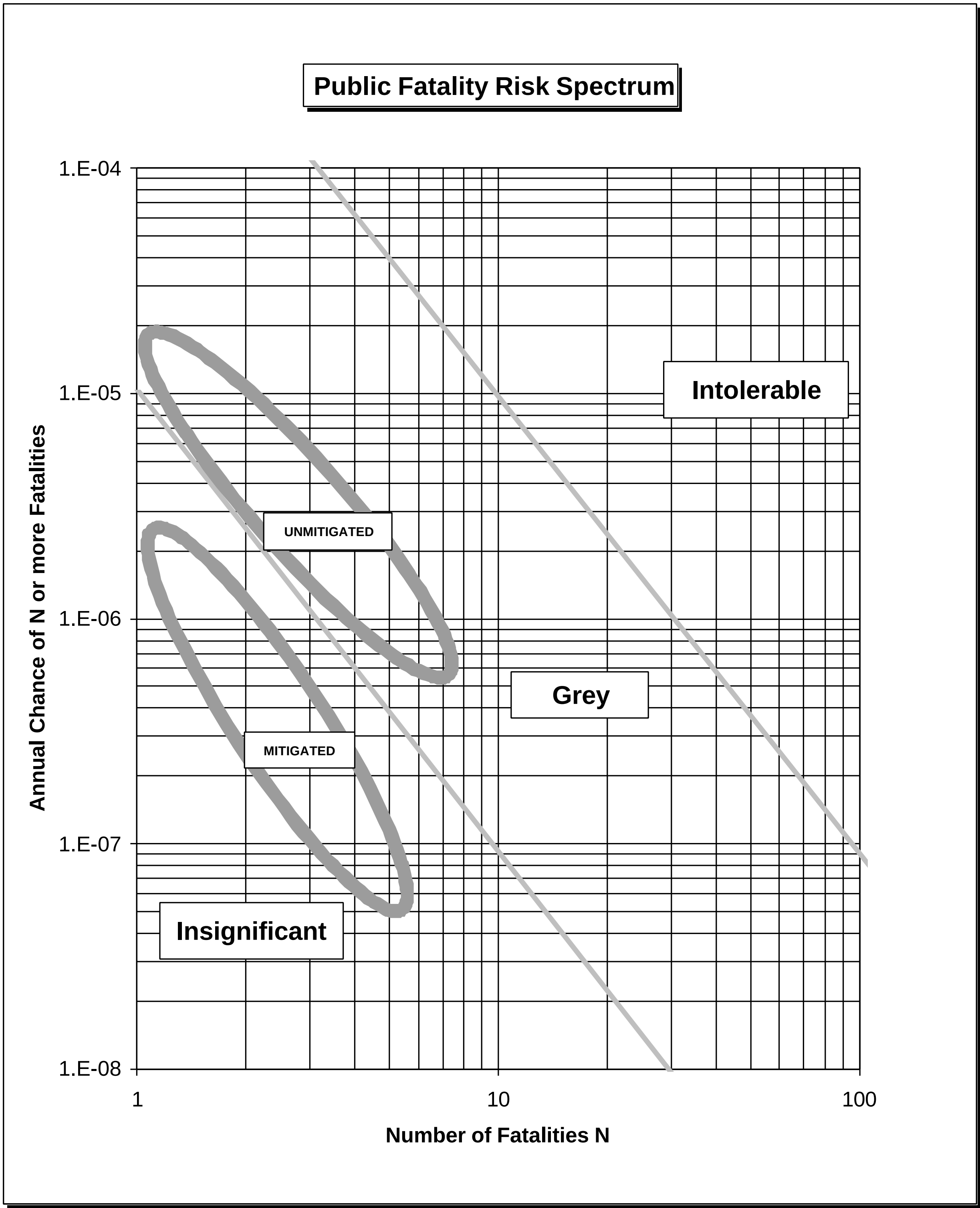


Figure 6.8
Collective Risk for Case Study #1

CHAPTER 7 – Case Study #2 – British Columbia

7.1 General Description of Case Study #2

Centra Gas BC Inc. (Centra) proposes to construct a high-pressure NPS 6 natural gas pipeline from Squamish, BC to Whistler, BC. Generally, the pipeline alignment is proposed along BC Highway #99, predominantly in Locations 1 and 2. The terrain through which the proposed pipeline runs can be broadly subdivided into two principal categories; namely, the valley or relatively level terrain and the mountainous terrain.

Figure 7.1 generally shows the location of the pipeline in a geographical context. More details of the proposed project were ascertained from the Design Basis Memorandum [26], the response to information requests relating to the proposed project [27], and the pipeline drawings and alignment sheets [28]. Centra Gas is proposing to install approximately 40 kilometres of the 62-kilometre pipeline within the Highway 99 ROW between Squamish and Whistler. Of the proposed alignment along the highway, approximately 50% will be in the centre of the ditch, 42% will be on the bench away from the highway and 8% will be in the shoulder of the highway.

The pipeline will first enter the Highway 99 ROW in Squamish, the final exit point will be in Function Junction. The pipeline will, for the most part, be within Highway 99 ROW except for a short segment where an alternative route away from the Highway has been selected to avoid road construction activities planned between Culliton Creek and Cheakamus Canyon. There are a few segments where the pipeline has been routed outside of the highway ROW for short distances near aerial crossings or other features. Along the alignment, the highway varies in width from 2-4 lanes with a number of upgrades planned for the next 10 years that will reduce or eliminate the length of 2 lane segments. The most imminent upgrade will be the two-lane section between Culliton Creek and Cheakamus Canyon. This work is currently scheduled for the years 1999 and 2000 and will increase the width of the Highway to either 3 or 4 lanes. Because of the imminent nature of the road work, Centra Gas has chosen a pipeline alignment along a dedicated pipeline ROW that avoids the Highway as much as reasonably possible.

Generally, the characteristics of the proposed pipeline for the purposes of this investigation, may be summarized as follows:

- There are two principal categories of terrain through which the pipeline passes, and these are Level Terrain (Case 2.1), and highly Mountainous Terrain in the Civil Defense Zone (Case 2.2).
- The pipeline is approximately 40 km with approximately 12 km of this in the Mountainous Terrain.
- The pipeline is NPS 6, can be approximated as operating in 12-km isolatable segments at a maximum allowable operating pressure of approximately 6,100 kPa.

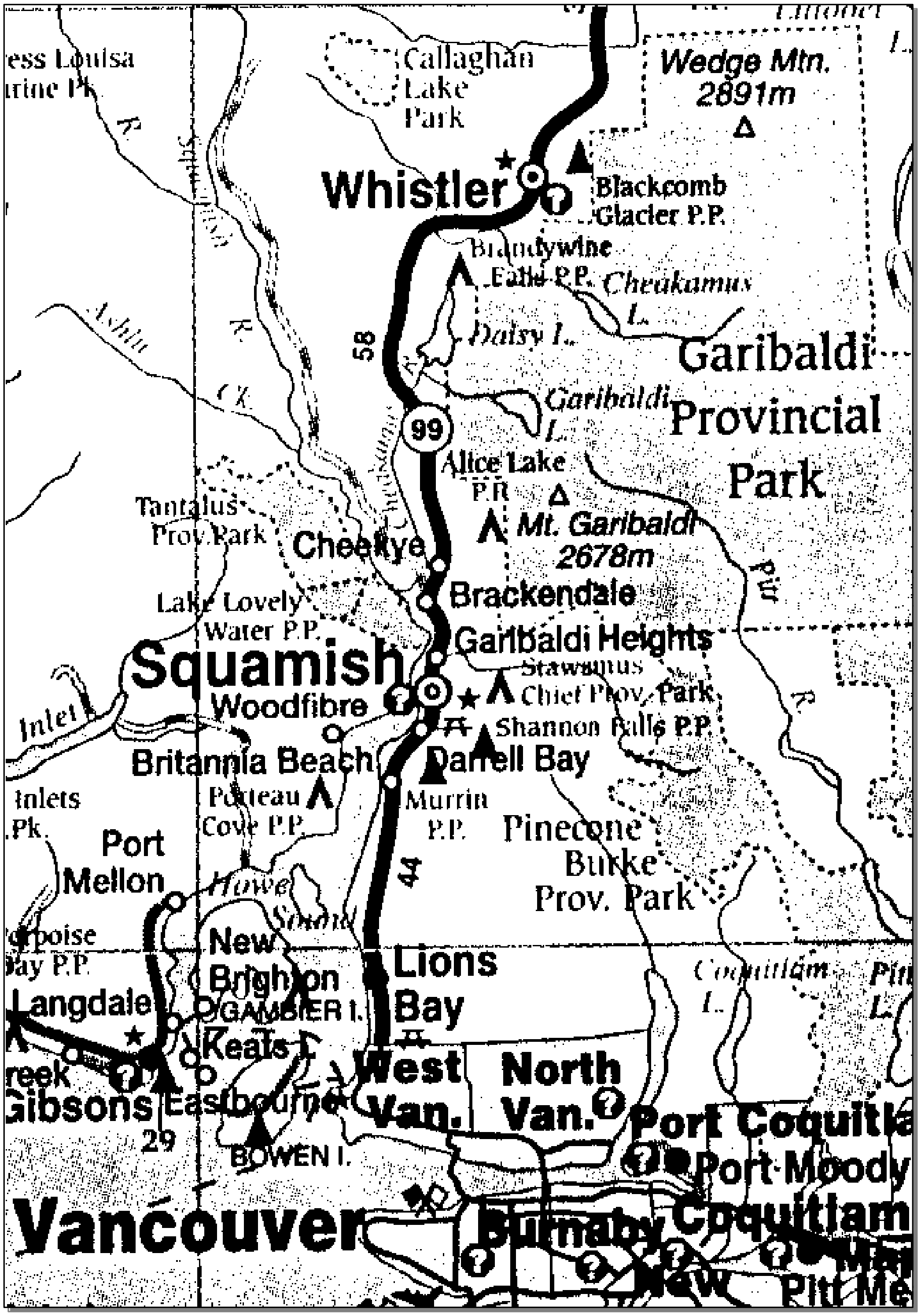


Figure 7.1
General Location of the Pipeline

- AADT of the road is 9,000 per day, with road speeds in the order of 80 to 90 km/h. Generally the pipeline is proposed for Locations 1 and 2.

A view of the typical low relief Level Terrain from [26] is shown in Figure 7.2, while a typical Mountainous Terrain view is shown in Figure 7.3.

7.2 Operational and Economic Impacts

7.2.1 Quantification of Impacts

As for Case Study #1, details of the quantification of impacts, including a screening analysis are given in Appendix B, the appendix dealing with economic and operational impacts. The results of the analysis of the medium and high impacts are given in Table 7.1. This table applies to both the Level and the Mountainous Terrain, since an integrated or cumulative impact assessment is not part of the scope of work (such an assessment would have to be carried out independently for each of the two homogeneous segments). Naturally, costs have been converted according to the appropriate multiplier for BC (1.096) for this case study.

The following items are most notable for this case study in regard to economic impacts of the pipeline locations:

- In terms of relative impact, the percentage change, the majority of the road and pipeline activities show a similar variation to most of those in the general case.
- The principal activity of note is B.7.1, the rock scaling activity. Without a detailed analysis of the activity itself, it is difficult to predict the actual economic impact of this activity, but it has been estimated at an 800% increase. It is singled out, because the matter of landslides, avalanches, washouts, and the associated control activities such as rock scaling do have an important impact on the risk.

7.2.2 Impact Mitigation Methods

The same basic impact mitigation methods as those described in Chapter 5 generally apply to Case Study #2.

Additional impact mitigation will have to be considered in regard to mitigating the impacts on the rock slide management (rock scaling activities). These activities are expected to be considerably inflated through the installation of additional protective measures to protect the pipeline. Clearly, mitigation of this inflationary trend on the rock scaling activity could be achieved by relocating the pipeline outside high rock fall areas, or by installing the pipeline in such a manner that its integrity would be assured in spite of any rockfalls. Various methods of increasing the likelihood of pipeline integrity in rockfall areas have been proposed and described by Centra [26, 27]. Most of these methods appear to be based primarily on theoretical or general guidelines; subject to final review by experts, full-scale tests should be conducted on various types of pipeline installations with actual maximum rock drops either from a crane of other controlled method of dropping. Subsequently, the pipeline segment tested should be removed and inspected and tested for integrity at a third party laboratory.

Figure 7.2
Typical Level Terrain

Figure 7.3
Typical Mountainous Terrain

Table 7.1
Pipeline Location Cost Impact – Case Study #2

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	BC		RLF	1.096
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12M	Ditch Grading - Continuous - with Grader	ALL	2	M	Use caution over p/l	1m^3	7.67	0.55	8.22	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock Scaling	ALL	ALL	H	Additional nets, p/l protection	day	1315.20	10684.80	12000.00	812
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R,4R Projects)***									
C.1.2	Major Section Repair, Excavation of Embankment	ALL	1&2	M	CPEP Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add Climbing/Passing Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.12	Blasting for Wider Road Surface	ALL	ALL	M	Pipeline relocation borne by p/l operator					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	3144.42	953.52	4097.94	30
			2	H	2m3 CPEP	ea	3144.42	253.18	3397.60	8
		GH	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	1303.14	1024.76	2327.90	79
			2	H	2m3 CPEP	ea	1303.14	349.62	1652.77	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2566.83	482.24	3049.07	19
			2		25m culvert;locate p/l	ea	2566.83	240.02	2806.86	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench;daylight p/l CPEP		2147.06	2411.20	4558.26	112
C.2.4	New Utility II	ALL	1&2	H	Assume im separation new NPS 12 p/l per Fig. 3.6	m	153.44	132.62	286.06	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km,total 100, scanp/l and hydrovac 100 holes	100	25257.32	5606.04	30863.36	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	72938.80	9042.00	81980.80	12
C.2.7	New O/H Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	87680.00	5480.00	93160.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	274000.00	10960.00	284960.00	4
C.2.9	New Power Poles	ALL	3	M	3km, 100 std. wood posts at 30m;locate p/l and hydrovac holes	100	42798.80	16275.60	59074.40	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					

Table 7.1
Pipeline Location Cost Impact – Case Study #2

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	BC		RLF	1.096
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
C.2.11	New Guard Rail	ALL	1	M	ikm,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	81850.38	15091.92	96942.30	18
C.2.12	New Driveway - Gravel	ALL	ALL	M	locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1265.88	613.76	1879.64	48
C.2.13	New Road Bridge	ALL	ALL	M	Design to suit; locate p/l hydrovac 5m3	ea	274000.00	2192.00	276192.00	1
C.2.14	Borrow Pit Access Driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1265.88	832.96	2098.84	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline Failure	ALL	ALL	H	Road closure - 4-12hr and lane closure TTC 24-48 hrs					H
D.3	Suspected Pipeline Damage	ALL	ALL	H	Road closure - 2-8hr and lane closure TTC 8-24hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline Repair (Major)	ALL	ALL	H	Road closure - 4-12hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (New Parallel Pipeline) - 10 km	ALL	ALL	H	Road closure - 4-12hr and lane closure TTC 2-4wks					H
F.2	Tap with Lateral Directed Away From Road	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
F.3	Tap with Lateral Directed Under Road	ALL	ALL	H	Road closure - 4-12hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure - TTC - 8-24hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
F.6	Section Replacement - 1 km	ALL	ALL	M	Road closure - 4-12hr and lane closureTTC 1-2wk					H
F.7	Lateral Away From Road	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
F.8	Lateral Under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic Protection	ALL	ALL	M	Lane closure - TTC - 8-24hrs					H
F.10	Instrument Installation	ALL	ALL	M	Lane closure - TTC - 8-24hrs					M
F.11	Blasting for New Trench	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure - TTC - 8-24hrs					M
F.13	New Pipeline Construction - 25 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 1-2months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	20% Increase in Roadside Maintenance Budget for P/L Effects on Structure	ALL	ALL	H	Yr 1 - Settlement; Yrs 2-3 - Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

Note re CPEP: ***If excavation more than 0.3 m deep planned:***

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

For Case Study #2, cost estimates of alternative routing have been provided under [26, 27]. Specifically, it was estimated by G.E. Bridges & Associates Inc. [27] that additional cost of an alternate route is approximately $12.8 million, which can be considered as an estimate of the savings to Centra Gas as a result of locating the pipeline in the proposed road right-of-way. From a review of the Bridges' study, it can be seen that the evaluation of this cost differential constitutes a major study, considerably beyond the scope of the present work as was mentioned in regard to Case Study #1. It may be interesting to note, however, that on a per-kilometre basis, this saving translates into a saving of $322,000/km.

7.3 Public Safety Risk Assessments

7.3.1 Unmitigated Individual Risk Assessment

As was done for Case Study #1, for this case study both unmitigated and mitigated risks were estimated. In this case, the predominant factor driving the unmitigated risk is the potential for landslides and associated necessity for rockfall management in the form of rock scaling. Table 7.2 summarizes the roadway effects on pipeline failure, including the unmitigated effect of rock scaling as well as relatively frequent and damaging landslide activity. The other activities and events are assumed to be mitigated with CPEP, etc. The landslide frequencies were obtained from the Agra Monenco [26] geotechnical studies, but the pipeline damage probabilities given there were unsubstantiated and replaced with ones considered more realistic.

Quantification of this frequency input data through the usual risk analysis process to obtain risk transects provides transects as shown in Figure 7.4 for Location 1, similar to those for Locations 2 and 3. As can be seen from the figure, the risks for residents in the area are well above the 1 in 1 million threshold at a value of 2 per 100 thousand, while risks to workers slightly exceed the 1 in 1 million threshold.

7.3.2 Risk Mitigation

The generic risk mitigation measures defined in Chapter 5 will apply uniformly throughout this case study.

Of primary concern, however, is the mitigation of risks associated with rock and landslides, as well as those associated with rock scaling, the risk management for rock and landslides. Clearly, the potential for impact at the pipeline location with consequent damage to the integrity of the pipeline from falling rock and soils through the extensive mountainous sections of the pipeline, needs to be mitigated. Possible mitigation measures are among the following:

- Risk management during the rock scaling operation itself, including safety net, plates protecting over the pipeline location, and other devices.
- Installation of the pipeline in a manner that integrity will be assured for even the largest mass and drop height rocks.
- Installation of the pipeline in alternate locations not susceptible to rock and rock scaling damage.

Table 7.2
Roadway and Location Effects on Pipeline Failure Rate – Case Study #2 – Unmitigated

CS2MU ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris, Rockfall	1	25	1	km	1.00E-05	1.00E-05	4.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continuous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock Scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	5	25	2	km	1.00E-05	2.00E-05	1.60E-07
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party Damage Total							**8.01E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		Earth Movement Total							**8.04E-03**
	Unknown	Other							8.81E-03
		Unknown Total							**8.81E-03**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris, Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading - Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading - Continuous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05

Table 7.2
Roadway and Location Effects on Pipeline Failure Rate – Case Study #2 – Unmitigated

Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
CS2MU ROAD TYPE E									
1	**Third Party Damage - *continued***	Rock Scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party Damage Total							**8.01E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		Earth Movement Total							**8.04E-03**
	Unknown	Other							8.81E-03
		Unknown Total							**8.81E-03**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock Scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New Power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party Damage Total							**8.00E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		Earth Movement Total							**8.04E-03**
	Unknown	Other							8.81E-03
		Unknown Total							**8.81E-03**

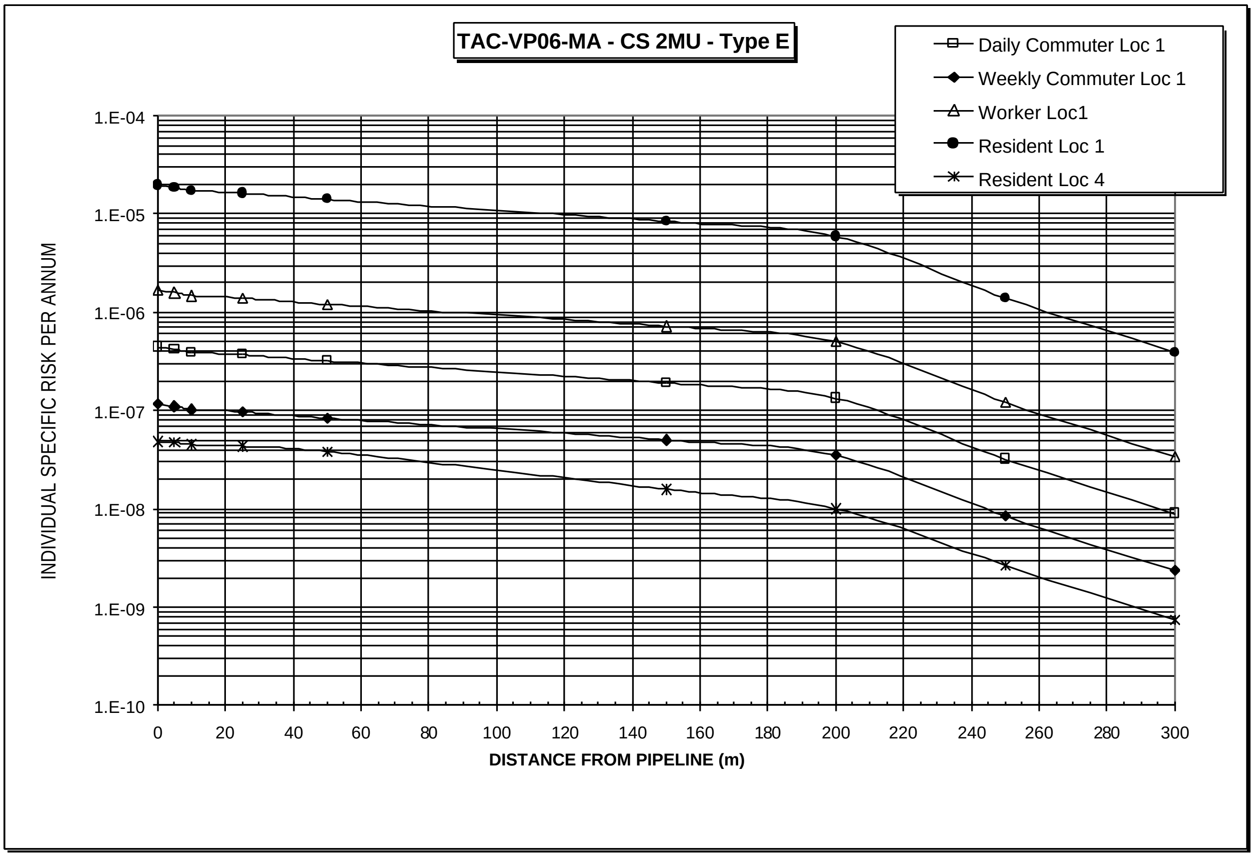


Figure 7.4
Transects for Case Study #2 – Unmitigated - Location 1

7.3.3 Mitigated Individual Risk Assessment

With the implementation of appropriate risk mitigation measures, generally as described in Section 7.3.2, and the generic risk mitigation measures described in Chapter 5, mitigated risks have been computed and presented in the form of risk transects once again. The resultant mitigated risk transects are shown as follows:

- Figure 7.5 – Flat Terrain, Location 1
- Figure 7.6 – Flat Terrain, Location 2
- Figure 7.7 – Mountainous Terrain, Location 1
- Figure 7.8 – Mountainous Terrain, Location 2

Generally, it can be noted that all individual specific risks in the mitigated configuration are shown to be below the threshold value of 1 in 1 million. For the flat portion of the terrain, risks are generally lower than for the mountainous portion. Also, risks for Location 1 for both terrain types are somewhat higher than those for Location 2.

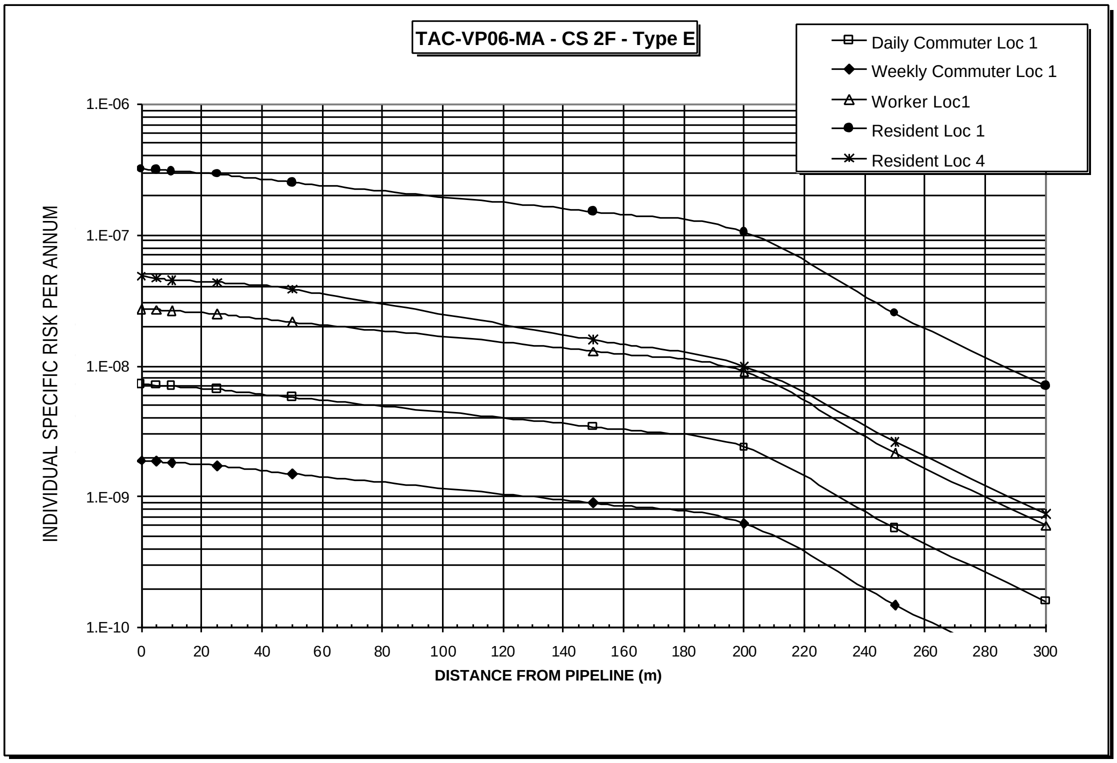


Figure 7.5
Transects – CS2F VP06 – Location 1

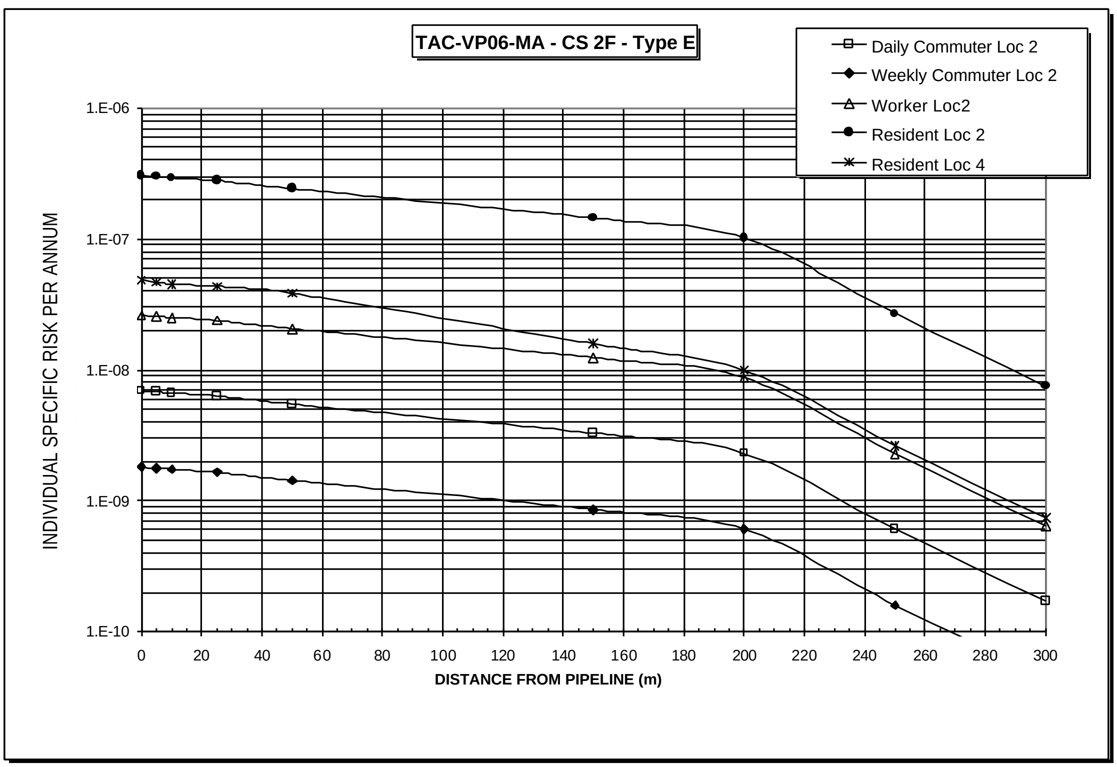


Figure 7.6
Transects – CS2F VP06 – Location 2

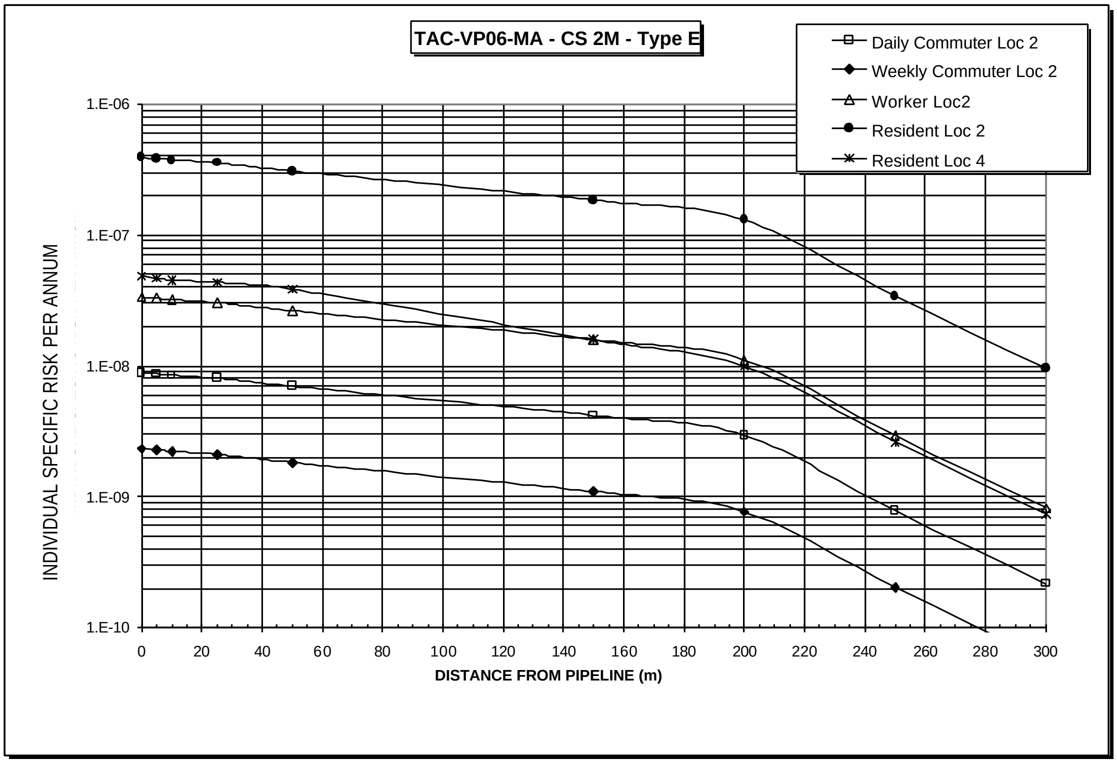


Figure 7.7
Transects – CS2M VP06 – Location 2

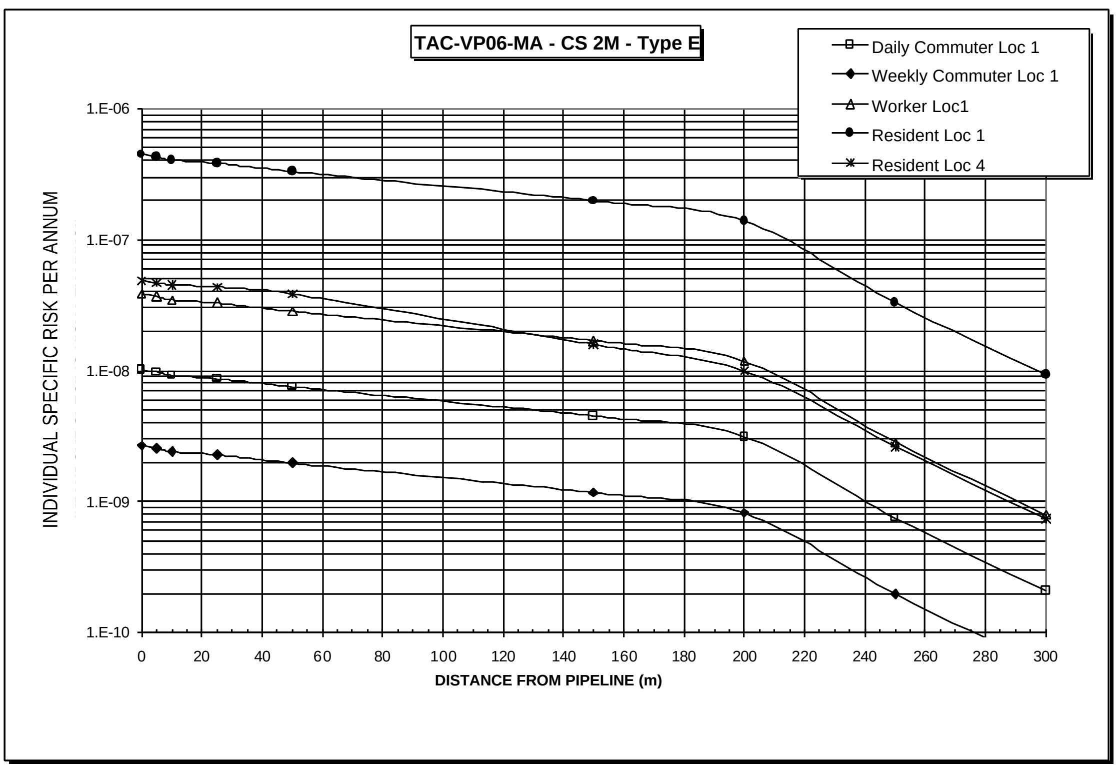


Figure 7.8
Transects – CS2M VP06 – Location 1

7.3.4 Collective Risks

Both mitigated and unmitigated collective risks were estimated for Case Study #2. Figure 7.9 shows the risk spectrum with the region for mitigated and unmitigated collective risks clearly depicted, showing the expected variability of the estimates. Clearly, mitigated risk for Case Study #2, based on some of the above mitigation measures fall in the insignificant area. Unmitigated risks fall entirely in the gray area, clearly mandating a cost-benefit approach to risk management and mitigation for this case study. It may be noted, that the unmitigated risk estimates for Case Study #2 are somewhat higher than those generated for Case Study #1.

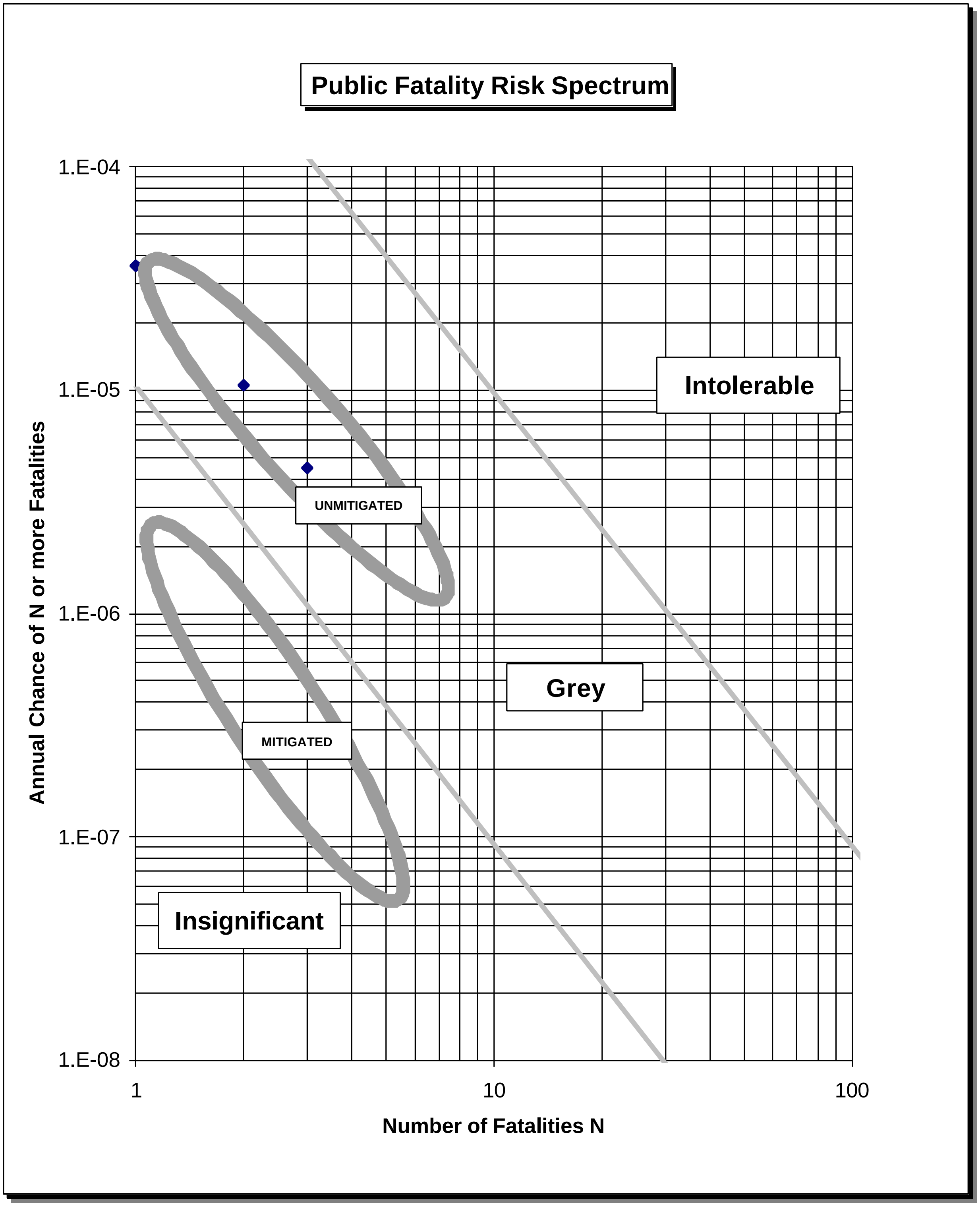


Figure 7.9
Collective Risk for Case Study #2

CHAPTER 8 – Regulatory Review

8.1 Approaches to Regulatory Review

The review of regulations relating to the location and installation of pipelines in road right-of-ways was approached through a review of literature compiled by the Nova Scotia Transportation and Public Works Department, a search online, selected literature from the Bercha library, regulations and guidelines from the Railway Association of Canada [45], and literature from selected jurisdictions in the United States.

8.2 Canadian Jurisdictions

8.2.1 General Considerations – Regulations and Standards

8.2.1.1 Alberta

In Alberta, there are two primary sources for regulations and standards, the fourth edition of "Technical Standards and Specifications Manual for Gas Distribution Systems" [7] and the Canadian Standards Association's "CSA Z662-99 Oil and Gas Pipeline Systems" [24]. Both of these documents were recently published in 1999. Additional sources of regulations and standards are found in the "Pipeline Act" [6], Pipeline Regulation and Alberta Infrastructure's Utility Application Procedures manual [7, 8].

The design, construction, and operation of gas distribution systems are subject to statutes and regulations issued in the Government of Alberta "Pipeline Act" [6] and the Government of Canada. In addition, applicable publications of the Canadian Standards Association (CSA), the Canadian Gas Association (CGA), and other organizations should be consulted. The latest edition the CSA standards published in "CSA Z662-99 Oil and Gas Pipeline systems" should be considered as the principal guideline for the design, construction, and operation of distribution systems.

8.2.1.2 British Columbia

Relevant regulations and standards in the Province of British Columbia appear in the following documents: Section 8.0 "Pipeline Regulations", revised 1994; "Permission to Construct Works within Crown Lands" H0021 (1997); and "Permit to Construct Works Upon Highways" H0021A (2000/05). [22]

Pipeline installations which run parallel to the highway centre line generally are not permitted in the following conditions: (i) high-pressure pipelines within and parallel to any class of highway right-of-way, or (ii) intermediate- or low-pressure pipelines within and parallel to freeways or expressways. The restrictions are based on safety considerations, because in most cases pipeline companies can keep construction and maintenance costs for high-pressure lines to a minimum by choosing a direct overland route. Restrictions on the use of freeway right-of-way for pipelines (and all other utilities) is based primarily on safety considerations and is the practice of most highway departments across North America. Drivers on freeways and expressways expect high-speed, free-flowing traffic. Any activity which disrupts traffic flow (e.g., construction or service vehicles) may increase the risk of an accident.

8.2.1.3 Manitoba

In Manitoba the installation of natural gas pipelines is specifically regulated under two provincial Statutes – The Oil and Gas Act (Chapter 034 SM) and The Gas Pipeline Act (Chapter G50 SM). In both instances these Acts specify any pipeline construction across or near highways require prior written consent of the Minister responsible for the administration of The Highways and Transportation Department Act.

Section 24(1) of The Gas Pipeline Act states:

> "Notwithstanding any provision of The Municipal Act or any other Act of the Legislature, no gas transmission line shall be constructed on, across, over or under a highway or within 100 feet thereof, or within 300 feet of a provincial trunk highway, as such highways are defined in The Highways and Transportation Department Act, without the written consent of the Minister responsible for highways."

8.2.1.4 Ontario

In Ontario, the Ministry of Transportation and Communications, Highway Operations and Maintenance Division addresses relevant regulations and standards in "The Corridor Control and Permit Procedures Manual 'Encroachment and Utilities'" (1986) [55].

The installation of any pipeline within MTC right-of-way is subject to approval of the Ministry. In most cases an Encroachment Permit with applicable conditions is issued. A gas or oil pipeline of 1.6 km or over in length may be placed within the limits of a highway only after the execution of an agreement between the encroaching party and the Minister. Certain pipelines carrying oil, gas, or other petroleum products may encroach upon the right-of-way by virtue of the Federal statutory authority granted by legislation such as the "National Energy Board Act". Such encroachments do not require the issuance of an Encroachment Permit or the execution of an agreement.

8.2.1.5 Saskatchewan

Section 16 of the "Pipelines Act" [60] provides that no pipeline shall be constructed on, across, over or under a public highway or within 100 metres of a provincial highway or within 30 metres of a public highway other than a provincial highway, without the written consent of the Minister of Highways and Transportation.

8.2.1.6 Québec

Quebec [56] public services regulations cover gas pipeline locations in the vicinity of highways, with respect to crossing and parallel requirements.

8.2.2 Location Guidelines and Definitions

8.2.2.1 Alberta

In Alberta, high pressure is defined as being greater than 700 kPa (100 psi), while low pressure is less than or equal to 700 kPa (100 psi). Pipeline locations should, where feasible, avoid land with sub-surface rock, swamp, muskeg, bodies of water, or dense brush. Further, the Alberta “Pipelines Act” specifies the following regarding the approval of pipelines:

- No pipeline shall be constructed on, across, over or under a highway without the approval of the Minister of Transportation and Utilities.
- An application for approval shall be accompanied by a plan and profile of the portion of highway affected.
- The land in which an interest is required for a pipeline parallel to a highway shall not be located nearer than 30 metres, or any greater distance the Board stipulates, to the boundary of the highway without the approval of the Minister of Transportation and Utilities.
- If a pipeline crosses a highway, no bend shall be permitted in that portion of the pipeline within: (a) the boundaries of the highway, or (b) 30 metres, or any greater distance the Board stipulates, of the boundaries of the highway, without the approval of the Minister of Transportation and Utilities.

8.2.2.2 British Columbia

British Columbia uses three classifications for pressure as described below:

- High pressure > 2,070 kPa (300 psi);
- Intermediate pressure 700 (100 psi) – 2070 kPa (300 psi); and
- Low pressure ≤ 700 kPa (100 psi).

In general, locations unsuitable for pipeline installations including road right-of-ways should be avoided. These include high embankments, bridge footings, culverts and retaining walls, or other locations where it is difficult to maintain full depth of cover. Exceptions may be made by the District Highways Manager.

8.2.2.3 Ontario

In Ontario, pipelines or pipeline installations which are above ground are not permitted within the limits of the right-of-way of a highway, except where the installation is not practicable such as through a deep ravine or gully. A pipeline carrying gas or gasoline or other volatile substances shall not be attached to a bridge or structure or facility which forms part of a highway, unless approval is given by the Regional Director.

8.2.2.4 Manitoba

In general, Manitoba Transportation prefers natural gas pipelines, and utilities/third party uses of highway right-of-way be placed outside of provincial highway right-of-ways at a sufficient setback and depth to minimize difficulties with future highway upgrading. Where it is necessary to accommodate pipelines within a provincial highway right-of-way, the preference is to have them placed as close to the right-of-way limit as practical and at such a depth to avoid difficulties in future highway upgrades.

8.2.3 Parallel to the Highway - Location

8.2.3.1 Alberta

a. Pipelines Parallel to Primary Highways

Adjacent to primary highways Alberta Infrastructure does not generally allow high-pressure natural gas pipelines to be placed within 30 metres of the highway right-of-ways. The “Pipeline Act” [6]requires that pipeline companies obtain the departments approval before acquiring an interest in lands within 30 metres of a highway.

b. Pipelines Parallel to Roads in Municipal Districts

In Alberta, pipelines parallel to roads are administered by the Municipal Districts. The following distances from the road centreline are required:

- 30 m from centreline for internal subdivision roads or service roads;
- 70 m from centreline of road for a local municipality;
- 50 m from centreline of road for municipal roads designated as secondary roads; and
- 100 m from centreline of any municipal road in areas of adverse terrain conditions.

c. Use of Road Right-of-Ways as Pipeline Right-of-Ways

The use of road right-of-ways as pipeline right-of-ways in Alberta should be avoided wherever possible, and should be used only in extenuating circumstances. The pipe should be located under the ditch on the back slope side. The entire length of the pipeline should be placed parallel to the centreline of the road or highway maintaining a consistent offset as much as physically possible.

8.2.3.2 British Columbia

In British Columbia, pipelines may be located parallel to the highway centreline and within 2 m of the inside boundary of the highway right-of-way. In the case of an irregular boundary, a reasonable alignment will be considered if it does not affect backslopes, drainage, or maintenance operations. Every effort must be made to locate pipelines a consistent distance from the edge of the highway right-of-way and the toe of the slope.

8.2.3.3 Ontario

Pipelines shall be installed as close as it is practical to the outside limits of the right-of-way in Ontario. The pipeline should be beyond the backslope of the highway ditch, but not closer to the traveled portion of the highway than 6.0 m beyond the outside shoulder. Pipeline installation is not to interfere with existing or planned highway facilities or with highway maintenance and operation processes.

8.2.3.4 Saskatchewan

In Saskatchewan, the “Pipelines Act” [60] provides that no pipeline shall be constructed on, across, over, or under a public highway or within 100 m of a provincial highway or within 30 m of a public highway other than a provincial highway without the written consent of the Minister of Highways and Transportation.

8.2.4 Depth of Cover

8.2.4.1 Alberta

In Alberta, the minimum depth of cover over the pipeline where it crosses the right-of-way of a highway or road shall be 1.4 metres under the lowest point in the cross section.

8.2.4.2 British Columbia

In British Columbia, the top of any pipeline or casing must be at least 1.2 m below the top of the pavement. The top of low-pressure pipelines must be at least 0.75 m below design ditch bottoms. In the case of intermediate- and high-pressure pipelines, the top must be at least 1.0 m below design ditch bottoms.

8.2.4.3 Ontario

In general, the minimum depth of cover in Ontario is 0.75 m. In the case of crossings, the top of the pipeline must be 1.2 m below the traveled portion of the highway. The depth of a pipeline or casing pipe below the bottom of a highway ditch shall be not less than 0.75 m in Southern Ontario and 1.0 m in Northern Ontario.

8.2.4.4 Saskatchewan

In Saskatchewan, pipeline crossings shall be buried to a depth of at least 1.2 m below the low point in the ditch. This depth shall be maintained from toe of backslope to toe of backslope.

8.2.4.5 Québec

Depth of cover of gas pipelines parallel to roads shall be a minimum of 1.0 m below the road grade, except for ditches where it shall be no less than 0.8 m.

8.2.4.6 Manitoba

Manitoba Transportation specifies a minimum 1.0 metre depth of cover below the ditch bottom elevation where a pipeline crosses the right-of-way of a highway or is to be installed parallel to the traveled portion of the highway (i.e., in the right-of-way). This minimum has been increased up to 1.5 metres due to local conditions or where the department is aware of the requirement for future highway upgrading and the minimum 1.0 metre depth is not acceptable.

8.2.5 Summary of Canadian Jurisdictional Requirements

Table 8.1 summarizes the salient points from the guidelines or regulations promulgated by Alberta, British Columbia, Quebec, Saskatchewan, and Ontario. As may be seen, these have been subdivided into general guidelines concerning locations parallel to the highway centreline, depth of cover, and specific comments. In general, it should be stated that [43], the Ministry of Transportation and Communications of Ontario, dated 1986, gives the most comprehensive set of guidelines and regulations and should be further reviewed by regulators within the context of this present study. In addition, the work by Stantech [49] commissioned by the Alberta Infrastructure Utility Installation Review and completed in March 2000 is an excellent document providing a picture of the above jurisdictions as well as some of the foreign jurisdictions referred to below.

8.2.6 Excavation and Construction near Pipelines

8.2.6.1 Alberta

The Alberta Pipeline Regulations [6] set out guidelines similar to those proposed for CPEP in Section 3.2.2.2 as follows:

- No excavation deeper than 0.3 metres may occur within 30 meters of the pipeline until the surface location of the line is marked by the owner/operator of the facility. Once the surface location is marked, mechanical excavation is permitted to within 5 metres of the pipelines.
- A person proposing to undertake a ground disturbance that will cross or be carried out within 5 metres of an existing pipeline shall, except if the maximum excavation depth is 0.3 m or less, and before commencing any mechanical excavation, locate and expose the existing pipeline by hand excavation.
- If a person is conducting an excavation for the purpose of locating a pipeline it shall be done by hand excavation until the pipeline is sufficiently exposed to enable its identification.
- A representative of the permittee or licensee of the existing pipeline shall be present at the time the pipeline is exposed, if requested by the person proposing to undertake the ground disturbance.
- After a pipeline has been located as above, no person shall use or cause to be used mechanical excavation equipment within 60 centimetres of the pipeline, except under the direct on-site supervision of a representative of the permittee or licensee of the existing pipeline.

Table 8.1
Summary of Pipeline Installation Regulations along Highway Right-of-way in Selected Jurisdictions

JURISDICTION	PARALLEL TO THE HIGHWAY LOCATION	DEPTH OF COVER	COMMENTS
ALBERTA	**Rural:** ▪ Under the bar ditch on the backslope. ▪ Parallel to the centreline of the highway.	▪ Minimum 800 mm for service lines and mains.	▪ Excluded from road right-of-way. ▪ Approved as exception.
	Municipal Districts: ▪ 30 m from centreline for internal subdivision roads. ▪ 40 m from centreline of road for local municipality. ▪ 50 m from centreline for MD roads designated as secondary roads. ▪ 100 m from centreline of any MD road in adverse terrain.	**Crossings:** ▪ Minimum depth of cover 1400 mm. ▪ Minimum depth of cover 1100 mm.	**Crossings:** ▪ For two-lane primaries and secondaries. ▪ Other secondary roads, local MD roads, and private roads.
BRITISH COLUMBIA	▪ Parallel to highway centreline and within 2 m of inside boundary of highway right-of-way. ▪ Irregular boundaries consistent distance from edge of right-of-way and toe of slope.		▪ Excluded from road right-of-way. ▪ Approved as exception. ▪ Must not affect backslope, drainage or maintenance operations.
		Crossings: ▪ 1.2 m from top of pipeline or casing to top of pavement. ▪ 0.75 m from top of pipe to design ditch bottom.	 ▪ Low pressure pipeline.
		▪ 1.0 m from top of pipe to design ditch bottom.	▪ Intermediate- and high-pressure pipelines.
ONTARIO	▪ As close as practical to outside limit of right-of-way, beyond the backslope but not closer than 6.0 m from outside shoulder.	▪ 0.75 m from top of pipeline to pavement surface.	▪ Should not interfere with existing or planned facilities or maintenance or operations.
		Crossings: ▪ 1.2 m from top of pipeline to pavement surface. ▪ 0.75 m from top of pipeline to ditch bottom.	 ▪ Southern Ontario
		▪ 1.0 m from top of pipeline to ditch bottom.	▪ Northern Ontario
QUÉBEC	**Distribution Lines:** ▪ May be located parallel to highway with special authorization.	▪ 1.0 m below road. ▪ 0.8 m below ditch. ▪ Trench backfill to be either originally excavated material or adequately compactible materials.	▪ Québec Transportation is initiating project to measure long-term geotechnical effects of pipeline on road system [56]
SASKATCHEWAN	▪ No pipeline to be constructed within 100 m of a provincial highway or 30 m of other public highways.		▪ Without consent of the Minister of Highways and Transportation, approved as exception.
		Crossings: ▪ Buried to a depth of 1.2 m below the low point in the ditch.	▪ Depth to be maintained from toe of backslope to toe of backslope.

8.2.6.2 Canada – National Energy Board

The National Energy Board [47] sets out similar guidelines to those of the Alberta Pipeline Regulations [6], except it extends the "30 metre safety zone" to within 30 metres "of the limits of the right-of-way", except where the ground disturbance is to a depth less than 0.3 metres (1 foot).

8.3 Foreign Jurisdictions

8.3.1 California

There is a significant amount of information available on the State of California websites, including policies, procedure manuals, permit handbooks and an encroachment permits manual.

Use of right-of-ways both for railways and highways is often authorized by means of franchise agreements granted by the local authority. One of the conditions of the franchises in California is that the pipeline operator must not only indemnify and hold harmless the municipality and its officers that have granted the franchise, but also must carry liability insurance required as set out in the encroachment permits manual.

In regard to depth of cover, the question has been addressed on the basis of whether the project involves high risk or low risk facilities, and also whether the facility is an existing facility or a newly constructed one. Natural gas pipelines of the category under study here would be considered as high risk facilities under the California jurisdiction. Specific clearances are proposed for by the State of California for high risk facilities, and are summarized as follows:

- 450 mm (18") below the grading plane;
- 450 mm (18") below flow line of unlined ditches; and
- 600 mm (24") horizontally from face of pile or side of an excavation.

The last of the above bears out the rule of hand excavation within 0.6 m of the pipeline.

8.3.2 Minnesota

Minnesota has prepared and implemented a master agreement to govern fibre optic network installation across the state, including a variety of guidelines and regulations associated with the synergy with other utilities such as hydrocarbon pipelines. In addition, the State of Minnesota in its statutes and highway system rules contain various guidelines for the installation of hydrocarbon pipelines in the vicinity of roads.

In terms of jurisdiction, the State of Minnesota maintains control of all permits associated with the construction or relocation of utilities on trunk highway right-of-ways, and such work cannot be commenced without a permit from the State under the Minnesota rules. For any maintenance work, the utility operator must obtain a work permit (from the Office of the Assistant District Engineer of Maintenance) prior to performing service and maintenance operations on any interstate highway right-of-ways, and must also obtain a work permit prior to service and maintenance operations on interstate highways where such operations require opening and disturbing the surface of the right-of-way. Thus, in general, the State of Minnesota under its rules and statutes, directly controls any activities on any of its highways.

The minimum depth of cover issue is addressed with respect to the installation of telecommunication facilities only, suggesting that pipeline depth of cover is governed by the relevant pipeline code ANSI B31.4 and B31.8.

8.4 Railway Regulations

8.4.1 Railway Association of Canada

In the Railway Association of Canada (RAC) [57] publication standards respecting pipeline crossing respecting railways, some useful guidelines on potential standards relating to the problem of pipeline locations in road right-of-ways appear. First, there is a differentiation between high-risk and low-risk facilities. The natural gas pipelines under study would be deemed high-risk facilities; water, sewer, and low-pressure air lines would be deemed as low risk facilities. In terms of cover requirement, it is interesting to note that the minimum cover and clearance requirements proposed by RAC as reproduced in Table 8.2 for high-risk facilities require a range of cover between 6 feet within roughly 50 metres from their centreline of the nearest track to 5 feet for locations greater than 50 metres from the centreline of the track.

8.4.2 Private Railway Regulations

Union Pacific Railways [69] have longitudinal utility guidelines similar to those recommended by the RAC.

Table 8.2
Minimum Cover and Clearance Requirements
Minimum Cover for Buried Pipelines, cm
(Measured to top of carrier or casing pipe, as applicable)

Location	Type of Pipeline	Class Location	Normal Excavation cm (ft)	Rock Excavation Requiring Blasting or Removal by Comparable Means cm (ft)
Crossing of railway right-of-ways: below base of rail All Tracks:				
Cased	Flammable or hazardous gas or liquid	All	168 (5.5 ft)	168 (5.5 ft)
Uncased	Flammable or hazardous gas or liquid	All	305 (10.0 ft)	305 (10.0 ft)
Crossings of railway right-of-ways: below bottom of ditches or ground surface				
Cased	Flammable or hazardous gas or liquid	All	91 (3.0 ft)	91 (3.0 ft)
Uncased	Flammable or hazardous gas or liquid	All	183 (6.0 ft)	183 (6.0 ft)
Railway right-of-ways for cased or uncased buried longitudinal pipelines				
Between 762 cm and 1524 cm from centreline of nearest track	Flammable or hazardous gas or liquid	All	183 (6.0 ft)	183 (6.0 ft)
Greater than 1524 cm from centreline of nearest track	Flammable or hazardous gas or liquid	All	152 (5.0 ft)	152 (5.0 ft)

CHAPTER 9 – Conclusions and Recommendations

9.1 Introduction

The placement and location of hydrocarbon pipelines with respect to road structural cross sections and geometrics can have an effect on the safety of the highway system and its users and adjacent residents, and an operational and economic impact on highway maintenance, construction, and modification activities, as well as on the integrity of the pipeline itself.

Pipeline operators in Nova Scotia and British Columbia have proposed locating natural gas pipelines within rural road right-of-ways (ROW's). Due to the concern regarding the impacts on both road operations and on public and personnel safety resulting from such natural gas pipeline placements, the Transportation Association of Canada (TAC) has initiated the present study of the operational, economic, and safety implications of natural gas pipelines in different locations within primary and secondary highway right-of-ways in Canada.

9.2 Summary of Work Done

Essentially, the work was directed at generating a qualitative and quantitative understanding of the implications of locating pressurized natural gas pipelines in various locations within rural road right-of-ways.

The following different characteristics of locations, road types, and pipeline types were quantitatively included in the study:

- Road Types - Freeway, arterial, collector, and local with associated variations in Average Design Daily Traffic (ADDT), vehicle speed, and cross section.
- Pipeline Types - Nominal Pipeline Size (NPS) 6, 8, and 12 (inches) for medium-, high-, and very-high pressure natural gas.
- Pipeline Locations - With respect to road system, Location 1, within the road shoulder; Location 2, below the ditch; Location 3, approximately 1 m inside the right-of-way boundary; and Location 4, a location away from the effects of the road providing a control location.

Considering the above combinations, as applicable, three cases were investigated; namely, the general case, and two case studies as follows:

- The general case for all combinations of road types, pipeline types, and pipeline locations, utilizing representative Canada-wide conditions to the fullest extent possible.

- Case Study #1, Nova Scotia – An NPS 6 very-high pressure line in locations within the right-of-way of arterial roads in Pictou County.
- Case Study #2, British Columbia – An NPS 6 very-high pressure natural gas pipeline within various locations of a two- to four-lane arterial road ROW, through both flat and mountainous terrain from Squamish to Whistler, BC.

For the above combinations and cases, an operational and economic impact and a public safety risk assessment were conducted. Operational and economic impact analysis consisted of the definition and classification of all road, pipeline, environmental, and other events with impact potential; identifying those with significant impact potential; and evaluation of the economic or operational impacts in a quantitative form whenever possible.

In the risk assessment, a similar classification and screening of significant risks was carried out followed by evaluation of risks. The risk evaluation consisted of hazard scenario definition, frequency analysis, consequence analysis, and risk analysis.

For both operational and economic impacts and risks, methods of mitigating their frequency and magnitude were reviewed and specific impact and risk mitigation methods were recommended for all three cases considered. Finally, a review of applicable regulatory provisions in Canadian and US jurisdictions was carried out and documented, together with a commentary on their relevance.

9.3 Significance and Limitations of the Work

Although previous studies in the public domain have been conducted on utility corridor concepts, these have been largely qualitative, and restricted to localized regions. No previous work on a qualitative and quantitative level, covering both generic and specific cases and integrating concepts of road and pipeline constructability, maintainability, and operability with risk and economic impacts has ever been carried out previously. The present work combines interactively the results of expertise in risk and reliability engineering; road and pipeline engineering, construction, operation, and maintenance; cost estimating and economic impact assessment; and regulatory experience and knowledge to provide a unified study of the problem of natural gas pipeline placement in right-of-ways in rural areas, with possible applications in urban areas as well. Thus, the comprehensive nature, multi-disciplinary approach, quantitative detail, rigorous methodology, and enormous volume of significant results from the present study is unprecedented and likely to set standards for new approaches to the problem.

It should be noted that the general case of impact and risk analysis was necessarily comprehensive in nature, but not site-specific. Its general indications should be taken as the definition of trends, but should not be expected to apply site specifically, except as a methodological basis for more detailed investigations. Even the case studies, although specific to certain site characteristics, and satisfactory for the identification of the principal factors creating impacts and risks, lack the level of detail that would be expected in a rigorous risk or impact analysis to be submitted to a regulatory body. The case studies do, however, bring out the predominant impact and risk factors germane to their geographic locations, and as such form a good basis for further advancement in the optimization of the subject projects.

9.4 Conclusions

9.4.1 General Conclusions

The placement of high-pressure natural gas pipelines in highway right-of-ways impacts on highway operations and creates additional risks. The impacts and risks are closely related. The majority of impacts to the highway system relate to the modification of highway maintenance and construction activities to manage risks from the pipeline presence. Modifications to the pipeline installation are also often required. These adjustments consist primarily of the integration of industry standard practices for construction and operation in the vicinity of high-pressure natural gas pipelines, and entail additional time, equipment, and manpower, and often reduce highway efficiency through full or partial closures. Without incurring these impacts, and making the necessary safety provisions, risk from the pipeline generally would be unacceptable, producing a high probability of property damage and loss of life. There are a few cases where the impacts relate mainly to constructability, such as dropping new culvert inverts so that the culverts can go below the pipeline. But even here, a portion of the impact relates to safe construction procedures in the vicinity of the pipeline.

The significant impacts of the pipeline location, caused largely by risk management provisions, were identified (from all potential impacts) and summarized as shown in Table 9.1. The majority of the impacts were generated as a result of the need to modify approaches to avoid pipeline hazards, by surveys, slower operation, extra equipment, and/or additional manpower. Some of the impacts of this were sufficiently high to make the activities unfeasible or to require an alternate pipeline location. As can be seen, the economic impacts varied, with their inflationary effects ranging from small percentages to very high percentages in the order of 2000% for selected activities. Most of the economic impacts ranged between 1 and 50 % inflationary effect on unit cost, with the higher impacts in excess of 50%. Certain activities' impacts could not be economically quantified, so were simply ranked in terms of their severity. This included impacts on road traffic, which were described but are difficult to quantify except on a site-specific basis. Similarly, where the impacts were to the pipeline operator, generally involving the relocation of the pipeline in order to accommodate road activities such as addition of a climbing/passing lane, estimates were also not made as they are highly dependent on site-specific and pipeline-specific conditions. Costs of pipeline relocation can range from $50,000 to $500,000 per kilometre. Some of the impacts appear to be sufficiently large to make the activity unfeasible, or require alternate pipeline routings.

In the conduct of the general case risk analysis, risks were assessed with the key assumption that all industry safety measures necessary for safe construction and operation in the vicinity of high-pressure natural gas pipelines were implemented. The public and personnel risks thus estimated provided an estimate of expected individual specific risks for people with different levels of exposure to potential pipeline accidents, and collective risks.

Table 9.1
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading - Continuous - with Backhoe	ALL	2	M-H	Use hydrovac or hand excavation - per CPEP	m3	6.00	114.00	120.00	1900
B.5.12 M	Ditch Grading - Continuous - with Grader	ALL	2	M	Use caution over p/l	$1m^3$	7.00	0.50	7.50	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock Scaling	ALL	ALL	H	Additional nets, p/l protection	day	1200.00	800.00	2000.00	67
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R, 4R Projects)***									
C.1.2	Major Section Repair, Excavation of Embankment	ALL	1&2	M	CPEP and Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add Climbing/Passing Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.12	Blasting for Wider Road Surface	ALL	ALL	M	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading; 3m3 CPEP	ea	2869.00	870.00	3739.00	30
			2	H	CPEP and 2m3 Hydrovac	ea	2869.00	231.00	3100.00	8
		GH	1	H	CPEP Drop invert .5m, 30m3 extra grading; 3m3 hand excav	ea	1189.00	935.00	2124.00	79
			2	H	CPEP and 2m3 Hydrovac	ea	1189.00	319.00	1508.00	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2342.00	440.00	2782.00	19
			2		25m culvert; locate p/l	ea	2342.00	219.00	2561.00	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench; daylight p/l CPEP		1959.00	2200.00	4159.00	112
C.2.4	New Utility II	ALL	1&2	H	Assume 32-inch separation new NPS 12 p/l per Fig. 3.6	m	140.00	121.00	261.00	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km, total 100, scan p/l and hydrovac 100 holes	100	23045.00	5115.00	28160.00	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	66550.00	8250.00	74800.00	12
C.2.7	New Overhead Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	80000.00	5000.00	85000.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	250000.00	10000.00	260000.00	4
C.2.9	New Power Poles	ALL	3	M	3km, 100 std. wood posts at 30m; locate p/l and hydrovac holes	100	39050.00	14850.00	53900.00	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					
C.2.11	New Guard Rail	ALL	1	M	1 km,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	74681.00	13770.00	88451.00	18
C.2.12	New Driveway - Gravel	ALL	ALL	M	Locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1155.00	560.00	1715.00	48
C.2.13	New Road Bridge	ALL	ALL	M	Design to suit; locate p/l hydrovac 5m3	ea	250000.00	2000.00	252000.00	1

Table 9.1
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
C.2.14	Borrow Pit Access Driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1155.00	760.00	1915.00	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline Failure	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
D.3	Suspected Pipeline Damage	ALL	ALL	H	Road closure - 2-8 hr and lane closure TTC 8-24 hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline Repair (Major)	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
E.9	Pipeline Repair (Minor) - Exposure	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (new parallel pipeline) -10 km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 2-4 wks					H
F.2	Tap with Lateral Directed away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.3	Tap with Lateral Directed under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.6	Section Replacement -1 km	ALL	ALL	M	Road closure - 4-12 hr and lane closure TTC 1-2 wk					H
F.7	Lateral away from Road	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					M
F.8	Lateral under Road	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic Protection	ALL	ALL	M	Lane closure - TTC - 8-24 hrs					H
F.10	Instrument Installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for New Trench	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure - TTC - 8-24 hrs					M
F.13	New Pipeline Construction - 25km	ALL	ALL	H	Road closure - 4-12 hr and lane closure TTC 1-2 months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1 - Settlement; Yr 2-3 - Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

***Note re CPEP:* If excavation more than 0.3 m deep planned:**

1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

Thus, risks were assessed with the key assumption that all activities will be carried out with proper safety precautions at an industry standard, including pipeline location, daylighting, and the necessary hand or air tool excavation in close proximity areas. If safety measures are not strictly implemented, risks can become intolerable, with unacceptable risk of major damage of property or loss of life.

Based on risk management implementation, the individual specific risks for all members of the public and work forces likely to be exposed to pipeline accidents were expressed as risk transects as shown in Figure 9.1. As explained in the background to risk analysis, generally risk levels in the order of 1 in 1 million are deemed to be acceptable. The following general conclusions may be drawn from the risk assessment on the assumption that risk mitigations to an industry standard level are in place:

- All of the general case risk levels thus quantified with risk mitigations in place were found to be less than 1 in 1 million.
- For comparative purposes, hypothetical residents near the roadway system and near the control location, Location 4, were also subjected to individual specific risk assessment and it was found that the risks for locations adjacent to the road system, such as Locations 1 and 2, were approximately 10 times greater for pipelines adjacent to freeways than they were for pipelines in the control or unaffected location.
- From sensitivity studies and the case study work, it was found that the risk model is quite robust, with generally insignificant effects on risk results from small (less than an order of magnitude) changes in input parameters. However, the complete absence of any risk mitigation measures can amplify the risk to unacceptable levels.
- Table 9.2 gives a summary of the variation of risks at maximum risk location (pipeline centre line) associated with different road types, pipeline types, and locations.
- In general, risks are higher for Location 1 than for 2, and least for Location 3.
- Similarly, as the traffic density on the road decreases as represented by a decrease in ADDT, risks also decrease.
- Risks associated with the smaller NPS 6 and 8 pipelines are slightly higher than those associated with the NPS 12 pipelines due to the higher failure rates associated with smaller diameter pipelines.
- Collective risks were also quantified and generally found to be in the insignificant region as shown in Figure 9.2 by the region entitled “mitigated”.
- Reference to the unmitigated risks shown in Figure 9.2 will be made with respect to each of the case studies discussed below.

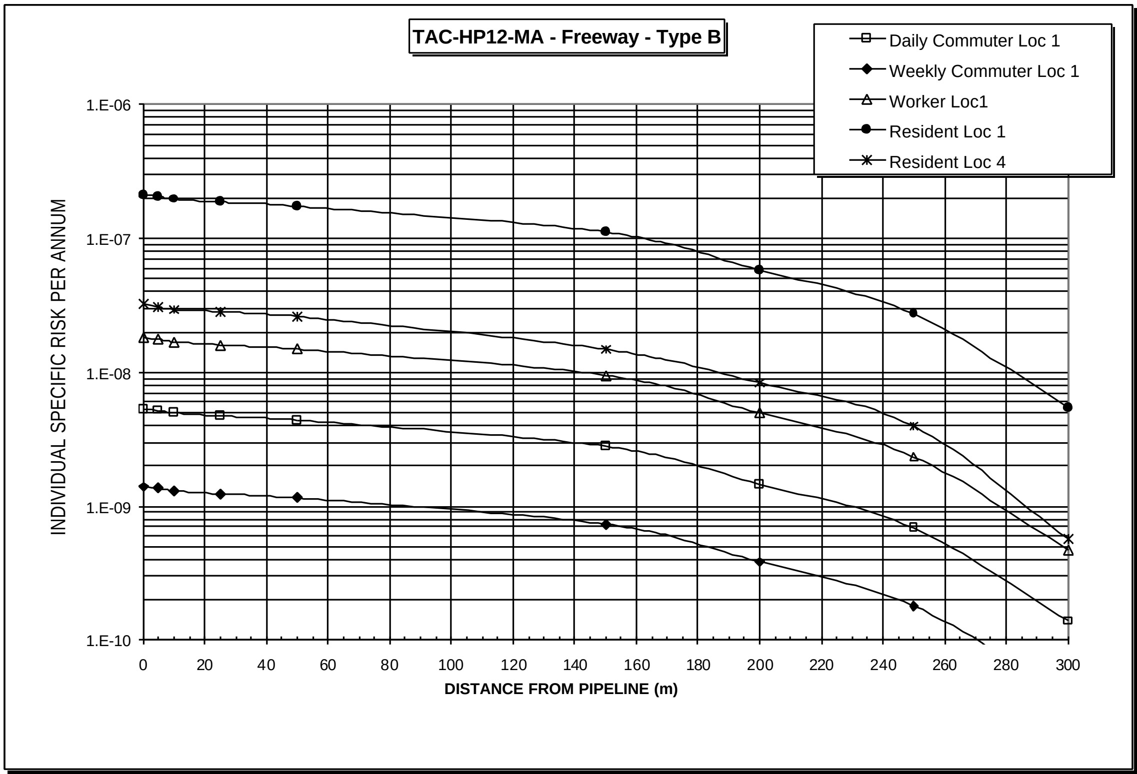


Figure 9.1
Transects – Freeway HP12 – Location 1

Table 9.2
Variations in Risk with Road and Pipeline Parameters

Road Type	HP P/L TYPE (inches)	MAXIMUM RESIDENT RISK (ANNUAL CHANCES OF FATALITY PER MILLION)			
		Loc. 1	Loc. 2	Loc. 3	Loc. 4
Freeway	12	0.21	0.20	0.18	0.03
	8	0.27	0.25	0.23	0.04
Arterial	12	0.16	0.15	0.14	0.03
	8	0.20	0.18	0.17	0.04
Collector	12	0.12	0.11	0.10	0.03
	8	0.15	0.14	0.12	0.04
Local	12	0.08	0.07	0.06	0.03
	8	0.10	0.09	0.08	0.04

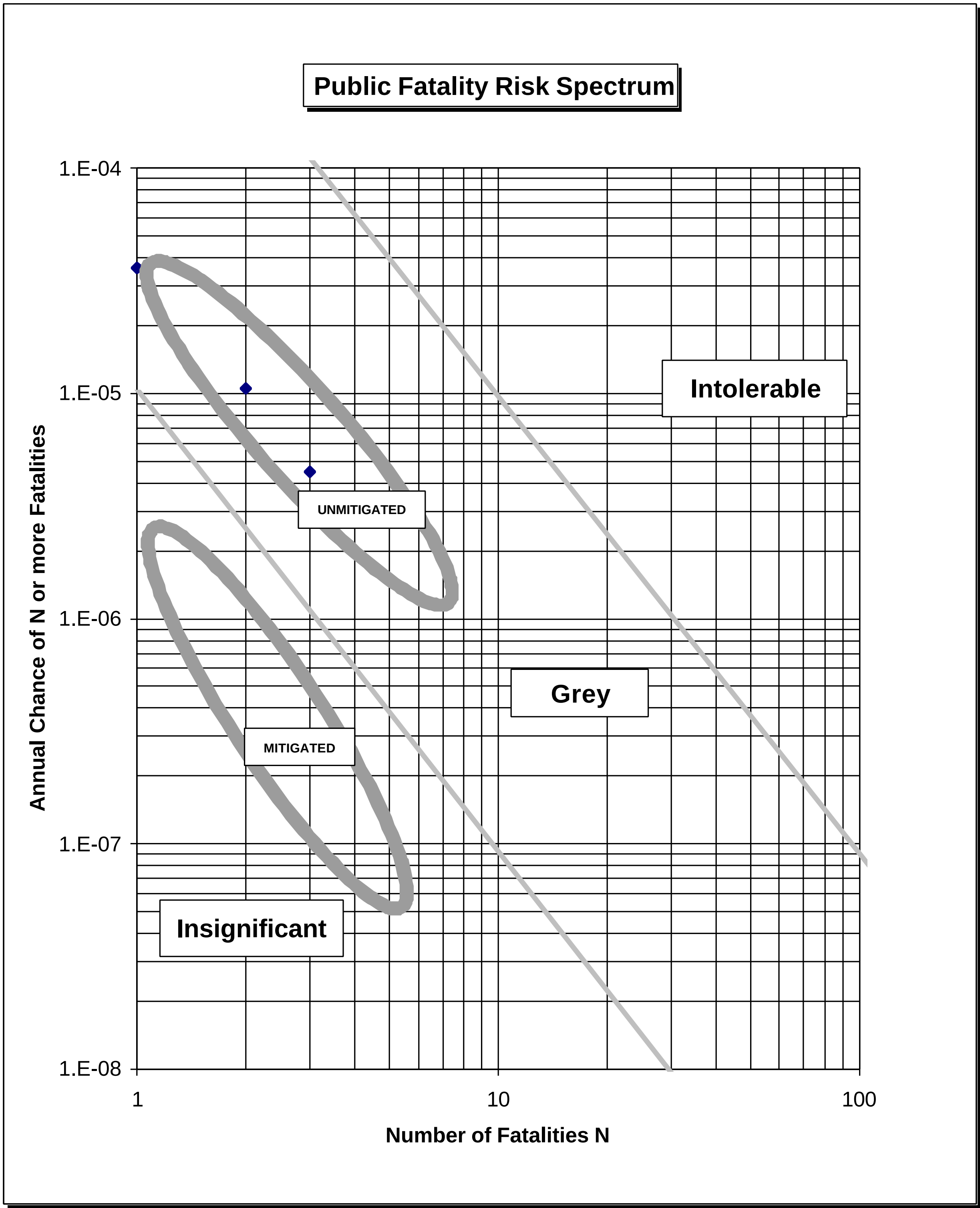


Figure 9.2
Collective Risk for Case Study #2

A variety of risk mitigation measures was identified for each of the significant risk causes. As mentioned above, it is essential to mitigate risks; without risk mitigation, risks are likely to be unacceptable. These risk mitigation measures are summarized in Table 9.3. A very common risk mitigation measure designed to avoid third party damage during excavations in the vicinity of pipeline locations is the Close Proximity Excavation Procedure (CPEP) summarized at the bottom of Table 9.3. Various risk mitigation measures are given for each of the risk causes, and it is expected that the optimal ones would be selected in accordance with a site-specific risk-cost-benefit assessment. In some cases, as will be pointed out later, risk mitigation may not be feasible, and the pipeline simply cannot be placed in one or all of the locations in the right-of-way, or must be constructed with special provisions.

9.4.2 Case Study #1

Case Study #1 involved the investigation of a proposed roughly 15-km length of NPS 6 very-high pressure natural gas pipeline largely within road right-of-ways within Pictou County, Nova Scotia. Significant risks were found to be associated with the following activities for the specified road conditions:

- Continuous ditch grading utilizing a backhoe for several kilometres of ditch, on a periodic, roughly 10-year return basis
- Installation of new guard rail posts using an impact auger.

Risk calculations were carried out considering these (and other) activities proceeding in an unmitigated fashion, with the result that risks to the workers and to the public would be at an unacceptably high level, requiring risk mitigation. The “Unmitigated” risk shown in Figure 9.2 corresponds to the unmitigated situation. Although it cannot be claimed that an optimal risk mitigation method (other than not locating the pipeline under the ditch or shoulder) was developed, several alternative risk mitigation methods were proposed, and selected ones were analyzed for economic impacts. As before, it was found that if an acceptable risk mitigation method is used with associated impacts then risks from the proposed development could be brought into the acceptable region. Naturally, the estimated cumulative effect of these impacts and determination of its acceptability must be done by the right-of-way owners.

As mentioned earlier, it should be noted, that although the predominant factors affecting impact and risk have been identified and quantified, this case study should not be viewed as a replacement for a detailed quantitative impact and risk assessment as may be required by the regulatory authority having jurisdiction.

Table 9.3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
External Corrosion				
	Percolation	ALL	ALL	1-Ensure adequate protective coating for expected soil ph/moisture conditions
				2-Ensure adequate drainage control
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	EMF	ALL	ALL	1-Ensure adequate Cathodic protection system and check regularly
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	Salt Effects	ALL	ALL	1-Ensure adequate protective coating for expected salt concentrations
				2-Ensure adequate drainage control to minimize road salt drainage to p/l
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
Third Party Damage				
	Roadway Clearing - Debris, Rockfall	ALL	ALL	1-Identify pipeline locations from p/l markers if grading to max .3m ok
				2-Use care with excavators or loaders CPEP within 30m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Culvert Maintenance	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Supply, Remove, & Install Minor Culverts	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Minor Signs (Single Post)	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Major Signs	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Guide Posts	ALL	ALL	1-Locate p/l and use CPEP
				2-Ensure guide post holes do not exceed .5m depth if within 3m
	Installation of Extra or Repl. Power Poles	ALL	ALL	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Ditch Grading - Continous, Grader	ALL	2	1-Locate p/l and use CPEP
				2-Conduct depth of cover survey prior to commencement of grading of ditches
	Ditch Grading - Continous, Excavator	ALL	2	1-Ditch grading with excavator not permitted if p/l installed less than 2m below ditch invert
				2-Install p/l in alternate location
				3-Develop safe ditch grading procedure and p/l installation method
	Snow Ploughing	1	ALL	1-Locate p/l (from markers) and use care if over p/l
	Rock Scaling	1	ALL	1-Avoid locating p/l in frequent (<20yr) rock fall locations
				2-Use nets/deflectors to deflect rockfalls from p/l locations
				3-Protect p/l with grade surface protectors -slabs, plates adequate to absorb rock fall impacts
				4-Design and install p/l for maximum rock fall impact resistance
	Mud Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Land Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Washout Repairs	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m

Table 9.3
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
Third Party Damage - *Continued*				
	Major Section Repair, Excavation of Embankment	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
				5-Conduct full scale p/l resistance/integrity tests for expected dynamic compaction methods
				6. P/l should be located at as depth where it is safe fromheavy equipment/vibratory compaction
	New Culvert X	1	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Culvert II	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Utility X (e.g., FOC)	ALL	ALL	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
	New Utility II	ALL	1,2	1-Locate p/l
				2-Use CPEP within 2m of p/l
	New Minor Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Major Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Power Line	ALL	ALL	1-Locate p/l and use CPEP
	New Ditch	ALL	1	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
			2	1-No new ditch over 1.2m cover p/l location
				2-Relocate p/l to alternate location
	New Guard Rail (Unmitigated)	ALL	ALL	1-Locate p/l and use CPEP
				2-Plan ahead and install p/l in location 3 or 4 where guardrail work expected
	New Guard Rail (Mitigated)	ALL	1,2	1-Locate p/l and use CPEP
	New Driveway	ALL	ALL	1-Locate p/l
				1-Locate p/l and use CPEP
				3-Plan ahead-Install new access grade at time of p/l installation
	Railway Crossing Accident Derailment	ALL	ALL	1-Install p/l as far as possible from railroad, preferred >20m to avoid derailed train impact
				2-Implement derailment ERP, including immediate p/l shutin and blowdown
Earth Movement				
	Vibration from Traffic	1	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Conduct regular inspection pigging to detect incipient damage and permit repairs
	Frost Heave	3	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Drainage control to avoid water/ice buildup in vicinity of p/l
	Landslide	5	ALL	1-Locate outside landslide zone
				2-If in landslide zone design and install p/l for maximum landslide survival
				3-Shut in and blowdown if landslide warning red alert
	Flood	10	ALL	1-Locate outside flood zone
				2-If on flood plain design/install to maintain integrity in max flood
				3-Shut in and blowdown if flood buildup predicted and underway

Note re CPEP: ***If excavation more than 0.3 m deep planned:***
1. Within 30 m of p/l contact p/l operator and locate and mark p/l.
2. Within 5 m of p/l, daylight p/l by hand excavation.
3. Within 0.6 m of p/l surface hand excavate.
4. Hand excavation includes low-pressure air or water jet or vacuum (Hydrovac).

9.4.3 Case Study #2

Case Study #2 consisted of the impact and risk assessment of the proposed NPS 6 very-high pressure natural gas pipeline from Squamish, BC to Whistler, BC. In the risk and impact assessment, the approximately 40-km pipeline was subdivided into two representative segments, the flat terrain segment in the valley and flood plain north of Squamish, and the mountainous portion just south of Whistler. Economic and operational impacts and resultant mitigated risks along the flat terrain, other than potential flooding, were generally similar to those assessed under the general case. For the mountainous terrain portion, however, the frequency of avalanches and rockfalls and associated mountainside hazard management involving rock scaling, appeared to pose significant hazards to the pipeline if left unmitigated. An unmitigated risk assessment was conducted for these operational and environmental hazards, and it was found that risks would be in the unacceptable region for both members of the public and workers on the road. Collective risks, similarly, were found to be in the gray (requiring mitigation) region marked “Unmitigated” in Figure 9.2.

A variety of mitigation methods, including some suggested by the proponents, were reviewed. Although it is beyond the scope of this work to comment on their quantitative reliability and operational cost-benefit, for the mitigated risk assessment, reliance was placed on the documentation and purported efficacy of the risk mitigation methods, and it was found that if such appropriate risk mitigation methods could be devised to eliminate risks from rock scaling and rockfalls in the mountainous region, and all other safety procedures were implemented, risk levels could be in an acceptable range.

9.4.4 Regulatory Review

Applicable regulations were reviewed for Canadian jurisdictions in Alberta, British Columbia, Manitoba, and Ontario, as well as federally. It was generally found that, although guidelines existed for depth of cover for utilities in the vicinity of roadways, together with provisions in some jurisdictions (BC) for different risk levels, location of pipelines in right-of-ways is not permitted except by special permit, and if allowed, preference was generally given to locations on the outside of the right-of-way (Location 3). No detailed regulations in regard to placement, construction methods, and maintenance operations existed. Detailed regulations for construction in the vicinity of pipelines are set out by the National Energy Board. Alberta industry associations also setout explicit safety regulations for construction and operation in the vicinity of natural gas pipelines. These safety regulations are generally summarized at the bottom of Table 9.3, under CPEP. Although jurisdictional and franchising requirements are more specific, detailed regulations were not evident for the US locations reviewed, California and Minnesota. Railway regulations on both sides of the border, however, do have provisions for utilities installed parallel to railroads, and include provisions such as variability in the depth of cover between 6 feet in close proximity to tracks, to a minimum of 5 feet further away on the right-of-way.

9.5 Recommendations

9.5.1 General Recommendations

In general, it is recommended that this work be viewed as a comprehensive treatment of the problem of locating natural gas pipelines in various locations of rural road right-of-ways including identification of impacts, risks, risk and impact mitigation, and applicable regulations. It should be viewed as a foundation for more site-specific detailed risk and impact investigation by regulators, road system or pipeline designers, and other interested parties. Although the methodology established, described, and applied is rigorous, results of the general case should be used primarily as indicators of possible trends. For the specific case studies, illustrating more specific applications of the methodologies devised, good estimates of the factors predominating the impacts and risks are given, but should not be expected to replace a detailed risk and impact assessment.

General recommendations made on the basis of the work may be summarized as follows:

- If high-pressure natural gas pipelines are located in the road right-of-ways (with 1.2 metres cover in Locations 1, 2, or 3), all industry standard and other appropriate safety measures must be defined, publicized, implemented, and strictly adhered to in all private or public road maintenance construction activities.
- If these safety measures are not in effect (as described above), high-pressure natural gas pipelines should not be installed in Locations 1, 2, or 3 with 1.2 metres of cover.
- When pipelines are in the right-of-way, road maintenance and construction contractors will need to change their basic approaches to avoid accidents. This will involve a change in attitude or culture, to one similar to that adopted by oil and gas facility contractors. Described safety measures alone will not assure adequate safety; the attitude regarding safety is needed in addition to adherence to safety measures as not all situations may be covered by these safety measures.
- Alternative specially mitigated pipeline installations in the right-of-way may be acceptable but must first be evaluated for risk and impact on a case-by-case basis.
- In general, Location 3 on the edge of the right-of-way is associated with the lowest risk and impact.

Although in general there are many possible risk mitigations, with associated impacts on both the pipeline installation and road activities, to be arrived at through risk-cost optimization, there are several combinations of pipeline locations, local conditions, and activities which are difficult to resolve in a practical fashion and in some cases may be mutually exclusive because of excessive costs, intolerable risks, or simple impracticability of adjustments either to the road activity or pipeline installation. Table 9.4 summarizes these combinations of activities and conditions. There may be others, but the final judgement on acceptability should be made by the stakeholders weighing all factors within the framework set out in this work.

Table 9.4
Location Excluding Activities and Conditions

LOCATION	ACTIVITY	CONDITION	REQUIREMENT	EXCLUSION FACTOR
1	New guardrail installation within 2 feet of 1.2 m cover pipeline.	Narrow shoulder, rocky soils, making Hydrovac ineffective.	Hand excavation of post holes.	Impractical
	All road widening activities including adding passing, climbing, turn, or extra lanes.	Adequate sub-base to limit excavation/fill to 0.3 metre depth so that pipeline need not be relocated.	Static compaction over pipeline.	Possible but often Impractical
	Paving of shoulder.	Adequate sub-base to limit excavation/fill to 0.3 metre depth so that pipeline need not be relocated.	Static compaction over pipeline.	Possible but often Impractical
2	Continuous ditch grading with backhoe over p/l originally installed with 1.2m cover.	Ditch eroded/silted and steep sided.	Daylight pipeline at close intervals and hand excavate within 0.6 metres of pipeline surface. Bury p/l initially with 2m cover, conduct pre-grading daylighting survey, mark on cut stakes, and proceed with Gradall or equal.	Impractical Possible
	New ditch.	New ditch within 3 metres of old one, extending several km.	Daylight pipeline, hand excavate within 0.6 metres.	Impractical
	Any road widening requiring excavation and backfill within 3 metres of ditch (pipeline).	Need to excavate and backfill roadways.	Static compaction only.	Impractical
1, 2, 3	High avalanche, rockfall, mudslide area.	Geotechnical instability.	Pipeline protection. Development of pipeline burial and protection method (foam, fillcrete, increased depth Directional drill through rockfall area at adequate depth (eg10m)	High Risk Possible High cost
	Rock scaling.	Cliff instability.	Pipeline protection.(as above)	High Risk
	Major road reconstruction and upgrading.	Reconstruction over pipeline locations.	Relocate pipeline. Replace p/l backfill with Fillcrete or equal	High Cost Possible

Note: Exclusion factor means the reason or potential reason that either the pipeline cannot be located at the given location, or the subject activity cannot be carried out.

To deal with the less obvious situations such as those identified in Table 9.4, it is recommended that a project or process be initiated to identify, develop, test, assess, and implement road maintenance and construction and associated pipeline installation and operation procedures and technologies to cost effectively and efficiently achieve the objectives of traditionally conducted activities. Such technologies, as an example, could include:

- Sensor/alarm systems on excavation equipment buckets or ploughs to warn operator of pipeline proximity, with ability to set the warning distance, with an increasing alarm intensity as the proximity increases.
- Excavation depth governors for augers, drills, and other post hole diggers.
- Pipeline installation and backfill methods to allow for future overpaving, including dynamic compaction.
- Pipeline installation and backfill methods (excluding directional drilling) to allow adequate protection in rock fall areas.
- Method for remotely but accurately surveying pipeline cover thickness.

9.5.2 Case Study #1

Case Study #1 has revealed that activities with the highest risk, and therefore impact potential, are the continuous ditch grading and guardrail installation. If the risks are unmitigated and the normal procedures applied, risks will be unacceptable. Mitigations, however, other than location of the pipeline in an alternative site, although imaginable and identifiable, are not obvious from a feasibility point of view, and will require further study.

Both the impact and risk assessments for Case Study #1 have been made on the assumption that the segment and surroundings modeled are homogeneous, other than the variation between Locations 1 and 2. In reality, there will be a significant variation in both risk and impact throughout the proposed project region, with possible risk hot spots, but this variation could be quantified only through a detailed risk and impact analysis.

Although the impact scenarios quantified for Case Study #1 are based on those of the general case, with adjustments for regional cost factors, they should serve as a good basis for a (recommended) cumulative cost assessment that can be made by the highway operators in the area. Similarly, because of the relatively robust nature of the risk model, and therefore its lack of sensitivity to small variations in inputs, it is expected that the predominant risk factors have been adequately identified, and should be addressed through more detailed operational and analytical assessments, to identify final cost and risk mitigation methods.

9.5.3 Case Study #2

In Case Study #2, the primary concern for both impacts and risks is the mountainous segment south of Whistler, extending approximately 12 km through the Civil Defense Zone. If no mitigation for the pipeline integrity risks are provided for this region, risks to the public, and incidentally, also to the pipeline system itself, would exceed acceptable bounds. Various risk and impact mitigation measures have been suggested by the proponents, and if indeed these are as effective as purported, risks and impacts would be manageable. The risk mitigations proposed, however, appear to be largely based on theory, and may require validation utilizing appropriate full-scale tests. Thus, in Case Study #2, most impacts and risks appear to be manageable except for those associated with the mountainous regions where rockfalls and the associated rockfall management practices of rock scaling result in unacceptably high levels of risks, and further study, and full-scale experiments as required.

Again, as for Case Study #1, even though it is believed that the dominant risk factors have been adequately identified in this relatively high level analysis carried out, a more detailed assessment to quantify the risk variation in a detailed fashion over the length of the pipeline alignment and to investigate specific risk mitigation measures remains to be done before the question of risk is sufficiently addressed to be able to stand before a regulatory authority and members of the public.

9.5.4 Regulatory Recommendations

At this time no uniform and comprehensive regulations addressing the control of impacts and risks and associated distribution of liability associated with placement of natural gas pipelines in road right-of-ways appear to exist in Canadian or US jurisdictions.

Similarly, although detailed standards for excavation in the vicinity of pipelines exist in various guidelines, including Canada-wide standards promulgated by the NEB, their existence is not widely publicized, and certain conflicts among the standards from various jurisdictions exist. No widely applicable standards exist, however, for liability, cost sharing, or authorities having jurisdiction for the location of pipelines in road right-of-ways. One basis for parallel installation standards could be the depth of cover and class of construction required for road and railway crossings (as opposed to parallel installations), excluding the casing requirements which are often included for crossings.

In order to develop such standards and regulations, one possible approach would be the formation of a Task Force under the Transportation Association of Canada, the Canadian Energy Pipeline Association (or other industry associations), and the National Energy Board to define the problem and finalize approaches. The present study would provide a good foundation for such a Task Force by giving the general trends in risks and impacts associated with different combinations of pipeline and road types and pipeline locations within the right-of-way, but issues of jurisdiction, liability, and method of promulgation of the regulations need to be generated.

9.5.5 Summary of Recommendations

The salient recommendations from this work may be summarized as follows:

- The work should be used as a basis or framework for site-specific detailed impact and risk assessments when pipelines are planned to be installed in right-of-ways. Specific assessments, on a relatively broad level of detail were illustrated by Case Studies #1 and #2. More detailed assessments may be required for final definition of impacts and risks together with appropriate mitigation measures.
- A process for the adoption of specific guidelines for close proximity excavation procedures, the development of standards for cost and liability distribution, and authority designation for the location of pipelines in road right-of-ways should be initiated.
- A process or project should be initiated to identify, develop, test, assess, and implement road maintenance and construction and associated pipeline installation and operation procedures and technologies to cost effectively and efficiently achieve the objectives of traditional activities (when no pipelines are present) on road right-of-ways.
- As the above two projects are unlikely to be completed in a short-term time framework, it is recommended that the methods set out in the present work be adopted as an interim basis for dealing with the problem of high-pressure natural gas pipeline on road right-of-ways.

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APPENDIX A

Terms of Reference

RE: Request for Proposal for Consulting Services to Study Natural Gas Pipeline Placement in the Rural Environment

1. Project Title

Natural Gas Pipeline Placement Study

2. Date of Solicitation

Friday, October 13, 2000

3. Closing Date

Friday, October 27, 2000 (3:00 PM Ottawa Time)

4. Proposals are to be provided in electronic format to:

John Kizas, P.Eng.
Program Manager, Roads & Education
Transportation Association of Canada
jkizas@tac-atc.ca

Note: Please provide your entire proposal in one file in Microsoft Word or Adobe PDF file format.

Mailing address:
2323 St. Laurent Blvd.
Ottawa, ON K1G 4J8

Phone: (613) 736-1350
Fax: (613) 736-1395

5. Proposal Requirements

You are requested to prepare a proposal to address the work detailed in the attached Project Terms of Reference. The proposal length is not to exceed ten (10) pages (CV's may be provided as supplementary material only). The proposal shall consist of the following:

6(a) Technical Component
This part of the proposal should be clear and concise but in sufficient depth to permit a complete assessment of the proposal. Detailed task descriptions should be included which adequately address each step of the project's objectives and research procedures outlined in the Project Terms of Reference. This section should identify project team members and detail their relevant experience and expertise.

6(b) Financial Component

The proposal should contain a financial breakdown for each task as appropriate for invoicing purposes. The financial component should reflect and also include: total project cost; hourly rate of pay for each project team member; expected hours to be worked by each team member; travel and living costs and other expenses.

6. Project Schedule and Level of Effort

This section should indicate the timetable for the project and the amount of the consulting fee which the project is not to exceed, as detailed in the Project Terms of Reference.

7. Special Conditions

The selected consultant must be a member in good standing with the Transportation Association of Canada.

8. Proposal Evaluation

Proposals will be reviewed and evaluated by the TAC project manager and the project steering committee members on the basis of the following criteria:

Percentages are provided for illustration only. The numerical weighing may be deleted and the Project Steering Committee can set other criteria, tailored to the specific objectives of the project.

(a) Workplan Technical Merit (**45%**)

- demonstrated understanding of project scope and objectives (**10%**)
- sound, practical approach toward production of useful report (**10%**)
- adequacy of workplan and schedule (**10%**)
- general approach and methodology (**15%**)

(b) Company and Project Team (**45%**)

- proven competence in relevant related work (**15%**)
- relevant experience, qualifications and planned participation of:
    - project manager (**10%**)
    - project team members (**15%**)
- sufficient manpower resources (**5%**)

(c) Other (**10%**)

- innovation, new ideas (**5%**)
- Canadian content (**5%**)

9. Contract Negotiations

This is a RFP and not an invitation to tender. You are hereby advised that TAC reserves the right to:

(a) accept a proposal without negotiation; or
(b) negotiate changes in the technical or financial content of the successful proposal.

10. Contract

The successful consultant will be required to sign TAC's standard client-consultant agreement.

11. Cancellation of the Project

TAC reserves the right to cancel and/or reissue this RFP at any time.

12. Source List

This RFP was sent to the following firms (in alphabetical order):

Mr. Frank Bercha
Bercha Engineering Limited
bgroup@cadvision.com

Mr. Tom Zimmerman
C-FER Technologies
T.Zimmerman@cfertech.com

Mr. Ian Williams
McCormick Rankin Corporation
williams@mrc.ca

Mr. Tomasz Kroman
UMA Engineering Limited
tkroman@umagroup.com

Terms of Reference

Natural Gas Pipeline Placement Study

Background:

All provincial and territorial transportation agencies within Canada are responsible to maintain the highway right-of-way under their jurisdiction and to preserve the operational safety, integrity, and function of the highway system. The placement of utilities, such as natural gas pipelines, parallel to and within the roadway structure and/or the right-of-way can affect the safe operation and maintenance of the highway system. As the practice of placing intermediate and high pressure natural gas pipeline within freeway and rural highway right-of-ways is not widespread in Canada, transportation agencies need to develop guidelines outlining safe and rational practices for accommodating natural gas distribution systems while preserving safe highway operations and maintaining the integrity of the highway system.

Nova Scotia is currently facing the question of allowing natural gas pipe lines with in its right-of-ways and this provides an opportunity to conduct a case study for a large green-field project. The Nova Scotia Department of Transportation and Public Works can supply a resource/materials list compiled during internal research, in regard to natural gas pipeline placement within the right-of way.(Appendix I). The study shall also look at British Columbia's experience with placing a natural gas pipeline system within the highway right-of-way through a mountain pass.

These Terms of Reference outlines the requirements for a study of the risks, from both a safety and liability perspective, of installing intermediate and high pressure natural gas pipelines in a roadway structure and/or the right-of-way.

The study shall focus on the experience of Canadian jurisdictions, however may also supplement with relative information from other jurisdictions.

Study Scope:

Items to be considered in the study include, but are not limited to:

1. The safety and risks associated with installing natural gas distribution/transmission pipelines in the roadway structure; other areas within the right-of-way (ROW); and outside the ROW of the provincial highway system. Safety and risk considerations include: the hazards to the traveling public, construction/ utility crews working in the vicinity for construction and maintenance activities, and those hazards including possible explosions caused by the accidental release of natural gas.

2. The operational implications for the roadway structure in terms of construction and maintenance of the pipeline in the roadway structure, in the ROW and outside the ROW, as well as future expansion of either the pipeline system or the roadway system.

3. The implications for other public utilities of allowing natural gas pipelines in the highway right-of-way and the potential for limiting the availability of the right-of-way for communications cabling, electrical power distribution etc.

4. The reviewer will consider the current practices within the various provincial transportation agencies with regards to the placement of natural gas pipelines within the right-of-way and parallel to the highway systems , as well as any existing regulations and/or conditions placed on natural gas pipeline installations in these jurisdictions.

Study's Goals:

The study should provide a summary of the risks in quantifiable form of allowing the installation of a gas transmission system consisting of different sized natural gas pipeline (in the range of 4 to 12 inch) operating at various operating pressures. For the purpose of this study intermediate pressure is defined as 700kPa. to 2,070 kPa.(100 to 300 psi.) and high pressure is defined as greater than 2,070 (300 psi.)

In addition to the impact of the pipeline operating pressures, the risk shall also be assessed with regard to traffic volumes, types of roads (see Appendix II) and the location of the pipeline (see Appendix III for locations and cross sections). Four locations include:

1. In the roadway shoulder
2. In the roadway ditch
3. Outside the roadway structure, but within 2 metres of the edge of ROW
4. Outside the transportation agency's ROW

Review Requirements of the Study:

1. Review the practices and policies of Canadian transportation agencies as well as the National Energy Boards regulations regarding natural gas pipelines. Comment on the rationale for these policies. In cases where agencies have allowed pipelines within the ROW, identify the terms and conditions that apply and comment on who has jurisdiction and authority if the transportation agency and the gas utility share the highway right-of-way.
2. Identify and quantify the safety risks for the types of natural gas pipelines noted in the Study's Goal for the four locations.
3. Identify and quantify the safety risks, operational limitations, and costs of maintaining, reconstructing or altering existing roadways, that have gas pipelines of varying operating pressure, sizes, locations, etc.
4. Identify and quantify all other issues which may be of concern to a transportation agency including, but not limited to, road integrity as well as recommended methods to mitigate these concerns if an agency were to approve placement of natural gas pipelines within the road structure or the ROW.
5. The consultant is to describe the various potential failure mechanisms associated with gas pipelines and quantify the results of the failures as it relates to pipe operating pressure, the size of the pipe, and the location of the pipe.

Study Final Report and Findings:

The final report plus background materials are to be supplied to Transportation Association of Canada by January 31, 2001. The final report shall contain the following:

1. Describe and quantify the safety risks (absolute and relative) for the traveling public and those working in the vicinity of the pipeline, associated with natural gas pipelines:
   - by pipe type/pressure
   - by location
   - by road type

   Also, suggest reasonable risk management methods (and additional costs if possible) of mitigating these safety risks.
2. List the limitations with regards to maintaining, reconstructing and altering the road structure, by location of the pipe.
3. Methods and additional costs (if possible) of mitigating the limitations in 2 above.
4. Provide a context by comparing the identified risks with those associated with other common road transportation activities.
5. An informed review on the policies of other provinces and the reasoning behind these policies.
6. Identify the implications associated with hosting a natural gas pipeline within the highway right-of-way.

Guidance:

Guidance and approval for the study shall be provided through a Transportation Association of Canada Project Steering Committee, comprised of Provincial, Territorial and Municipal transportation agencies. The proponents workplan and schedule should provide time for necessary consultation, guidance, and approval by the Project Steering Committee.

Ownership:

All information and final reports shall become the property of the Transportation Association of Canada.

Consultant Expertise:

The consultant shall have demonstrated expertise in the field of risk assessment with regard to transportation infrastructure and utilities, specifically natural gas distribution systems. If sub-consultants are to be used for components of the study they and their experience must be clearly illustrated .

Study Schedule:

Progress meetings will take on November 24, 2000 and December 15, 2000, and as otherwise required by the Project Steering Committee. A draft report is due January 10, 2001 with the final report due January 31,2001.

Submission of Proposal:

The Consultant should clearly identify in a written proposal to the Transportation Association of Canada, the following:

- proposed work plan and study methodology
- experience of the firm
- personnel involved and their experience
- a study schedule and timing
- costs including consulting fee and expenses

Proposals in excess of CDN$75,000.00 (exclusive of GST) will represent a misunderstanding of the scope of this assignment

Appendix I

Resource/Materials List

Resource/Materials List

Contact	Agency	Telephone	Material
John Shaw Manager of Operations Policy	British Columbia Ministry of Transportation & Highways	(250)387-7605	Utility Policy, Section 8.0 Pipelines
Bruce Partington	Alberta Resource Development	(780)427-0111	Technical Standards & Specifications Manual for Gas Distribution Systems
Glen Tjostheim	Alberta Infrastructure	(780)415-1269	Alberta Infrastructure Utility Review
Jon Wyatt Director of Operations Services Branch	Saskatchewan Highways & Transportation	(306)787-4937	Gas Line Permit & Application Requirements
Dave Paul	SaskEnergy	(306)777-9529	
Don Bdnaruk	Manitoba Highways and Transportation	(204)945-7111	Interim Policy, Procedures & Guidelines for Processing & Approval of Utility & Underground Installations Within Right-of Way & Lands
Doug Peeling Standards Branch	Ontario Ministry of Transportation and Communications	(905)704-2916	The Corridor Control and Permit Procedures Manual
Clare Riepma Supervisor Corridor Policy	Ontario Ministry of Transportation and Communications	(905)704-2997	
Ronald Blanchet	Ministere des Transport Quebec	(418)643-0024	
Brian McEwing Director Planning and Land Management Branch	New Brunswick Department of Transportation	(506)453-2754	

Appendix II

Highway Classification, Traffic Volumes and Design Standards

HIGHWAY CLASSIFICATION, TRAFFIC VOLUME, DESIGN STANDARDS

	FREEWAY	ARTERIAL		COLLECTOR		LOCAL			
	TYPE B	TYPE C	TYPE D	TYPE E	TYPE F	TYPE G	TYPE H	TYPE I	TYPE J
Design Year Traffic. ADDT	<10000	>5000 (*1)	<5000	>3000 (*1)	<3000	>300 (*1)	<300	<50	
Design Hourly Volume	<450	>450	<450	>250	<250				
Design Speed Range, km/h	110–90	100–80	90–80	90–80	80–70	80–60	70–50		50
Gradient – Maximum, %	8	7	7	8	9	10	12		8
Surface Type	Paved	Paved	Paved	Paved	Paved	Optional	Unpaved	Unpaved	Optional
Lane Width, m	3.7	3.7	3.5	3.5	3.3	3.0			3.0
Shoulder Type	Paved 1.0	Paved 0.5	Paved 0.5	Opt.0.2	Unpaved	Unpaved			Optional
Shoulder Width (usable, m	2.5	2.2	2.2	2.0	1.5	1.2			1.6
Shoulder Rounding, m	0.8	0.6	0.6	0.4	0.4	0.4			0.4
Finished Top Width, m	14.0	12.6	12.6	11.8	10.4	9.2	8.0	6.6	10.0
Side Slopes (a)	4:1	3:1	3:1	2:1	2:1	2:1	1.5:1	1.5:1	2:1
Back Slpoes (b)	2:1	2:1	2:1	2:1	2:1	2:1	1.5:1	1.5:1	2:1

NOTES:

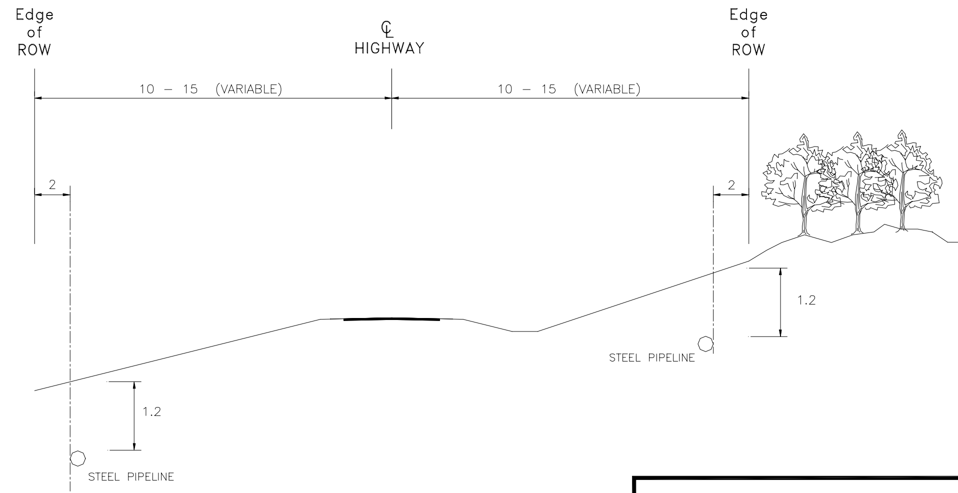
*1. While Arterial Type C, Collector Type E, and Local Type G have standard design year traffic ADDT's, it is common for these types of roads to experience a range in ADDT's.

In a sample from Nova Scotia, the following ADDT's were found:
Type C 360 to 19,770 ADDT
Type E 430 to 11,000 ADDT
Type G 100 to 8,820 ADDT

2. On embankments over 3m, side slopes may be reduced to 2:1 with the installation of guard rail if economically feasible.

3. Maximum back slopes to be 2:1 but flatter slopes will be permitted for slope stability as determined by laboratory tests. Back slopes in cuts over 3m must be determined by laboratory tests prior to construction.

Appendix III
Cross Sections



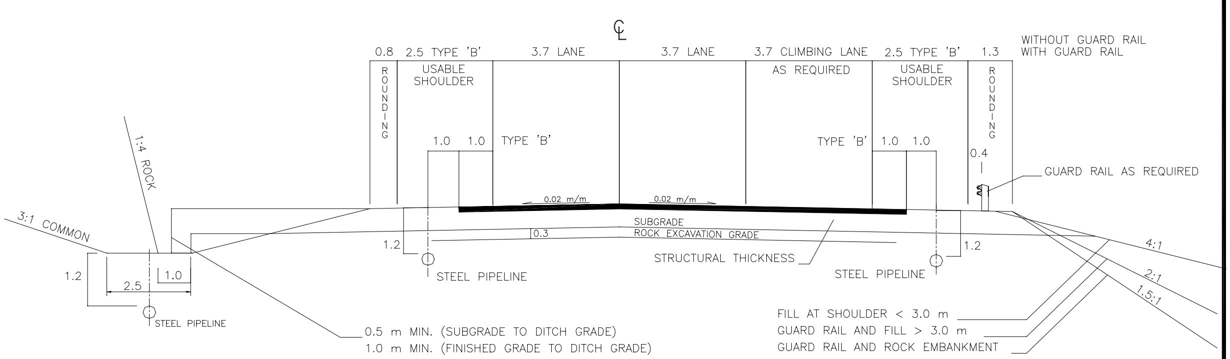
NOTES:

1) ALL DIMENSIONS ARE IN METERS

STANDARD CROSS SECTION

Drawn by: Date:	Approved by: Title: Date:

File No. :	File Name:	Sheet 1 of 1



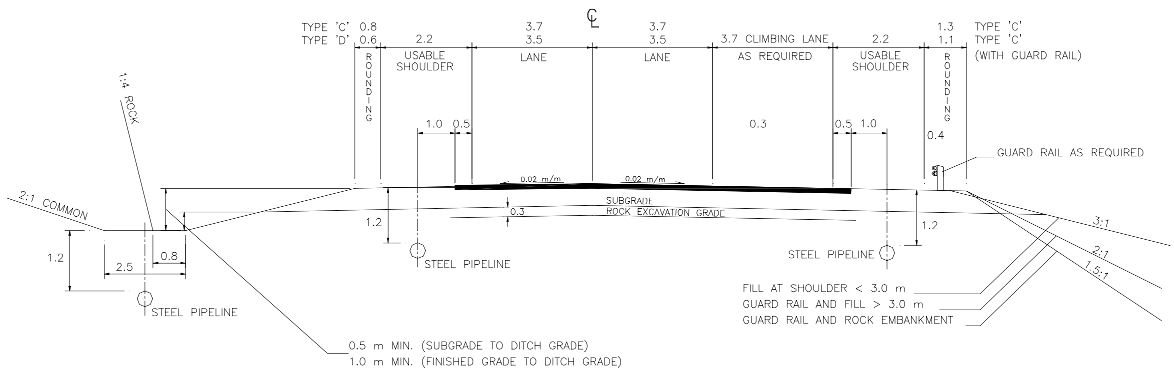
NOTES:

- BACK SLOPES MAY BE INCREASED IF LABORATORY TESTS WARRANT OR IF SLOPES COVERED IN ROCK.
- WIDTH OF SUBGRADE IS DEPENDENT UPON STRUCTURAL THICKNESS WHICH SHALL BE DETERMINED BY CBR TESTING.
- ALL DIMENSIONS ARE IN METERS

STANDARD CROSS SECTION
FREEWAY TYPE "B"

Drawn by: Date:	Approved by: Title: Date:

File No. :	File Name:	Sheet 1 of 1



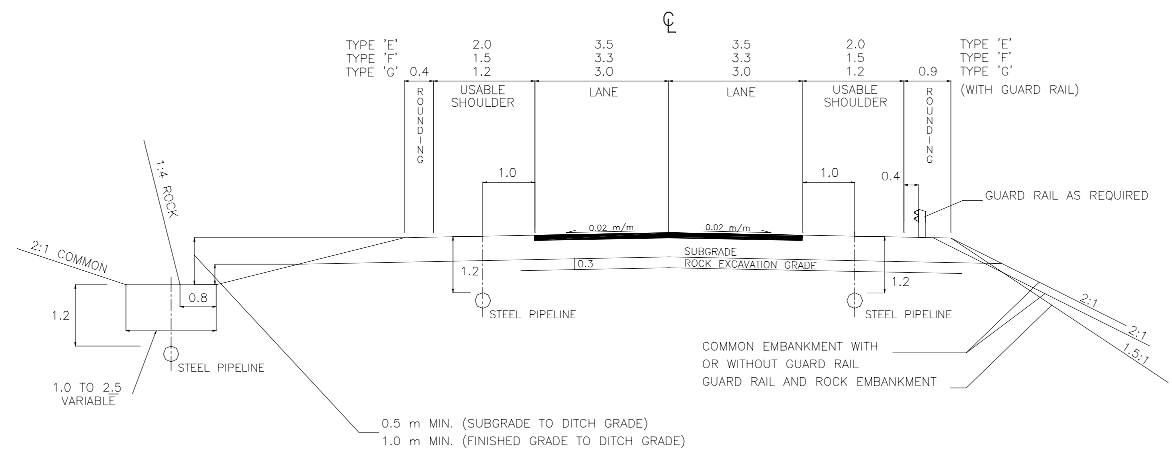
NOTES:

- MAXIMUM BACK SLOPES ARE 2:1 EXCEPT WHERE FLATTER SLOPES ARE REQUIRED FOR STABILITY AS DETERMINED BY LABORATORY TESTS.
- ALL DIMENSIONS ARE IN METERS

STANDARD CROSS SECTION
ARTERIAL TYPE 'C' & 'D'

Drawn by: Date:	Approved by: Title: Date:

File No. : | File Name: | Sheet 1 of 1



NOTES:

- MAXIMUM BACK SLOPES ARE 2:1 EXCEPT WHERE FLATTER SLOPES ARE REQUIRED FOR STABILITY AS DETERMINED BY LABORATORY TESTS.
- ALL DIMENSIONS ARE IN METERS

STANDARD CROSS SECTION
COLLECTOR TYPE 'E' & 'F', LOCAL TYPE 'G'

Drawn by: Date:	Approved by: Title: Date:

File No. : | File Name: | Sheet 1 of 1

APPENDIX B

Operational and Economic Impact Calculations

Table B.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
A	**NORMAL ROAD OPERATION**	**IMPACT OF P/L ON ACTIVITY**				
A.1	Vehicle Traffic Flow	Pipeline warning signs visible	ALL	ALL	L	L
A.2	Road Accident Follow Up-emergency vehicles	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.3	Road traffic-pulling over	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.4	Emergency vehicle passing offroad	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.5	Road accident cleanup	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.6	Wide load transit	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
A.7	Detour on shoulder	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
B	**ROAD MAINTENANCE**	**IMPACT OF P/L ON ACTIVITY**				
B.1	***Routine Maintenance***					
B.1.1	Daytime road inspections	None	ALL	ALL	L	L
B.1.2	Litter pickup	None	ALL	ALL	L	L
B.1.3	Minor fence repairs	None	ALL	ALL	L	L
B.1.4	Inspecting culvert ends for damage or blockage	None	ALL	ALL	L	L
B.1.5	Removing road kill (mostly deer)	None	ALL	ALL	L	L
B.1.6	Cleaning signs and guide posts	None	ALL	ALL	L	L
B.1.7	Straightening sign and guide posts	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.1.8	Replace reflector strips on guide & guardrail posts	None	ALL	ALL	L	L
B.1.9	Removing illegal signs	None	ALL	ALL	L	L
B.2	***Road Surface Maintenance***					
B.2.1	Roadway Sweeping	None	BCE	1&2	L	L
B.2.2	Raised Median Washing –	None	BCE	1	L	L
B.2.3	Line Painting	None	BCE	1	L	L
B.2.4	Message Painting	None	BCE	1	L	L
B.2.5	Maintaining Gravel Roads	None	H	1	L	L
B.2.6	Re-Gravelling	Minimize driving or parking heavy equipment over p/l	H	2	L	L
B.2.7	Dust Control	None	H	1	L	L
B.2.8	Livestock Guard Cleaning	Use close Proximity Excavation Procedure-CPEP (see note below)	H	1&2	L	L
B.2.9	Roadway Clearing-debris,rockfall	Minimize driving or parking heavy equipment over p/l, if using excavator use CPEP	ALL	1&2	L	M
B.3	***Roadside Maintenance***					
B.3.1	Mowing	None	ALL	ALL	L	L
B.3.2	Hand Trimming	None	ALL	ALL	L	L
B.3.3	Brushing	None	ALL	ALL	L	L
B.3.4	Chemical Vegetation Control	None	ALL	ALL	L	L
B.3.5	Drainage Maintenance/Improvements	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.3.6	Culvert Maintenance	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.3.7	Bridge Washing	None	ALL	ALL	L	L
B.3.8	Beaver Control	Use close Proximity Excavation Procedure-CPEP and blast mats if blasting	ALL	3	L	L
B.3.9	Removal of Large Road Kill	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
B.3.10	Ditch Grading-localized	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	M
B.4	***Road Surface Repairs***					
B.4.1	Pavement Surface Failures -	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.2	Fog Coat	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.3	Crack Sealing	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.4	Spray Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.5	Pothole Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.6	Paver Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.7	Grader Patching	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L
B.4.8	Milling	Minimize driving or parking heavy equipment over p/l	BCE	ALL	L	L

Table B.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
B.5	***Roadside Repairs and Installations***					
B.5.1	Supply, Remove, & Install Minor Culverts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	L	M
B.5.2	Installation of Minor Signs (single post)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.3	Installation of Major Signs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.4	Installation of Guide Posts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.5	Installation of Wildlife Reflectors	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.6	Installation of Guardrail (box beam, W-Beam)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.7	Installation of Concrete Barriers	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.5.8	Installation/Repair of Fencing – chain link or barbwire	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.9	Bridge Maintenance and Repair	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	L
B.5.10	Erosion Control/Repairs-minor	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.11	Installation of Extra or repl. Power Poles	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.12	Ditch Grading-continuous	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	M-H	H
B.5.13	Railway Crossing Repairs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.6	***Winter Operations***					
B.6.1	Application of Sand and salt	None -increased corrosion potential	ALL	ALL	L	L
B.6.2	Snow Ploughing	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	M
B.6.3	Installation of Snow Fencing	None	ALL	ALL	L	L
B.7	***Mountain Operations***					
B.7.1	Rock scaling	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	H	H
B.7.2	Mud Slide cleanup	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.3	Land slide cleanup	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.4	Washout Repairs	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	L	M
B.7.5	Avalanche Stabilization	Avoid locating cannon near p/l; assure that avalanche avoids p/l locations	ALL	ALL	L	L
C	**ROAD CONSTRUCTION**	**IMPACT OF P/L ON ACTIVITY**				
C.1	***Road Surface (3R,4R Projects)***					
C.1.1	Resurface	Minimize driving or parking heavy equipment over p/l	ALL	1&2	L	L
C.1.2	Major Section Repair, excavation of embankment	Locate p/l and use CPEP if within 5m; static compaction within 3m	ALL	1&2	M	M
C.1.3	Add climbing/Passing Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.4	Add Turn Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.5	Widen Road	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.6	Pave Shoulder	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.7	New Exit/Entry	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.8	New Overpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.9	New Underpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.10	Test Section	Locate p/l and use CPEP if within 5m	ALL	1&2	L	L
C.1.11	Rumble Strips	Locate p/l and use CPEP if within 5m	ALL	1&2	L	L
C.1.12	Blasting for wider road surface	Shut down and blowdown p/l for duration of blasting operations;use blast mats	ALL	ALL	M	L
C.1.13	Geotechnical drilling	Locate p/l and avoid drilling within 6m	ALL	ALL	L	L
C.2	***ROW (Off Surface)***					
C.2.1	New Culvert X	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.2	New Culvert II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.3	New Utility X (e.g., FOC)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.4	New Utility II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.5	New Minor Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	M	M
C.2.6	New Major Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.7	New O/H Sign Structure	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.8	New Pedestrian Bridge	Engineering design to avoid conflict with p/l	ALL	ALL	M	L
C.2.9	New power Line	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.10	New Ditch	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	H	M

Table B.1
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H) IMPACT	SEVERITY (L, M, H) RISK
C.2.11	New guard rail	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	M	H
C.2.12	New Driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.13	New road bridge	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.14	Borrow pit access driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.15	Farm animal fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	3	L	L
C.2.16	Diking	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.17	Emergency detour road designation and operation	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
C.2.18	Construction detour road construction	Minimize driving or parking heavy equipment over p/l min 1.5m cover	ALL	ALL	L	L
C.2.19	Wildlife control fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.20	Private sign installation	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
D	**NORMAL PIPELINE OPERATION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
D.1	Pipeline remotely operated	As described above	ALL	ALL	L	L
D.2	Pipeline failure	Close road until isolation and blowdown completed	ALL	ALL	H	H
D.3	Suspeected pipeline damage	Close road until damage repaired or p/l confirmed ok	ALL	ALL	H	L
E	**PIPELINE MAINTENANCE**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
E.1	Pipeline repair (major)	P/l segment blowdown and isolation; construction zone speed restriction, road closure during equipment mvmt	ALL	ALL	H	L
E.2	Leak Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.3	ROW Surveillance	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.4	Leak (Sniffer) Inspection	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.5	Cathodic Protection Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.6	Pipeline Exposure for Coating/Pipe Inspection	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
E.7	Internal Pigging	None	ALL	ALL	L	L
E.8	Valve Testing (Valve in underground pit)	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.9	Pipeline Repair (minor) - Exposure	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
F	**PIPELINE CONSTRUCTION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
F.1	Looping (new parallel pipeline)	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
F.2	Tap with lateral directed away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.3	Tap with lateral directed under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.4	New Valve	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.5	Valve Replacement	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.6	Section Replacement	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.7	Lateral away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.8	Lateral under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.9	New Cathodic protection	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.10	Instrument installation	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.11	Blasting for new trench	Road closure	ALL	ALL	H	L
F.12	Hydrotesting	Road closure	ALL	ALL	H	L
F.13	New Pipeline Construction	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
G	**LONG TERM**	**IMPACT OF P/L ON ACTIVITY**				
G.1	ROW Usability	Usability of a strip approx 1m width on each side of p/l c/l for other utilities eliminated,and cost increases for close proximity construction within 2m of p/l c/l significant	ALL	ALL	H	L
G.2	Road System Structural Integrity	Settlement of p/l backfill and possible deformation and localized failures of roadbed	ALL	ALL	H	L
G.3	Chronic health effects	None	ALL	ALL	L	L

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet or vacuum (Hydrovac)

Table B.2
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading-Continuous-with backhoe	ALL	2	M-H	Use hydrovac or hand excavation-per CPEP	m3	6.00	114.00	120.00	1900
B.5.12M	Ditch Grading-Continuous-with grader	ALL	2	M	Use caution over p'l	$1m^3$	7.00	0.50	7.50	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock scaling	ALL	ALL	H	Additional nets,p/l protection	day	1200.00	800.00	2000.00	67
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R,4R Projects)***									
C.1.2	Major Section Repair, excavation of embankment	ALL	1&2	M	CPEP and Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add climbing/Passing Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.1.12	Blasting for wider road surface	ALL	ALL	M	Pipeline relocation by p/l operator or pave over p/l with p/l operator superv.					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	2869.00	870.00	3739.00	30
			2	H	CPEP and 2m3 Hydrovac	ea	2869.00	231.00	3100.00	8
		GH	1	H	CPEP Drop invert .5m, 30m3 extra grading;3m3 hand excav	ea	1189.00	935.00	2124.00	79
			2	H	CPEP and 2m3 Hydrovac	ea	1189.00	319.00	1508.00	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2342.00	440.00	2782.00	19
			2		25m culvert;locate p/l	ea	2342.00	219.00	2561.00	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench;daylight p/l CPEP		1959.00	2200.00	4159.00	112
C.2.4	New Utility II	ALL	1&2	H	Assume im separation new NPS 12 p/l per Fig. 3.6	m	140.00	121.00	261.00	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km,total 100, scanp/l and hydrovac 100 holes	100	23045.00	5115.00	28160.00	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	66550.00	8250.00	74800.00	12
C.2.7	New O/H Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	80000.00	5000.00	85000.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	250000.00	10000.00	260000.00	4
C.2.9	New power poles	ALL	3	M	3km, 100 std. wood posts at 30m;locate p/l and hydrovac holes	100	39050.00	14850.00	53900.00	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					
C.2.11	New guard rail	ALL	1	M	ikm,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	74681.00	13770.00	88451.00	18
C.2.12	New Driveway-gravel	ALL	ALL	M	locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1155.00	560.00	1715.00	48
C.2.13	New road bridge	ALL	ALL	M	Design to suit;locate p/l hydrovac 5m3	ea	250000.00	2000.00	252000.00	1
C.2.14	Borrow pit access driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1155.00	760.00	1915.00	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline failure	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
D.3	Suspeected pipeline damage	ALL	ALL	H	Road closure-2-8hr and lane closure TTC 8-24hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline repair (major)	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
E.9	Pipeline Repair (minor) - Exposure	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (new parallel pipeline)-10km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 2-4wks					H
F.2	Tap with lateral directed away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.3	Tap with lateral directed under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H

Table B.2
Pipeline Location Cost Impact

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	AB		RLF	1.000
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
F.4	New Valve	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.6	Section Replacement-1km	ALL	ALL	M	Road closure-4-12hr and lane closureTTC 1-2wk					H
F.7	Lateral away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.8	Lateral under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic protection	ALL	ALL	M	Lane closure-TTC-8-24hrs					H
F.10	Instrument installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for new trench	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.13	New Pipeline Construction-25km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 1-2months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1-Settlement; Yr 2- 3-Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

Note re CPEP:If excavation more than 0.3m deep planned:
1.Within 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

Table B.3
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS1

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
A	**NORMAL ROAD OPERATION**	**IMPACT OF P/L ON ACTIVITY**				
A.1	Vehicle Traffic Flow	Pipeline warning signs visible	ALL	ALL	L	L
A.2	Road Accident Follow Up-emergency vehicles	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.3	Road traffic-pulling over	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.4	Emergency vehicle passing offroad	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.5	Road accident cleanup	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.6	Wide load transit	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
A.7	Detour on shoulder	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
B	**ROAD MAINTENANCE**	**IMPACT OF P/L ON ACTIVITY**				
B.1	***Routine Maintenance***					
B.1.1	Daytime road inspections	None	ALL	ALL	L	L
B.1.2	Litter pickup	None	ALL	ALL	L	L
B.1.3	Minor fence repairs	None	ALL	ALL	L	L
B.1.4	Inspecting culvert ends for damage or blockage	None	ALL	ALL	L	L
B.1.5	Removing road kill (mostly deer)	None	ALL	ALL	L	L
B.1.6	Cleaning signs and guide posts	None	ALL	ALL	L	L
B.1.7	Straightening sign and guide posts	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.1.8	Replace reflector strips on guide & guardrail posts	None	ALL	ALL	L	L
B.1.9	Removing illegal signs	None	ALL	ALL	L	L
B.2	***Road Surface Maintenance***					
B.2.1	Roadway Sweeping	None	BCE	1&2	L	L
B.2.2	Raised Median Washing –	None	BCE	1&2	L	L
B.2.3	Line Painting	None	BCE	1&2	L	L
B.2.4	Message Painting	None	BCE	1&2	L	L
B.2.5	Maintaining Gravel Roads	None	H	1	L	L
B.2.6	Re-Gravelling	Minimize driving or parking heavy equipment over p/l	H	2	L	L
B.2.7	Dust Control	None	H	1	L	L
B.2.8	Livestock Guard Cleaning	Locate p/l and use extreme care if within 2m	H	1&2	L	L
B.2.9	Roadway Clearing-debris,rockfall	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use CPEP	ALL	1&2	L	M
B.3	***Roadside Maintenance***					
B.3.1	Mowing	None	ALL	ALL	L	L
B.3.2	Hand Trimming	None	ALL	ALL	L	L
B.3.3	Brushing	None	ALL	ALL	L	L
B.3.4	Chemical Vegetation Control	None	ALL	ALL	L	L
B.3.5	Drainage Maintenance/Improvements	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.3.6	Culvert Maintenance	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.3.7	Bridge Washing	None	ALL	ALL	L	L
B.3.8	Beaver Control	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	3	L	L
B.3.9	Removal of Large Road Kill	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
B.3.10	Ditch Grading-localized	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	M
B.4	***Road Surface Repairs***					
B.4.1	Pavement Surface Failures -	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.2	Fog Coat	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.3	Crack Sealing	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.4	Spray Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.5	Pothole Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.6	Paver Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.7	Grader Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.8	Milling	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L

Table B.3
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS1

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H): IMPACT	SEVERITY (L, M, H): RISK
B.5	***Roadside Repairs and Installations***					
B.5.1	Supply, Remove, & Install Minor Culverts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	L	M
B.5.2	Installation of Minor Signs (single post)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.3	Installation of Major Signs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.4	Installation of Guide Posts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.5	Installation of Wildlife Reflectors	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.6	Installation of Guardrail (box beam, W-Beam)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.7	Installation of Concrete Barriers	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.8	Installation/Repair of Fencing – chain link or barbwire	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.9	Bridge Maintenance and Repair	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	L
B.5.10	Erosion Control/Repairs-minor	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.11	Installation of Extra or repl. Power Poles	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.12	Ditch Grading-continuous	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	H	H
B.5.13	Railway Crossing Repairs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.6	***Winter Operations***					
B.6.1	Application of Sand and salt	None -increased corrosion potential-qra	ALL	ALL	L	L
B.6.2	Snow Ploughing	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	M
B.6.3	Installation of Snow Fencing	None	ALL	ALL	L	L
B.7	***Mountain Operations***					
B.7.1	Rock scaling	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	H	H
B.7.2	Mud Slide cleanup	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.3	Land slide cleanup	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.4	Washout Repairs	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.5	Avalanche Stabilization	Avoid locating cannon near p/l; assure that avalanche avoids p/l locations	ALL	ALL	L	L
C	**ROAD CONSTRUCTION**	**IMPACT OF P/L ON ACTIVITY**				
C.1	***Road Surface (3R,4R Projects)***					
C.1.1	Resurface	Minimize driving or parking heavy equipment over p/l	ALL	1&2	L	L
C.1.2	Major Section Repair, excavation of embankment	Locate p/l and use extreme care if within 6m static compaction within 3m	ALL	1&2	M	M
C.1.3	Add climbing/Passing Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.4	Add Turn Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.5	Widen Road	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.6	Pave Shoulder	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.7	New Exit/Entry	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.8	New Overpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.9	New Underpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.10	Test Section	Locate p/l and use extreme care if within 6m	ALL	1&2	L	L
C.1.11	Rumble Strips	Locate p/l and use extreme care if within 6m	ALL	1&2	L	L
C.1.12	Blasting for wider road surface	Shut down and blowdown p/l for duration of blasting operations;use blast mats	ALL	ALL	M	L
C.1.13	Geotechnical drilling	Locate p/l and avoid drilling within 6m	ALL	ALL	L	L
C.2	***ROW (Off Surface)***					
C.2.1	New Culvert X	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.2	New Culvert II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.3	New Utility X (e.g., FOC)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.4	New Utility II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.5	New Minor Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	M	M
C.2.6	New Major Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.7	New O/H Sign Structure	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.8	New Pedestrian Bridge	Engineering design to avoid conflict with p/l	ALL	ALL	M	L
C.2.9	New power Line	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M

Table B.3
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS1

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
C.2.10	New Ditch	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	H	M
C.2.11	New guard rail	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	M	H
C.2.12	New Driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.13	New road bridge	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.14	Borrow pit access driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.15	Farm animal fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	3	L	L
C.2.16	Diking	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.17	Emergency detour road designation and operation	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
C.2.18	Construction detour road construction	Minimize driving or parking heavy equipment over p/l min 1.5m cover	ALL	ALL	L	L
C.2.19	Wildlife control fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.20	Private sign installation	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
D	**NORMAL PIPELINE OPERATION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
D.1	Pipeline remotely operated	As described above	ALL	ALL	L	L
D.2	Pipeline failure	Close road until isolation and blowdown completed	ALL	ALL	H	H
D.3	Suspeected pipeline damage	Close road until damage repaired or p/l confirmed ok	ALL	ALL	H	L
E	**PIPELINE MAINTENANCE**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
E.1	Pipeline repair (major)	P/l segment blowdown and isolation; construction zone speed restriction, road closure during equipment mvmt	ALL	ALL	H	L
E.2	Leak Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.3	ROW Surveillance	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.4	Leak (Sniffer) Inspection	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.5	Cathodic Protection Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.6	Pipeline Exposure for Coating/Pipe Inspection	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
E.7	Internal Pigging	None	ALL	ALL	L	L
E.8	Valve Testing (Valve in underground pit)	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.9	Pipeline Repair (minor) - Exposure	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
F	**PIPELINE CONSTRUCTION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
F.1	Looping (new parallel pipeline)	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
F.2	Tap with lateral directed away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.3	Tap with lateral directed under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.4	New Valve	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.5	Valve Replacement	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.6	Section Replacement	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.7	Lateral away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.8	Lateral under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.9	New Cathodic protection	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.10	Instrument installation	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.11	Blasting for new trench	Road closure	ALL	ALL	H	L
F.12	Hydrotesting	Road closure	ALL	ALL	H	L
F.13	New Pipeline Construction	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
G	**LONG TERM**	**IMPACT OF P/L ON ACTIVITY**				
G.1	ROW Usability	Usability of a strip approx 1m width on each side of p/l c/l for other utilities eliminated,and cost increases for close	ALL	ALL	H	L
G.2	Road System Structural Integrity	Settlement of p/l backfill and possible deformation and localized failures of roadbed	ALL	ALL	H	L
G.3	Chronic health effects	None	ALL	ALL	L	L

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

Table B.4
Pipeline Location Cost Impact CS1

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	NS		RLF	0.987
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12	Ditch Grading-Continuous-with backhoe	ALL	2	M-H	Use hydrovac or hand excavation	1m3	5.92	112.52	118.44	1900
B.5.12M	Ditch Grading-Continuous-with grader	ALL	2	M	Use caution over p'l	1m3	6.91	0.49	7.40	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***				None					
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R,4R Projects)***									
C.1.2	Major Section Repair, excavation of embankment	ALL	1&2	M	CPEP Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add climbing/Passing Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.12	Blasting for wider road surface	ALL	ALL	M	Pipeline relocation borne by p/l operator					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	2831.70	858.69	3690.39	30
			2	H	2m3 CPEP	ea	2831.70	228.00	3059.70	8
		GH	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	1173.54	922.85	2096.39	79
			2	H	2m3 CPEP	ea	1173.54	314.85	1488.40	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2311.55	434.28	2745.83	19
			2		25m culvert;locate p/l	ea	2311.55	216.15	2527.71	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench;daylight p/l CPEP		1933.53	2171.40	4104.93	112
C.2.4	New Utility II	ALL	1&2	H	Assume im separation new NPS 12 p/l per Fig. 3.6	m	138.18	119.43	257.61	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km,total 100, scanp/l and hydrovac 100 holes	100	22745.42	5048.51	27793.92	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	65684.85	8142.75	73827.60	12
C.2.7	New O/H Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	78960.00	4935.00	83895.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	246750.00	9870.00	256620.00	4
C.2.9	New power poles	ALL	3	M	3km, 100 std. wood posts at 30m;locate p/l and hydrovac holes	100	38542.35	14656.95	53199.30	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					0
C.2.11	New guard rail	ALL	1	M	ikm,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	73710.15	13590.99	87301.14	18
C.2.12	New Driveway-gravel	ALL	ALL	M	locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1139.99	552.72	1692.71	48
C.2.13	New road bridge	ALL	ALL	M	Design to suit;locate p/l hydrovac 5m3	ea	246750.00	1974.00	248724.00	1
C.2.14	Borrow pit access driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1139.99	750.12	1890.11	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline failure	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
D.3	Suspeected pipeline damage	ALL	ALL	H	Road closure-2-8hr and lane closure TTC 8-24hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline repair (major)	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
E.9	Pipeline Repair (minor) - Exposure	ALL	ALL	M	Lane closure-TTC-8-24hrs					M

Table B.4
Pipeline Location Cost Impact CS1

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	NS		RLF	0.987
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
F	**PIPELINE CONSTRUCTION**									
F.1	Looping (new parallel pipeline)-10km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 2-4wks					H
F.2	Tap with lateral directed away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.3	Tap with lateral directed under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.6	Section Replacement-1km	ALL	ALL	M	Road closure-4-12hr and lane closureTTC 1-2wk					H
F.7	Lateral away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.8	Lateral under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic protection	ALL	ALL	M	Lane closure-TTC-8-24hrs					H
F.10	Instrument installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for new trench	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.13	New Pipeline Construction-25km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 1-2months					H
G	**LONG TERM**									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	Road System Structural Integrity	ALL	ALL	H	Yr 1-Settlement; Yr 2- 3-Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

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Table B.5
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS2

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
A	**NORMAL ROAD OPERATION**	**IMPACT OF P/L ON ACTIVITY**				
A.1	Vehicle Traffic Flow	Pipeline warning signs visible	ALL	ALL	L	L
A.2	Road Accident Follow Up-emergency vehicles	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.3	Road traffic-pulling over	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.4	Emergency vehicle passing offroad	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.5	Road accident cleanup	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
A.6	Wide load transit	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
A.7	Detour on shoulder	Minimize driving or parking heavy equipment over p/l	ALL	1	L	L
B	**ROAD MAINTENANCE**	**IMPACT OF P/L ON ACTIVITY**				
B.1	***Routine Maintenance***					
B.1.1	Daytime road inspections	None	ALL	ALL	L	L
B.1.2	Litter pickup	None	ALL	ALL	L	L
B.1.3	Minor fence repairs	None	ALL	ALL	L	L
B.1.4	Inspecting culvert ends for damage or blockage	None	ALL	ALL	L	L
B.1.5	Removing road kill (mostly deer)	None	ALL	ALL	L	L
B.1.6	Cleaning signs and guide posts	None	ALL	ALL	L	L
B.1.7	Straightening sign and guide posts	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.1.8	Replace reflector strips on guide & guardrail posts	None	ALL	ALL	L	L
B.1.9	Removing illegal signs	None	ALL	ALL	L	L
B.2	***Road Surface Maintenance***					
B.2.1	Roadway Sweeping	None	BCE	1&2	L	L
B.2.2	Raised Median Washing –	None	BCE	1&2	L	L
B.2.3	Line Painting	None	BCE	1&2	L	L
B.2.4	Message Painting	None	BCE	1&2	L	L
B.2.5	Maintaining Gravel Roads	None	H	1	L	L
B.2.6	Re-Gravelling	Minimize driving or parking heavy equipment over p/l	H	2	L	L
B.2.7	Dust Control	None	H	1	L	L
B.2.8	Livestock Guard Cleaning	Locate p/l and use extreme care if within 2m	H	1&2	L	L
B.2.9	Roadway Clearing-debris,rockfall	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	1&2	L	M
B.3	***Roadside Maintenance***					
B.3.1	Mowing	None	ALL	ALL	L	L
B.3.2	Hand Trimming	None	ALL	ALL	L	L
B.3.3	Brushing	None	ALL	ALL	L	L
B.3.4	Chemical Vegetation Control	None	ALL	ALL	L	L
B.3.5	Drainage Maintenance/Improvements	Locate p/l and use extreme care if within 2m	ALL	ALL	L	L
B.3.6	Culvert Maintenance	Locate p/l and use extreme care if within 2m	ALL	ALL	L	M
B.3.7	Bridge Washing	None	ALL	ALL	L	L
B.3.8	Beaver Control	Locate p/l and use extreme care if within 2m	ALL	3	L	L
B.3.9	Removal of Large Road Kill	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	L
B.3.10	Ditch Grading-localized	Locate p/l and use extreme care if within 2m	ALL	2	L	M
B.4	***Road Surface Repairs***					
B.4.1	Pavement Surface Failures -	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.2	Fog Coat	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.3	Crack Sealing	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.4	Spray Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.5	Pothole Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.6	Paver Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.7	Grader Patching	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
B.4.8	Milling	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L

Table B.5
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS2

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR:		SEVERITY (L, M, H)	
			ROAD TYPE	PIPELINE LOCATION	IMPACT	RISK
B.5	***Roadside Repairs and Installations***					
B.5.1	Supply, Remove, & Install Minor Culverts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	L	M
B.5.2	Installation of Minor Signs (single post)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.3	Installation of Major Signs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.4	Installation of Guide Posts	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.5	Installation of Wildlife Reflectors	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.6	Installation of Guardrail (box beam, W-Beam)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.7	Installation of Concrete Barriers	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.8	Installation/Repair of Fencing – chain link or barbwire	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.9	Bridge Maintenance and Repair	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	L	L
B.5.10	Erosion Control/Repairs-minor	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.5.11	Installation of Extra or repl. Power Poles	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	M
B.5.12	Ditch Grading-continuous	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1,2	M-H	H
B.5.13	Railway Crossing Repairs	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
B.6	***Winter Operations***					
B.6.1	Application of Sand and salt	None -increased corrosion potential-qra	ALL	ALL	L	L
B.6.2	Snow Ploughing	Minimize driving or parking heavy equipment over p/l	ALL	1,2	L	M
B.6.3	Installation of Snow Fencing	None	ALL	ALL	L	L
B.7	***Mountain Operations***					
B.7.1	Rock scaling	Ensure rocks over limit mass/drop height do not drop on or near p/l	ALL	ALL	H	H
B.7.2	Mud Slide cleanup	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.3	Land slide cleanup	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.4	Washout Repairs	Minimize driving or parking heavy equipment over p/l, if using excavator locate p/l use extreme care within 2m	ALL	ALL	L	M
B.7.5	Avalanche Stabilization	Avoid locating cannon near p/l; assure that avalanche avoids p/l locations	ALL	ALL	L	L
C	**ROAD CONSTRUCTION**	**IMPACT OF P/L ON ACTIVITY**				
C.1	***Road Surface (3R,4R Projects)***					
C.1.1	Resurface	Minimize driving or parking heavy equipment over p/l	ALL	1&2	L	L
C.1.2	Major Section Repair, excavation of embankment	Locate p/l and use extreme care if within 6m static compaction within 3m	ALL	1&2	M	M
C.1.3	Add climbing/Passing Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.4	Add Turn Lane	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.5	Widen Road	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.6	Pave Shoulder	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.7	New Exit/Entry	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.8	New Overpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.9	New Underpass	Relocate p/l or pave over p/l with special construction,static comp within 3m, and p/l oper supervision	ALL	ALL	H	L
C.1.10	Test Section	Locate p/l and use extreme care if within 6m	ALL	1&2	L	L
C.1.11	Rumble Strips	Locate p/l and use extreme care if within 6m	ALL	1&2	L	L
C.1.12	Blasting for wider road surface	Shut down and blowdown p/l for duration of blasting operations;use blast mats	ALL	ALL	M	L
C.1.13	Geotechnical drilling	Locate p/l and avoid drilling within 6m	ALL	ALL	L	L
C.2	***ROW (Off Surface)***					
C.2.1	New Culvert X	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.2	New Culvert II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.3	New Utility X (e.g., FOC)	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.4	New Utility II	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	H	M
C.2.5	New Minor Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	1&2	M	M
C.2.6	New Major Sign	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.7	New O/H Sign Structure	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.8	New Pedestrian Bridge	Engineering design to avoid conflict with p/l	ALL	ALL	M	L
C.2.9	New power Line	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M

Table B.5
Identification of Pipeline Location Impacts on Road System for Different Road and Pipeline Activities CS2

ITEM	ACTIVITY	DESCRIPTION OF IMPACT - ROADS - B,C,E,H	APPLICABLE FOR: ROAD TYPE	APPLICABLE FOR: PIPELINE LOCATION	SEVERITY (L, M, H): IMPACT	SEVERITY (L, M, H): RISK
C.2.10	New Ditch	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	H	M
C.2.11	New guard rail	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	2	M	H
C.2.12	New Driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	M
C.2.13	New road bridge	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.14	Borrow pit access driveway	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	M	L
C.2.15	Farm animal fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	3	L	L
C.2.16	Diking	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.17	Emergency detour road designation and operation	Minimize driving or parking heavy equipment over p/l	ALL	ALL	L	L
C.2.18	Construction detour road construction	Minimize driving or parking heavy equipment over p/l min 1.5m cover	ALL	ALL	L	L
C.2.19	Wildlife control fencing	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
C.2.20	Private sign installation	Use close Proximity Excavation Procedure-CPEP (see note below)	ALL	ALL	L	L
D	**NORMAL PIPELINE OPERATION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
D.1	Pipeline remotely operated	As described above	ALL	ALL	L	L
D.2	Pipeline failure	Close road until isolation and blowdown completed	ALL	ALL	H	H
D.3	Suspeected pipeline damage	Close road until damage repaired or p/l confirmed ok	ALL	ALL	H	L
E	**PIPELINE MAINTENANCE**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
E.1	Pipeline repair (major)	P/l segment blowdown and isolation; construction zone speed restriction, road closure during equipment mvmt	ALL	ALL	H	L
E.2	Leak Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.3	ROW Surveillance	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.4	Leak (Sniffer) Inspection	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.5	Cathodic Protection Check	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.6	Pipeline Exposure for Coating/Pipe Inspection	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
E.7	Internal Pigging	None	ALL	ALL	L	L
E.8	Valve Testing (Valve in underground pit)	Construction zone speed restriction for p/l vehicles on ROW offroad	ALL	ALL	L	L
E.9	Pipeline Repair (minor) - Exposure	Construction zone speed restriction, possible lane closure during equipment manoeuvres	ALL	ALL	M	L
F	**PIPELINE CONSTRUCTION**	**IMPACT OF P/L ACTIVITY ON ROAD OPERATION**				
F.1	Looping (new parallel pipeline)	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
F.2	Tap with lateral directed away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.3	Tap with lateral directed under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.4	New Valve	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.5	Valve Replacement	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.6	Section Replacement	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.7	Lateral away from road	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.8	Lateral under road	Construction zone speed restriction, possible road closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	H	L
F.9	New Cathodic protection	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.10	Instrument installation	Construction zone speed restriction, possible lane closure during equipment manoeuvres (exst. p/l empty)	ALL	ALL	M	L
F.11	Blasting for new trench	Road closure	ALL	ALL	H	L
F.12	Hydrotesting	Road closure	ALL	ALL	H	L
F.13	New Pipeline Construction	Combination of road closures, lane closures, and speed restrictions	ALL	ALL	H	L
G	**LONG TERM**	**IMPACT OF P/L ON ACTIVITY**				
G.1	ROW Usability	Usability of a strip approx 1m width on each side of p/l c/l for other utilities eliminated,and cost increases for close	ALL	ALL	H	L
G.2	Road System Structural Integrity	Settlement of p/l backfill and possible deformation and localized failures of roadbed	ALL	ALL	H	L
G.3	Chronic health effects	None	ALL	ALL	L	L

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

Table B.6
Pipeline Location Cost Impact CS2

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	BC		RLF	1.096
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
A	**NORMAL ROAD OPERATION**				None					
B	**ROAD MAINTENANCE**				None					
B.1	***Routine Maintenance***				None					
B.3	***Roadside Maintenance***				None					
B.4	***Road Surface Repairs***				None					
B.5	***Roadside Repairs and Installations***									
B.5.12M	Ditch Grading-Continuous-with grader	ALL	2	M	Use caution over p'l	$1m^3$	7.67	0.55	8.22	7
B.6	***Winter Operations***				None					
B.7	***Mountain Operations***									
B.7.1	Rock scaling	ALL	ALL	H	Additional nets,p/l protection	day	1315.20	10684.80	12000.00	812
C	**ROAD CONSTRUCTION**									
C.1	***Road Surface (3R,4R Projects)***									
C.1.2	Major Section Repair, excavation of embankment	ALL	1&2	M	CPEP Static compaction within 3m of p/l	job	100000.00	20000.00	120000.00	20
C.1.3	Add climbing/Passing Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.4	Add Turn Lane	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.5	Widen Road	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.6	Pave Shoulder	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.7	New Exit/Entry	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.8	New Overpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.9	New Underpass	ALL	ALL	H	Pipeline relocation borne by p/l operator					H
C.1.12	Blasting for wider road surface	ALL	ALL	M	Pipeline relocation borne by p/l operator					H
C.2	***ROW (Off Surface)***									
C.2.1	New Culvert X	BCE	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	3144.42	953.52	4097.94	30
			2	H	2m3 CPEP	ea	3144.42	253.18	3397.60	8
		GH	1	H	Drop invert .5m, 30m3 extra grading;3m3 CPEP;	ea	1303.14	1024.76	2327.90	79
			2	H	2m3 CPEP	ea	1303.14	349.62	1652.77	27
C.2.2	New Culvert II	ALL	1	H	25m culvert, locate p/l, bed w/ CPEP 1m3, use caution backfilling	ea	2566.83	482.24	3049.07	19
			2		25m culvert;locate p/l	ea	2566.83	240.02	2806.86	9
C.2.3	New Utility X (e.g., FOC)	ALL	1&2	H	Assume utility 2m deep .75m trench;daylight p/l CPEP		2147.06	2411.20	4558.26	112
C.2.4	New Utility II	ALL	1&2	H	Assume im separation new NPS 12 p/l per Fig. 3.6	m	153.44	132.62	286.06	86
C.2.5	New Minor Sign	ALL	1&2	M	4signs/km,total 100, scanp/l and hydrovac 100 holes	100	25257.32	5606.04	30863.36	22
C.2.6	New Major Sign	ALL	ALL	M	4 signs/km, total 100, scan p/l and hydrovac 200 holes	100	72938.80	9042.00	81980.80	12
C.2.7	New O/H Sign Structure	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 4m3	ea	87680.00	5480.00	93160.00	6
C.2.8	New Pedestrian Bridge	BCE	ALL	M	Locate p/l, daylight 2 loc's, and hydrovac 10m3	ea	274000.00	10960.00	284960.00	4
C.2.9	New power poles	ALL	3	M	3km, 100 std. wood posts at 30m;locate p/l and hydrovac holes	100	42798.80	16275.60	59074.40	38
C.2.10	New Ditch	ALL	2	H	Pipeline relocation costs borne by p/l operator					
C.2.11	New guard rail	ALL	1	M	ikm,10 sections @ 100m over 25km;loc p/l and hydrovac holes	1km	81850.38	15091.92	96942.30	18
C.2.12	New Driveway-gravel	ALL	ALL	M	locate p/l, use CPEP 2m3 and add 10m3 for clearance	ea	1265.88	613.76	1879.64	48
C.2.13	New road bridge	ALL	ALL	M	Design to suit;locate p/l hydrovac 5m3	ea	274000.00	2192.00	276192.00	1
C.2.14	Borrow pit access driveway	ALL	ALL	M	Use protective plate and build as C.2.12	ea	1265.88	832.96	2098.84	66
D	**NORMAL PIPELINE OPERATION**									
D.2	Pipeline failure	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
D.3	Suspeected pipeline damage	ALL	ALL	H	Road closure-2-8hr and lane closure TTC 8-24hrs					H
E	**PIPELINE MAINTENANCE**									
E.1	Pipeline repair (major)	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
E.6	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
E.9	Pipeline Repair (minor) - Exposure	ALL	ALL	M	Lane closure-TTC-8-24hrs					M

Table B.6
Pipeline Location Cost Impact CS2

ITEM	ACTIVITY	ROAD TYPE	PIPELINE LOCATION	IMPACT SEVERITY	IMPACT QUANTITY	COST ESTIMATES				
						Loc	BC		RLF	1.096
						Unit	Base Cost per Unit	Extra Cost per Unit	Total Unit Cost	
							$	$	$	?%
F	PIPELINE CONSTRUCTION									
F.1	Looping (new parallel pipeline)-10km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 2-4wks					H
F.2	Tap with lateral directed away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.3	Tap with lateral directed under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.4	New Valve	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.5	Valve Replacement	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.6	Section Replacement-1km	ALL	ALL	M	Road closure-4-12hr and lane closureTTC 1-2wk					H
F.7	Lateral away from road	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.8	Lateral under road	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.9	New Cathodic protection	ALL	ALL	M	Lane closure-TTC-8-24hrs					H
F.10	Instrument installation	ALL	ALL	M	Lane closure-TTC-8-24hrs					M
F.11	Blasting for new trench	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 24-48 hrs					H
F.12	Hydrotesting	ALL	ALL	H	Lane closure-TTC-8-24hrs					M
F.13	New Pipeline Construction-25km	ALL	ALL	H	Road closure-4-12hr and lane closure TTC 1-2months					H
G	LONG TERM									
G.1	ROW Usability	ALL	ALL	H	See C.2.4					H
G.2	20% ncrease in roadside maintenance budget for p/l effec	ALL	ALL	H	Yr 1-Settlement; Yr 2- 3-Longitudinal cracks in and off pavement	km.	120000.00	24000.00	144000.00	20

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

Note re CPEP:If excavation more than 0.3m deep planned:
1.Wiithin 30m of p/l contact p/l operator, locate and mark p/l
2. Within 5m of p/l daylight p/l
3. Within 0.6m of p/l surface hand excavation only
4. Hand excavation includes low pressure air or water jet
or vacuum (Hydrovac)

APPENDIX C

Risk Analysis Calculations

Table C.1.1
P/L 08(06)" Leak Failure Rates

AEUB LEAK CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08 DISTRIBUTION (%)	PL HP08 FAILURE RATE [per km-yr]
CORROSION	**52.4**	**4.21E-04**	**61.7**	**20.1**	**35.7**	**1.61E-04**
Internal	25.6	2.06E-04	75.0	6.4	11.4	5.14E-05
External	26.3	2.11E-04	50.0	13.2	23.4	1.06E-04
Girth/Filet Weld	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
EXTERNAL FORCES	**15.1**	**1.21E-04**	**43.1**	**8.6**	**15.3**	**6.90E-05**
Construction Damage	5.1	4.10E-05	70.7	1.5	2.7	1.20E-05
Third Party Damage	8.8	7.07E-05	25.0	6.6	11.8	5.30E-05
Earth Movement	1.2	9.64E-06	58.5	0.5	0.9	4.00E-06
WELD FAILURES	**10.6**	**8.51E-05**	**0.0**	**10.6**	**18.9**	**8.51E-05**
Girth Weld	6.2	4.98E-05	0.0	6.2	11.0	4.98E-05
Other	2.8	2.25E-05	0.0	2.8	5.0	2.25E-05
Seam Rupture	1.6	1.28E-05	0.0	1.6	2.8	1.28E-05
JOINT FAILURES	**5.6**	**4.50E-05**	**0.0**	**5.6**	**10.0**	**4.50E-05**
Mechanical	5.0	4.02E-05	0.0	5.0	8.9	4.02E-05
Miscellaneous	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
SURFACE EQUIPMENT FAILURE	**5.0**	**4.02E-05**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	4.02E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	4.5	3.61E-05	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**11.3**	**9.07E-05**	**0.0**	**11.3**	**20.1**	**9.07E-05**
Pipe Failure	5.3	4.26E-05	0.0	5.3	9.4	4.26E-05
Overpressure	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
Operator Error	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
Miscellaneous	2.0	1.61E-05	0.0	2.0	3.6	1.61E-05
Unknown	2.9	2.33E-05	0.0	2.9	5.2	2.33E-05
TOTALS	**100.0**	**8.03E-04**	**43.9**	**56.1**	**100.0**	**4.51E-04**

Table C.1.2
P/L 08(06)" Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08 DISTRIBUTION (%)	PL HP08 FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**2.8**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	0.8	1.78E-06
External	3.2	9.50E-06	50.0	1.6	2.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**21.9**	**62.6**	**80.1**	**1.86E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	6.5	1.51E-05
Third Party Damage	70.1	2.08E-04	25.0	52.6	67.3	1.56E-04
Earth Movement	4.9	1.46E-05	0.0	4.9	6.3	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**3.5**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	1.5	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	1.9	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**1.5**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**12.0**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	5.6	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**21.9**	**78.1**	**100.0**	**2.32E-04**

Table C.1.3
P/L 12" Leak Failure Rates

AEUB LEAK CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP12 DISTRIBUTION (%)	PL HP12 FAILURE RATE [per km-yr]
CORROSION	**52.4**	**4.21E-04**	**61.7**	**20.1**	**37.8**	**1.61E-04**
Internal	25.6	2.06E-04	75.0	6.4	12.1	5.14E-05
External	26.3	2.11E-04	50.0	13.2	24.8	1.06E-04
Girth/Filet Weld	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
EXTERNAL FORCES	**15.1**	**1.21E-04**	**63.5**	**5.5**	**10.4**	**4.43E-05**
Construction Damage	5.1	4.10E-05	70.7	1.5	2.8	1.20E-05
Third Party Damage	8.8	7.07E-05	60.0	3.5	6.6	2.83E-05
Earth Movement	1.2	9.64E-06	58.5	0.5	0.9	4.00E-06
WELD FAILURES	**10.6**	**8.51E-05**	**0.0**	**10.6**	**20.0**	**8.51E-05**
Girth Weld	6.2	4.98E-05	0.0	6.2	11.7	4.98E-05
Other	2.8	2.25E-05	0.0	2.8	5.3	2.25E-05
Seam Rupture	1.6	1.28E-05	0.0	1.6	3.0	1.28E-05
JOINT FAILURES	**5.6**	**4.50E-05**	**0.0**	**5.6**	**10.6**	**4.50E-05**
Mechanical	5.0	4.02E-05	0.0	5.0	9.4	4.02E-05
Miscellaneous	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
SURFACE EQUIPMENT FAILURE	**5.0**	**4.02E-05**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	4.02E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	4.5	3.61E-05	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**11.3**	**9.07E-05**	**0.0**	**11.3**	**21.3**	**9.07E-05**
Pipe Failure	5.3	4.26E-05	0.0	5.3	10.0	4.26E-05
Overpressure	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
Operator Error	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
Miscellaneous	2.0	1.61E-05	0.0	2.0	3.8	1.61E-05
Unknown	2.9	2.33E-05	0.0	2.9	5.5	2.33E-05
TOTALS	**100.0**	**8.03E-04**	**46.9**	**53.1**	**100.0**	**4.26E-04**

Table C.1.4
P/L 12" Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP12 DISTRIBUTION (%)	PL HP12 FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**4.1**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	1.1	1.78E-06
External	3.2	9.50E-06	50.0	1.6	3.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**52.5**	**38.0**	**71.0**	**1.13E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	9.5	1.51E-05
Third Party Damage	70.1	2.08E-04	60.0	28.0	52.3	8.32E-05
Earth Movement	4.9	1.46E-05	0.0	4.9	9.2	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**5.0**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	2.2	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	2.8	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**2.2**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.9	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.4	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**17.6**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	8.2	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	3.6	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.4	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	3.6	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.9	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**46.5**	**53.5**	**100.0**	**1.59E-04**

Table C.1.5
Roadway Effects on Pipeline Failure Rate

ROAD TYPE B, C, E, H									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**7.94E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							1.04E-05
		Unknown Total							**1.04E-05**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07

Table C.1.5
Roadway Effects on Pipeline Failure Rate

ROAD TYPE B, C, E, H									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**5.92E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							8.36E-06
		Unknown Total							**8.36E-06**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**9.25E-06**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							3.36E-06
		Unknown Total							**3.36E-06**

Table C.1.6
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

ROAD TYPE B, C, E, H Pipeline 08(06)								
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.97E-05	2.49E-04	119.0
		Leak	5.30E-05	Leak	36	2.86E-05	8.16E-05	153.9
		Rupture	1.56E-04	Rupture	14	1.11E-05	1.67E-04	107.1
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.19E-06	3.14E-05	119.8
		Leak	2.33E-05	Leak	36	3.74E-06	2.70E-05	116.1
		Rupture	2.97E-06	Rupture	14	1.45E-06	4.42E-06	148.9
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	2.96E-05	2.39E-04	114.2
		Leak	5.30E-05	Leak	36	2.13E-05	7.43E-05	140.2
		Rupture	1.56E-04	Rupture	14	8.29E-06	1.64E-04	105.3
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	4.18E-06	3.04E-05	115.9
		Leak	2.33E-05	Leak	36	3.01E-06	2.63E-05	112.9
		Rupture	2.97E-06	Rupture	14	1.17E-06	4.14E-06	139.4
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.62E-06	2.14E-04	102.2
		Leak	5.30E-05	Leak	36	3.33E-06	5.64E-05	106.3
		Rupture	1.56E-04	Rupture	14	1.29E-06	1.57E-04	100.8
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.68E-06	2.79E-05	106.4
		Leak	2.33E-05	Leak	36	1.21E-06	2.45E-05	105.2
		Rupture	2.97E-06	Rupture	14	4.71E-07	3.44E-06	115.9

Table C.1.7
Roadway Effects on Pipeline Failure Rate
P/L 12

ROAD TYPE B, C, E, H Pipeline 12								
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	3.97E-05	1.51E-04	135.6
		Leak	2.83E-05	Leak	36	2.86E-05	5.69E-05	201.1
		Rupture	8.32E-05	Rupture	14	1.11E-05	9.43E-05	113.4
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.19E-06	3.14E-05	119.8
		Leak	2.33E-05	Leak	36	3.74E-06	2.70E-05	116.1
		Rupture	2.97E-06	Rupture	14	1.45E-06	4.42E-06	148.9
2	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	2.96E-05	1.41E-04	126.6
		Leak	2.83E-05	Leak	36	2.13E-05	4.96E-05	175.4
		Rupture	8.32E-05	Rupture	14	8.29E-06	9.15E-05	110.0
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	4.18E-06	3.04E-05	115.9
		Leak	2.33E-05	Leak	36	3.01E-06	2.63E-05	112.9
		Rupture	2.97E-06	Rupture	14	1.17E-06	4.14E-06	139.4
3	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	1.11E-04	NLC	50	4.62E-06	1.16E-04	104.1
		Leak	2.83E-05	Leak	36	3.33E-06	3.16E-05	111.8
		Rupture	8.32E-05	Rupture	14	1.29E-06	8.45E-05	101.6
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.68E-06	2.79E-05	106.4
		Leak	2.33E-05	Leak	36	1.21E-06	2.45E-05	105.2
		Rupture	2.97E-06	Rupture	14	4.71E-07	3.44E-06	115.9

Table C.1.8
Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	ROAD TYPE B, C, E, H Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**1.06E-04**	**9.88E-05**	**8.08E-05**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	8.16E-05	7.43E-05	5.64E-05	5.30E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.45E-05**	**9.37E-05**	**9.20E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	2.63E-05	2.45E-05	2.33E-05
TOTALS	**4.51E-04**	**4.92E-04**	**4.84E-04**	**4.64E-04**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	ROAD TYPE B, C, E, H Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**2.00E-04**	**1.97E-04**	**1.90E-04**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.67E-04	1.64E-04	1.57E-04	1.56E-04
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**2.91E-05**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.42E-06	4.14E-06	3.44E-06	2.97E-06
TOTALS	**2.32E-04**	**2.48E-04**	**2.45E-04**	**2.37E-04**	**2.32E-04**

Table C.1.9
Failure Rate Calculation Leak and Rupture 12"

LEAK CAUSE CLASSIFICATION	PL 12 FAILURE RATE [per km-yr]	ROAD TYPE B, C, E, H Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**4.43E-05**	**8.13E-05**	**7.40E-05**	**5.60E-05**	**4.43E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	2.83E-05	5.69E-05	4.96E-05	3.16E-05	2.83E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.45E-05**	**9.37E-05**	**9.20E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	2.63E-05	2.45E-05	2.33E-05
TOTALS	**4.26E-04**	**4.67E-04**	**4.59E-04**	**4.39E-04**	**4.26E-04**

RUPTURE CAUSE CLASSIFICATION	PL 12 FAILURE RATE [per km-yr]	ROAD TYPE B, C, E, H Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.13E-04**	**1.27E-04**	**1.24E-04**	**1.17E-04**	**1.13E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	8.32E-05	9.43E-05	9.15E-05	8.45E-05	8.32E-05
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**2.91E-05**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.42E-06	4.14E-06	3.44E-06	2.97E-06
TOTALS	**1.59E-04**	**1.75E-04**	**1.72E-04**	**1.64E-04**	**1.59E-04**

Table C.1.10
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	ROAD TYPE B, C, E, H							
	Pipeline 08(06)"							
Base Leak	73.0%	**4.92E-04**	73.0%	**4.84E-04**	73.0%	**4.64E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**2.48E-04**	27.0%	**2.45E-04**	27.0%	**2.37E-04**	27.0%	**2.32E-04**
Leak	73.0%	4.92E-04	73.0%	4.84E-04	73.0%	4.64E-04	73.0%	4.51E-04
Hole	20.0%	1.84E-04	20.0%	1.81E-04	20.0%	1.76E-04	20.0%	1.72E-04
Rupture	4.6%	4.22E-05	4.6%	4.17E-05	4.6%	4.04E-05	4.6%	3.95E-05
D Rupture	2.4%	2.20E-05	2.4%	2.18E-05	2.4%	2.11E-05	2.4%	2.06E-05
	Pipeline 12"							
Base Leak	73.0%	**4.67E-04**	73.0%	**4.59E-04**	73.0%	**4.39E-04**	73.0%	**4.26E-04**
Base Rupture	27.0%	**1.75E-04**	27.0%	**1.72E-04**	27.0%	**1.64E-04**	27.0%	**1.59E-04**
Leak	73.0%	4.67E-04	73.0%	4.59E-04	73.0%	4.39E-04	73.0%	4.26E-04
Hole	20.0%	1.30E-04	20.0%	1.27E-04	20.0%	1.22E-04	20.0%	1.18E-04
Rupture	4.6%	2.98E-05	4.6%	2.93E-05	4.6%	2.80E-05	4.6%	2.71E-05
D Rupture	2.4%	1.55E-05	2.4%	1.53E-05	2.4%	1.46E-05	2.4%	1.41E-05

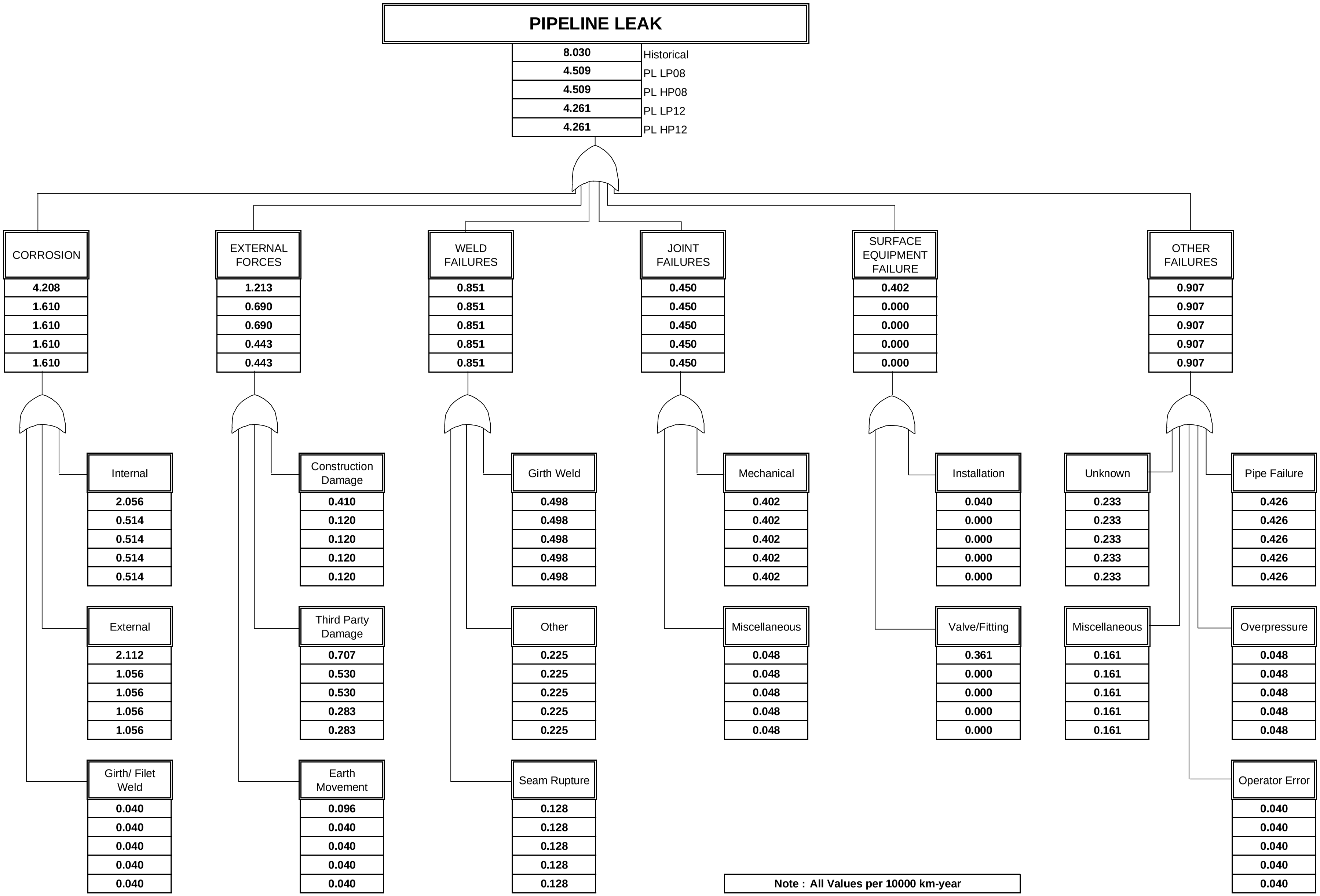


Figure C.1.1. Pipeline Leak Rate Variation Fault Tree

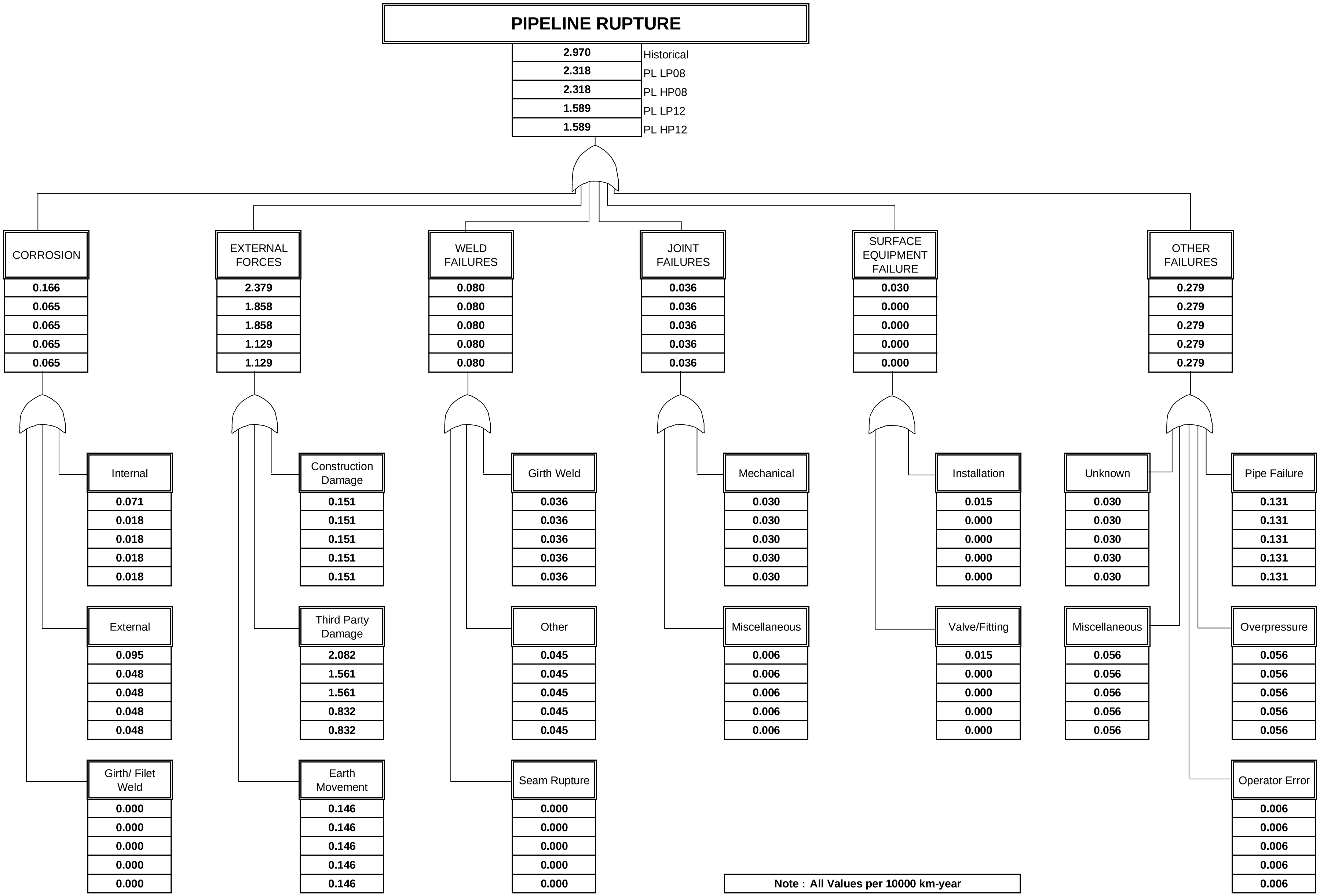


Figure C.1.2. Pipeline Rupture Rate Variation Fault Tree

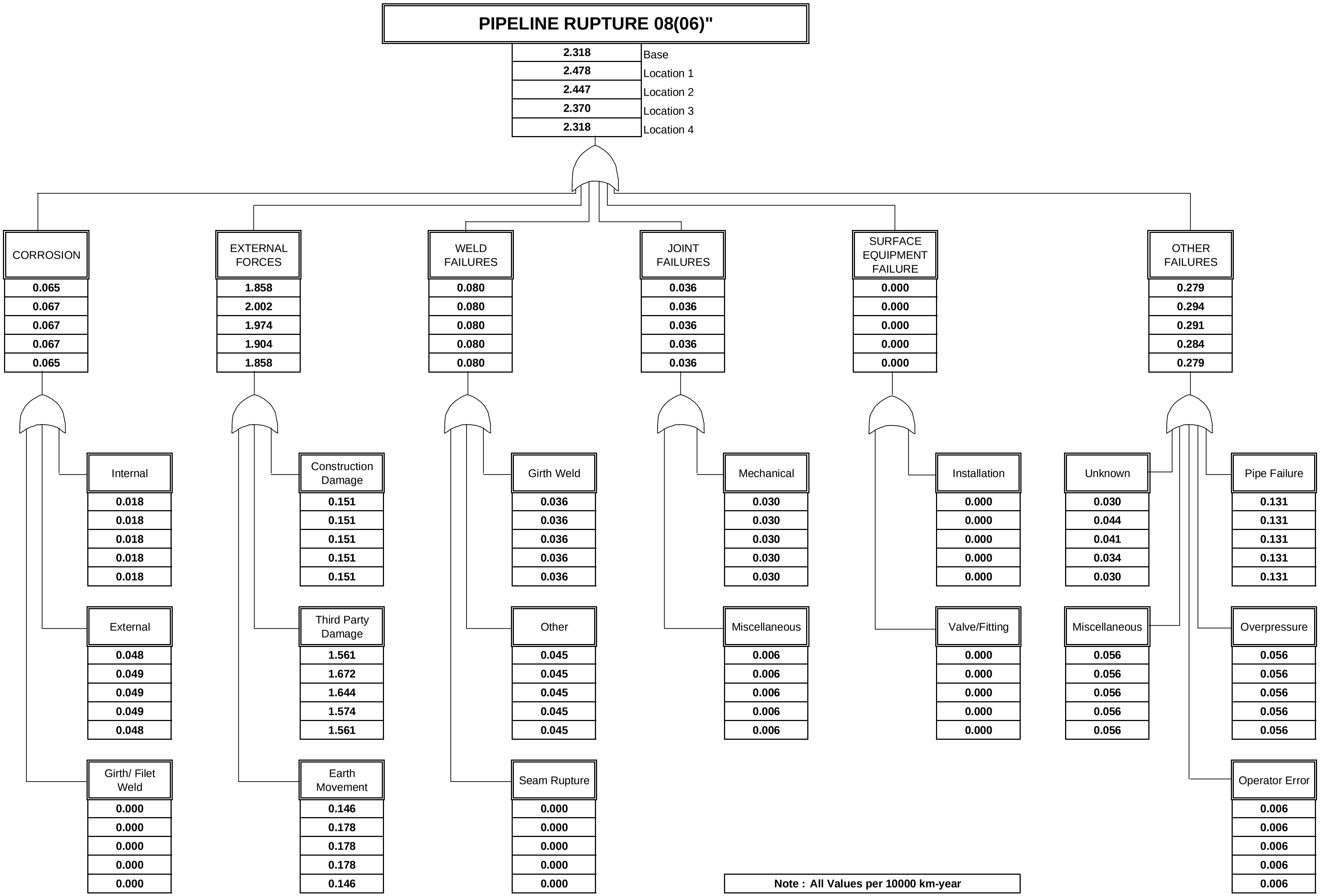


Figure C.1.3 Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

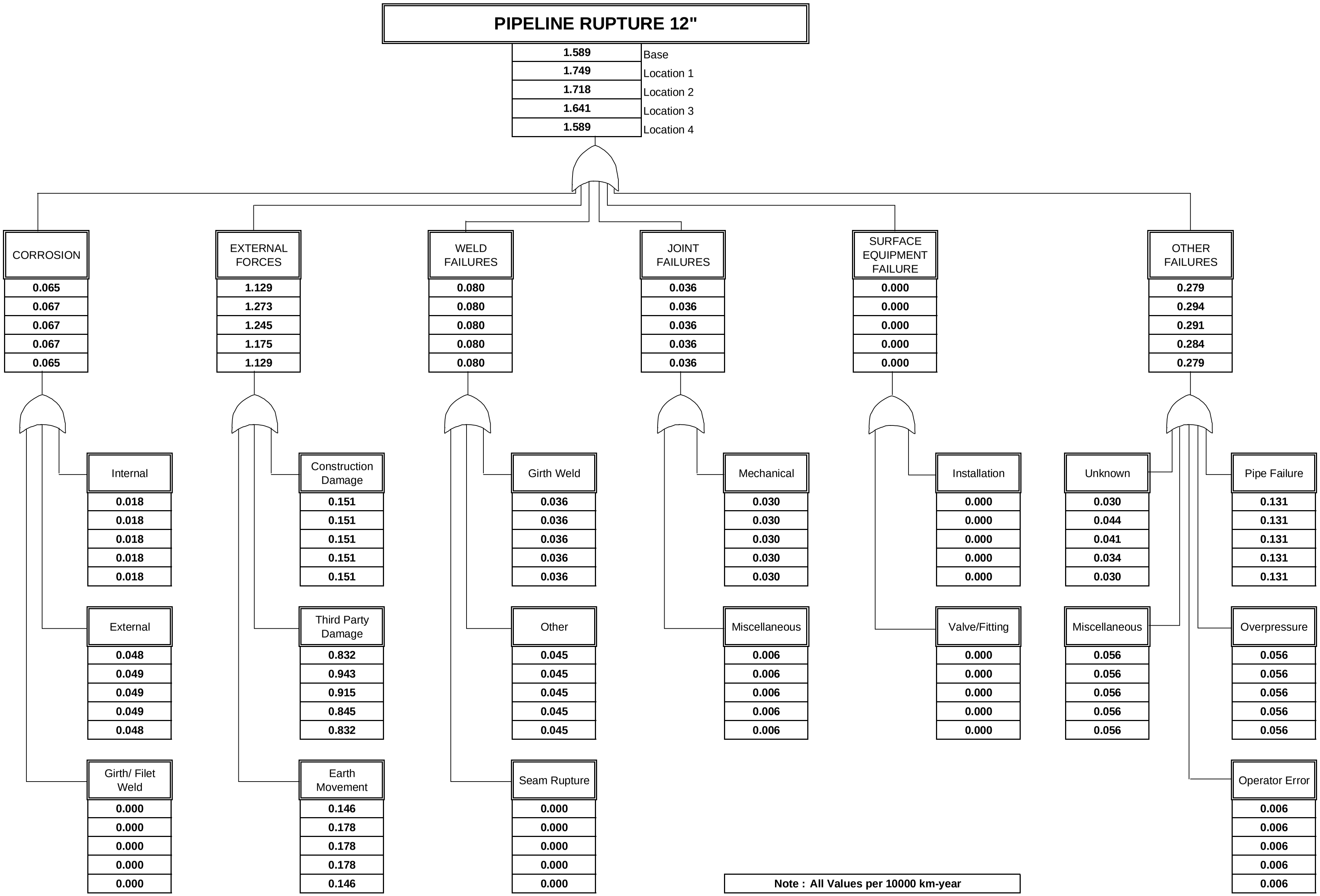


Figure C.1.4 Pipeline Rupture Rate Variation Fault Tree by Location 12"

Table C.2.1 Ignition Probability Calculation

Ignition Probability Calculation - for All Scenarios

Release Type	ADDT	Speed [km/h]	Cloud Length [m]	Cloud Probability	Ignition per Vehicle	Probability of Autoign.	Location Factor	Probability of Ignition	Release Type	ADDT	Speed [km/h]	Cloud Length [m]	Cloud Probability	Ignition per Vehicle	Probability of Autoign.	Location Factor	Probability of Ignition
Freeway - Type B - Location 1									**Arterial - Type C,D - Location 1**								
Leak	10000	90	10	0.95	0.50	0.15	1.00	**0.172**	Leak	5000	80	10	0.95	0.50	0.15	1.00	**0.162**
Hole	10000	90	150	0.95	0.50	0.15	1.00	**0.480**	Hole	5000	80	150	0.95	0.50	0.15	1.00	**0.336**
Rupture	10000	90	200	0.95	0.50	0.15	1.00	**0.590**	Rupture	5000	80	200	0.95	0.50	0.15	1.00	**0.397**
D Rupture	10000	90	200	0.95	0.50	0.15	1.00	**0.590**	D Rupture	5000	80	200	0.95	0.50	0.15	1.00	**0.397**
Freeway - Type B - Location 2									**Arterial - Type C,D - Location 2**								
Leak	10000	90	10	0.95	0.50	0.15	0.90	**0.170**	Leak	5000	80	10	0.95	0.50	0.15	0.90	**0.161**
Hole	10000	90	150	0.95	0.50	0.15	0.90	**0.447**	Hole	5000	80	150	0.95	0.50	0.15	0.90	**0.317**
Rupture	10000	90	200	0.95	0.50	0.15	0.90	**0.546**	Rupture	5000	80	200	0.95	0.50	0.15	0.90	**0.373**
D Rupture	10000	90	200	0.95	0.50	0.15	0.90	**0.546**	D Rupture	5000	80	200	0.95	0.50	0.15	0.90	**0.373**
Freeway - Type B - Location 3									**Arterial - Type C,D - Location 3**								
Leak	10000	90	10	0.95	0.50	0.15	0.80	**0.168**	Leak	5000	80	10	0.95	0.50	0.15	0.80	**0.160**
Hole	10000	90	150	0.95	0.50	0.15	0.80	**0.414**	Hole	5000	80	150	0.95	0.50	0.15	0.80	**0.298**
Rupture	10000	90	200	0.95	0.50	0.15	0.80	**0.502**	Rupture	5000	80	200	0.95	0.50	0.15	0.80	**0.348**
D Rupture	10000	90	200	0.95	0.50	0.15	0.80	**0.502**	D Rupture	5000	80	200	0.95	0.50	0.15	0.80	**0.348**
Freeway - Type B - Location 4									**Arterial - Type C,D - Location 4**								
Leak	10000	90	10	0.95	0.50	0.15	0.10	**0.152**	Leak	5000	80	10	0.95	0.50	0.15	0.10	**0.151**
Hole	10000	90	150	0.95	0.50	0.15	0.10	**0.183**	Hole	5000	80	150	0.95	0.50	0.15	0.10	**0.169**
Rupture	10000	90	200	0.95	0.50	0.15	0.10	**0.194**	Rupture	5000	80	200	0.95	0.50	0.15	0.10	**0.175**
D Rupture	10000	90	200	0.95	0.50	0.15	0.10	**0.194**	D Rupture	5000	80	200	0.95	0.50	0.15	0.10	**0.175**
Collector - Type E,F - Location 1									**Local - Type G,H,I,J - Location 1**								
Leak	3000	70	10	0.95	0.50	0.15	1.00	**0.158**	Leak	300	50	10	0.95	0.50	0.15	1.00	**0.151**
Hole	3000	70	150	0.95	0.50	0.15	1.00	**0.277**	Hole	300	50	150	0.95	0.50	0.15	1.00	**0.168**
Rupture	3000	70	200	0.95	0.50	0.15	1.00	**0.320**	Rupture	300	50	200	0.95	0.50	0.15	1.00	**0.174**
D Rupture	3000	70	200	0.95	0.50	0.15	1.00	**0.320**	D Rupture	300	50	200	0.95	0.50	0.15	1.00	**0.174**
Collector - Type E,F - Location 2									**Local - Type G,H,I,J - Location 2**								
Leak	3000	70	10	0.95	0.50	0.15	0.90	**0.158**	Leak	300	50	10	0.95	0.50	0.15	0.90	**0.151**
Hole	3000	70	150	0.95	0.50	0.15	0.90	**0.265**	Hole	300	50	150	0.95	0.50	0.15	0.90	**0.166**
Rupture	3000	70	200	0.95	0.50	0.15	0.90	**0.303**	Rupture	300	50	200	0.95	0.50	0.15	0.90	**0.171**
D Rupture	3000	70	200	0.95	0.50	0.15	0.90	**0.303**	D Rupture	300	50	200	0.95	0.50	0.15	0.90	**0.171**
Collector - Type E,F - Location 3									**Local - Type G,H,I,J - Location 3**								
Leak	3000	70	10	0.95	0.50	0.15	0.80	**0.157**	Leak	300	50	10	0.95	0.50	0.15	0.80	**0.151**
Hole	3000	70	150	0.95	0.50	0.15	0.80	**0.252**	Hole	300	50	150	0.95	0.50	0.15	0.80	**0.164**
Rupture	3000	70	200	0.95	0.50	0.15	0.80	**0.286**	Rupture	300	50	200	0.95	0.50	0.15	0.80	**0.169**
D Rupture	3000	70	200	0.95	0.50	0.15	0.80	**0.286**	D Rupture	300	50	200	0.95	0.50	0.15	0.80	**0.169**
Collector - Type E,F - Location 4									**Local - Type G,H,I,J - Location 4**								
Leak	3000	70	10	0.95	0.50	0.15	0.10	**0.151**	Leak	300	50	10	0.95	0.50	0.15	0.10	**0.150**
Hole	3000	70	150	0.95	0.50	0.15	0.10	**0.163**	Hole	300	50	150	0.95	0.50	0.15	0.10	**0.152**
Rupture	3000	70	200	0.95	0.50	0.15	0.10	**0.167**	Rupture	300	50	200	0.95	0.50	0.15	0.10	**0.152**
D Rupture	3000	70	200	0.95	0.50	0.15	0.10	**0.167**	D Rupture	300	50	200	0.95	0.50	0.15	0.10	**0.152**

Table C.2.2 Event Tree Database

Event Tree Database - for All Scenarios

Release Type	Ignition		Timing		Consequence			Ratio of Occurrence ROO			
	Yes	No	Im.	De.	F Fire	Expl.	Imm. J Fire	J Fire	F Fire	Expl.	Disp.
Freeway - Type B - Location 1											
Leak	0.172	0.828	0.300	0.700	0.900	0.100	0.052	0.172	0.108	0.012	0.828
Hole	0.480	0.520	0.600	0.400	0.700	0.300	0.288	0.480	0.134	0.058	0.520
Rupture	0.590	0.410	0.700	0.300	0.700	0.300	0.413	0.590	0.124	0.053	0.410
D Rupture	0.590	0.410	0.700	0.300	0.700	0.300	0.413	0.590	0.124	0.053	0.410
Freeway - Type B - Location 2											
Leak	0.170	0.830	0.300	0.700	0.900	0.100	0.051	0.170	0.107	0.012	0.830
Hole	0.447	0.553	0.600	0.400	0.700	0.300	0.268	0.447	0.125	0.054	0.553
Rupture	0.546	0.454	0.650	0.350	0.700	0.300	0.355	0.546	0.134	0.057	0.454
D Rupture	0.546	0.454	0.650	0.350	0.700	0.300	0.355	0.546	0.134	0.057	0.454
Freeway - Type B - Location 3											
Leak	0.168	0.832	0.300	0.700	0.900	0.100	0.050	0.168	0.106	0.012	0.832
Hole	0.414	0.586	0.600	0.400	0.700	0.300	0.248	0.414	0.116	0.050	0.586
Rupture	0.502	0.498	0.600	0.400	0.700	0.300	0.301	0.502	0.141	0.060	0.498
D Rupture	0.502	0.498	0.600	0.400	0.700	0.300	0.301	0.502	0.141	0.060	0.498
Freeway - Type B - Location 4											
Leak	0.152	0.848	0.900	0.100	0.900	0.100	0.137	0.152	0.014	0.002	0.848
Hole	0.183	0.817	0.900	0.100	0.700	0.300	0.165	0.183	0.013	0.005	0.817
Rupture	0.194	0.806	0.900	0.100	0.700	0.300	0.175	0.194	0.014	0.006	0.806
D Rupture	0.194	0.806	0.900	0.100	0.700	0.300	0.175	0.194	0.014	0.006	0.806
Collector - Type E,F - Location 1											
Leak	0.158	0.842	0.300	0.700	0.900	0.100	0.048	0.158	0.100	0.011	0.842
Hole	0.277	0.723	0.600	0.400	0.700	0.300	0.166	0.277	0.078	0.033	0.723
Rupture	0.320	0.680	0.700	0.300	0.700	0.300	0.224	0.320	0.067	0.029	0.680
D Rupture	0.320	0.680	0.700	0.300	0.700	0.300	0.224	0.320	0.067	0.029	0.680
Collector - Type E,F - Location 2											
Leak	0.158	0.842	0.300	0.700	0.900	0.100	0.047	0.158	0.099	0.011	0.842
Hole	0.265	0.735	0.600	0.400	0.700	0.300	0.159	0.265	0.074	0.032	0.735
Rupture	0.303	0.697	0.650	0.350	0.700	0.300	0.197	0.303	0.074	0.032	0.697
D Rupture	0.303	0.697	0.650	0.350	0.700	0.300	0.197	0.303	0.074	0.032	0.697
Collector - Type E,F - Location 3											
Leak	0.157	0.843	0.300	0.700	0.900	0.100	0.047	0.157	0.099	0.011	0.843
Hole	0.252	0.748	0.600	0.400	0.700	0.300	0.151	0.252	0.071	0.030	0.748
Rupture	0.286	0.714	0.600	0.400	0.700	0.300	0.171	0.286	0.080	0.034	0.714
D Rupture	0.286	0.714	0.600	0.400	0.700	0.300	0.171	0.286	0.080	0.034	0.714
Collector - Type E,F - Location 4											
Leak	0.151	0.849	0.900	0.100	0.900	0.100	0.136	0.151	0.014	0.002	0.849
Hole	0.163	0.837	0.900	0.100	0.700	0.300	0.146	0.163	0.011	0.005	0.837
Rupture	0.167	0.833	0.900	0.100	0.700	0.300	0.150	0.167	0.012	0.005	0.833
D Rupture	0.167	0.833	0.900	0.100	0.700	0.300	0.150	0.167	0.012	0.005	0.833

Release Type	Ignition		Timing		Consequence			Ratio of Occurrence ROO			
	Yes	No	Imm.	Del.	F Fire	Expl.	Imm. J Fire	J Fire	F Fire	Expl.	Disp.
Arterial - Type C,D - Location 1											
Leak	0.162	0.838	0.300	0.700	0.900	0.100	0.049	0.162	0.102	0.011	0.838
Hole	0.336	0.664	0.600	0.400	0.700	0.300	0.201	0.336	0.094	0.040	0.664
Rupture	0.397	0.603	0.700	0.300	0.700	0.300	0.278	0.397	0.083	0.036	0.603
D Rupture	0.397	0.603	0.700	0.300	0.700	0.300	0.278	0.397	0.083	0.036	0.603
Arterial - Type C,D - Location 2											
Leak	0.161	0.839	0.300	0.700	0.900	0.100	0.048	0.161	0.102	0.011	0.839
Hole	0.317	0.683	0.600	0.400	0.700	0.300	0.190	0.317	0.089	0.038	0.683
Rupture	0.373	0.627	0.650	0.350	0.700	0.300	0.242	0.373	0.091	0.039	0.627
D Rupture	0.373	0.627	0.650	0.350	0.700	0.300	0.242	0.373	0.091	0.039	0.627
Arterial - Type C,D - Location 3											
Leak	0.160	0.840	0.300	0.700	0.900	0.100	0.048	0.160	0.101	0.011	0.840
Hole	0.298	0.702	0.600	0.400	0.700	0.300	0.179	0.298	0.084	0.036	0.702
Rupture	0.348	0.652	0.600	0.400	0.700	0.300	0.209	0.348	0.097	0.042	0.652
D Rupture	0.348	0.652	0.600	0.400	0.700	0.300	0.209	0.348	0.097	0.042	0.652
Arterial - Type C,D - Location 4											
Leak	0.151	0.849	0.900	0.100	0.900	0.100	0.136	0.151	0.014	0.002	0.849
Hole	0.169	0.831	0.900	0.100	0.700	0.300	0.152	0.169	0.012	0.005	0.831
Rupture	0.175	0.825	0.900	0.100	0.700	0.300	0.157	0.175	0.012	0.005	0.825
D Rupture	0.175	0.825	0.900	0.100	0.700	0.300	0.157	0.175	0.012	0.005	0.825
Local - Type G,H,I,J - Location 1											
Leak	0.151	0.849	0.300	0.700	0.900	0.100	0.045	0.151	0.095	0.011	0.849
Hole	0.168	0.832	0.600	0.400	0.700	0.300	0.101	0.168	0.047	0.020	0.832
Rupture	0.174	0.826	0.700	0.300	0.700	0.300	0.122	0.174	0.036	0.016	0.826
D Rupture	0.174	0.826	0.700	0.300	0.700	0.300	0.122	0.174	0.036	0.016	0.826
Local - Type G,H,I,J - Location 2											
Leak	0.151	0.849	0.300	0.700	0.900	0.100	0.045	0.151	0.095	0.011	0.849
Hole	0.166	0.834	0.600	0.400	0.700	0.300	0.100	0.166	0.046	0.020	0.834
Rupture	0.171	0.829	0.650	0.350	0.700	0.300	0.111	0.171	0.042	0.018	0.829
D Rupture	0.171	0.829	0.650	0.350	0.700	0.300	0.111	0.171	0.042	0.018	0.829
Local - Type G,H,I,J - Location 3											
Leak	0.151	0.849	0.300	0.700	0.900	0.100	0.045	0.151	0.095	0.011	0.849
Hole	0.164	0.836	0.600	0.400	0.700	0.300	0.099	0.164	0.046	0.020	0.836
Rupture	0.169	0.831	0.600	0.400	0.700	0.300	0.101	0.169	0.047	0.020	0.831
D Rupture	0.169	0.831	0.600	0.400	0.700	0.300	0.101	0.169	0.047	0.020	0.831
Local - Type G,H,I,J - Location 4											
Leak	0.150	0.850	0.900	0.100	0.900	0.100	0.135	0.150	0.014	0.002	0.850
Hole	0.152	0.848	0.900	0.100	0.700	0.300	0.137	0.152	0.011	0.005	0.848
Rupture	0.152	0.848	0.900	0.100	0.700	0.300	0.137	0.152	0.011	0.005	0.848
D Rupture	0.152	0.848	0.900	0.100	0.700	0.300	0.137	0.152	0.011	0.005	0.848

Table C.2.3
06" Pipeline Consequence Modelling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m]						Max Isopleth Distance [m]						Max Isopleth Distance [m]		
							Flash Fire, Thermal Radiation Flux [W/m2]						Jet Fire, Thermal Radiation Flux [W/m2]						Explosion Overpressure [Pa]		
							12500		25000		37500		12500		25000		37500		6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-LP06-L-MU	Leak .5 cm Dia		0.05	A,B,C	15.9	0.9	0.3	0.4	0.2	0.3	0.2	4.0	1.2	3.6	0.6	3.4	0.5	0	0	0
2	TAC-LP06-L-MN				D	53.9	2.9	0.6	1.4	0.6	0.9	0.6	3.2	1.2	2.9	0.6	2.8	0.5	0	0	0
3	TAC-LP06-L-MS				E,F	30.2	13.8	3.2	13.8	2.0	13.8	1.5	4.5	1.1	4.1	0.6	3.9	0.5	0	0	0
4	TAC-LP06-L-MA				**Average**	**100**	**6**	**1**	**5**	**1**	**5**	**1**	**4**	**1**	**3**	**1**	**3**	**1**	**0**	**0**	**0**
5	TAC-LP06-H-MU	Hole 10 cm Dia		19.6	A,B,C	15.9	152	28	151	18	150	14	64	24	59	14	56	10	334	103	61
6	TAC-LP06-H-MN				D	53.9	209	20	207	10	208	10	58	25	52	15	50	10	334	103	61
7	TAC-LP06-H-MS				E,F	30.2	139	32	114	20	108	16	70	22	65	11	62	9	334	103	61
8	TAC-LP06-H-MA				**Average**	**100**	**179**	**25**	**170**	**14**	**169**	**12**	**63**	**24**	**57**	**14**	**55**	**10**	**334**	**103**	**61**
9	TAC-LP06-R-MU	Rupture 15 cm Dia			A,B,C	15.9															
10	TAC-LP06-R-MN				D	53.9															
11	TAC-LP06-R-MS				E,F	30.2															
12	TAC-LP06-R-MA				**Average**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
13	TAC-LP06-DR-MU	Double Rupture 21.2 cm Equ. Dia			A,B,C	15.9															
14	TAC-LP06-DR-MN				D	53.9															
15	TAC-LP06-DR-MS				E,F	30.2															
16	TAC-LP06-DR-MA				**Average**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
17	TAC-HP06-L-MU	Leak .5 cm Dia		0.1	A,B,C	15.9	13.0	3.0	13.0	1.5	13.0	1.5	5.4	1.6	5.0	0.9	4.7	0.6	0	0	0
18	TAC-HP06-L-MN				D	53.9	1.1	0.6	0.8	0.5	0.6	0.4	4.6	1.6	3.9	1.0	3.8	0.6	0	0	0
19	TAC-HP06-L-MS				E,F	30.2	22.0	0.6	22.0	0.3	22.0	0.3	6.1	1.6	5.6	0.8	5.3	0.6	0	0	0
20	TAC-HP06-L-MA				**Average**	**100**	**9**	**1**	**9**	**1**	**9**	**1**	**5**	**2**	**5**	**1**	**4**	**1**	**0**	**0**	**0**
21	TAC-HP06-H-MU	Hole 10 cm Dia		47	A,B,C	15.9	205	42	182	29	181	25	94	35	86	22	82	16	447	138	82
22	TAC-HP06-H-MN				D	53.9	247	32	247	20	247	16	85	36	77	24	73	16	447	138	82
23	TAC-HP06-H-MS				E,F	30.2	167	36	149	29	140	27	103	34	94	20	90	15	447	138	82
24	TAC-HP06-H-MA				**Average**	**100**	**216**	**35**	**207**	**24**	**204**	**21**	**92**	**35**	**84**	**22**	**80**	**16**	**447**	**138**	**82**
25	TAC-HP06-R-MU	Rupture 15 cm Dia			A,B,C	15.9															
26	TAC-HP06-R-MN				D	53.9															
27	TAC-HP06-R-MS				E,F	30.2															
28	TAC-HP06-R-MA				**Average**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
29	TAC-HP06-DR-MU	Double Rupture 21.2 cm Equ. Dia			A,B,C	15.9															
30	TAC-HP06-DR-MN				D	53.9															
31	TAC-HP06-DR-MS				E,F	30.2															
32	TAC-HP06-DR-MA				**Average**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
33	TAC-VP06-L-MU	Leak .5 cm Dia	7772	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
34	TAC-VP06-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
35	TAC-VP06-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
36	TAC-VP06-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
37	TAC-VP06-H-MU	Hole 10 cm Dia	19.4	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	231	71	42
38	TAC-VP06-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	142	44	26
39	TAC-VP06-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
40	TAC-VP06-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**277**	**86**	**51**
41	TAC-VP06-R-MU	Rupture 15 cm Dia			A,B,C	15.9	280	70	251	50	250	50	174	70	158	40	150	30	686	212	126
42	TAC-VP06-R-MN				D	53.9	352	70	305	40	298	30	157	70	141	50	134	30	686	212	126
43	TAC-VP06-R-MS				E,F	30.2	344	130	278	120	244	120	190	70	174	40	166	30	187	58	34
44	TAC-VP06-R-MA				**Average**	**100**	**338**	**88**	**288**	**66**	**274**	**60**	**170**	**70**	**154**	**45**	**146**	**30**	**535**	**165**	**98**
45	TAC-VP06-DR-MU	Double Rupture 21.2 cm Equ. Dia			A,B,C	15.9	417	140	348	120	313	120	237	100	215	60	205	50	509	158	93
46	TAC-VP06-DR-MN				D	53.9	491	120	387	100	340	80	213	100	192	60	181	50	380	118	70
47	TAC-VP06-DR-MS				E,F	30.2	424	160	338	140	294	140	259	90	237	60	226	40	217	67	40
48	TAC-VP06-DR-MA				**Average**	**100**	**459**	**135**	**366**	**115**	**322**	**104**	**231**	**97**	**209**	**60**	**198**	**47**	**351**	**109**	**65**

Table C.2.4
08" Pipeline Consequence Modelling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m] Flash Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Jet Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Explosion Overpressure [Pa]		
							12500		25000		37500		12500		25000		37500		6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-LP08-L-MU	Leak .5 cm Dia	19512	0.05	A,B,C	15.9	0.9	0.3	0.4	0.2	0.3	0.2	4.0	1.2	3.6	0.6	3.4	0.5	0	0	0
2	TAC-LP08-L-MN				D	53.9	2.9	0.6	1.4	0.6	0.9	0.6	3.2	1.2	2.9	0.6	2.8	0.5	0	0	0
3	TAC-LP08-L-MS				E,F	30.2	13.8	3.2	13.8	2.0	13.8	1.5	4.5	1.1	4.1	0.6	3.9	0.5	0	0	0
4	TAC-LP08-L-MA				**Average**	**100**	**6**	**1**	**5**	**1**	**5**	**1**	**4**	**1**	**3**	**1**	**3**	**1**	**0**	**0**	**0**
5	TAC-LP08-H-MU	Hole 10 cm Dia	49.8	19.6	A,B,C	15.9	152	28	151	18	150	14	64	24	59	14	56	10	334	103	61
6	TAC-LP08-H-MN				D	53.9	209	20	207	10	208	10	58	25	52	15	50	10	334	103	61
7	TAC-LP08-H-MS				E,F	30.2	139	32	114	20	108	16	70	22	65	11	62	9	334	103	61
8	TAC-LP08-H-MA				**Average**	**100**	**179**	**25**	**170**	**14**	**169**	**12**	**63**	**24**	**57**	**14**	**55**	**10**	**334**	**103**	**61**
9	TAC-LP08-R-MU	Rupture 20 cm Dia	12.4	78.5	A,B,C	15.9	237	56	197	36	180	32	120	44	110	24	104	20	522	162	96
10	TAC-LP08-R-MN				D	53.9	263	42	252	26	252	22	108	44	98	30	93	22	279	86	51
11	TAC-LP08-R-MS				E,F	30.2	189	40	165	30	154	30	132	44	121	26	115	20	116	36	21
12	TAC-LP08-R-MA				**Average**	**100**	**237**	**44**	**217**	**29**	**211**	**26**	**117**	**44**	**107**	**28**	**101**	**21**	**268**	**83**	**49**
13	TAC-LP08-DR-MU	Double Rupture 28 cm Equ. Dia	6.3	153.8	A,B,C	15.9	274	60	235	50	235	48	163	65	148	40	141	30	634	196	116
14	TAC-LP08-DR-MN				D	53.9	339	60	293	36	288	28	146	70	132	40	125	30	235	73	43
15	TAC-LP08-DR-MS				E,F	30.2	213	50	184	35	169	35	178	60	163	30	155	20	117	36	21
16	TAC-LP08-DR-MA				**Average**	**100**	**291**	**57**	**251**	**38**	**244**	**33**	**158**	**66**	**144**	**37**	**137**	**27**	**263**	**81**	**48**
17	TAC-HP08-L-MU	Leak .5 cm Dia	25120	0.1	A,B,C	15.9	13.0	3.0	13.0	1.5	13.0	1.5	5.4	1.6	5.0	0.9	4.7	0.6	0	0	0
18	TAC-HP08-L-MN				D	53.9	1.1	0.6	0.8	0.5	0.6	0.4	4.6	1.6	3.9	1.0	3.8	0.6	0	0	0
19	TAC-HP08-L-MS				E,F	30.2	22.0	0.6	22.0	0.3	22.0	0.3	6.1	1.6	5.6	0.8	5.3	0.6	0	0	0
20	TAC-HP08-L-MA				**Average**	**100**	**9**	**1**	**9**	**1**	**9**	**1**	**5**	**2**	**5**	**1**	**4**	**1**	**0**	**0**	**0**
21	TAC-HP08-H-MU	Hole 10 cm Dia	62.8	47.0	A,B,C	15.9	205	42	182	29	181	25	94	35	86	22	82	16	447	138	82
22	TAC-HP08-H-MN				D	53.9	247	32	247	20	247	16	85	36	77	24	73	16	447	138	82
23	TAC-HP08-H-MS				E,F	30.2	167	36	149	29	140	27	103	34	94	20	90	15	447	138	82
24	TAC-HP08-H-MA				**Average**	**100**	**216**	**35**	**207**	**24**	**204**	**21**	**92**	**35**	**84**	**22**	**80**	**16**	**447**	**138**	**82**
25	TAC-HP08-R-MU	Rupture 20 cm Dia	15.7	188.2	A,B,C	15.9	278	60	250	50	249	50	175	70	159	40	152	30	703	218	129
26	TAC-HP08-R-MN				D	53.9	352	60	305	40	298	40	158	70	142	45	135	30	703	218	129
27	TAC-HP08-R-MS				E,F	30.2	221	50	190	40	175	40	192	70	175	40	167	30	703	218	129
28	TAC-HP08-R-MA				**Average**	**100**	**301**	**57**	**262**	**42**	**253**	**42**	**171**	**70**	**155**	**43**	**147**	**30**	**703**	**218**	**129**
29	TAC-HP08-DR-MU	Double Rupture 28 cm Equ. Dia	8.0	368.9	A,B,C	15.9	336	80	298	60	280	60	237	100	215	60	204	40	855	265	157
30	TAC-HP08-DR-MN				D	53.9	403	78	346	58	345	48	213	100	192	60	181	50	855	265	157
31	TAC-HP08-DR-MS				E,F	30.2	244	60	207	50	188	42	259	90	237	60	226	40	855	265	157
32	TAC-HP08-DR-MA				**Average**	**100**	**344**	**73**	**296**	**56**	**287**	**48**	**231**	**97**	**209**	**60**	**198**	**45**	**855**	**265**	**157**
33	TAC-VP08-L-MU	Leak .5 cm Dia	28646	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
34	TAC-VP08-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
35	TAC-VP08-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
36	TAC-VP08-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
37	TAC-VP08-H-MU	Hole 10 cm Dia	71.6	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	541	168	99
38	TAC-VP08-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	541	168	99
39	TAC-VP08-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
40	TAC-VP08-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**541**	**168**	**99**
41	TAC-VP08-R-MU	Rupture 20 cm Dia	17.9	334	A,B,C	15.9	402	130	333	120	301	120	225	90	205	60	194	40	480	149	88
42	TAC-VP08-R-MN				D	53.9	472	120	380	90	336	80	203	90	182	60	172	50	351	109	64
43	TAC-VP08-R-MS				E,F	30.2	407	160	325	140	283	140	246	80	225	55	215	40	207	64	38
44	TAC-VP08-R-MA				**Average**	**100**	**441**	**134**	**356**	**110**	**314**	**104**	**219**	**87**	**199**	**58**	**188**	**45**	**328**	**102**	**60**
45	TAC-VP08-DR-MU	Double Rupture 28 cm Equ. Dia	9.1	566	A,B,C	15.9	500	180	409	160	362	160	286	120	259	70	246	60	297	92	55
46	TAC-VP08-DR-MN				D	53.9	557	160	431	140	374	120	257	120	231	80	218	60	503	156	92
47	TAC-VP08-DR-MS				E,F	30.2	503	205	397	180	342	180	312	120	285	70	272	50	275	85	50
48	TAC-VP08-DR-MA				**Average**	**100**	**532**	**177**	**417**	**155**	**362**	**144**	**278**	**120**	**252**	**75**	**239**	**57**	**401**	**124**	**73**

Table C.2.5
12" Pipeline Consequence Modelling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m] Flash Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Jet Fire, Thermal Radiation Flux [W/m2]						Max Isopleth Distance [m] Explosion Overpressure [Pa]		
							12500		25000		37500		12500		25000		37500		6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-LP12-L-MU	Leak .5 cm Dia	44763	0.05	A,B,C	15.9	0.9	0.3	0.4	0.2	0.3	0.2	4.0	1.2	3.6	0.6	3.4	0.5	0	0	0
2	TAC-LP12-L-MN				D	53.9	2.9	0.6	1.4	0.6	0.9	0.6	3.2	1.2	2.9	0.6	2.8	0.5	0	0	0
3	TAC-LP12-L-MS				E,F	30.2	13.8	3.2	13.8	2.0	13.8	1.5	4.5	1.1	4.1	0.6	3.9	0.5	0	0	0
4	TAC-LP12-L-MA				**Average**	**100**	**6**	**1**	**5**	**1**	**5**	**1**	**4**	**1**	**3**	**1**	**3**	**1**	**0**	**0**	**0**
5	TAC-LP12-H-MU	Hole 10 cm Dia	112	19.6	A,B,C	15.9	152	28	151	18	150	14	64	24	59	14	56	10	334	103	61
6	TAC-LP12-H-MN				D	53.9	209	20	207	10	208	10	58	25	52	15	50	10	334	103	61
7	TAC-LP12-H-MS				E,F	30.2	139	32	114	20	108	16	70	22	65	11	62	9	334	103	61
8	TAC-LP12-H-MA				**Average**	**100**	**179**	**25**	**170**	**14**	**169**	**12**	**63**	**24**	**57**	**14**	**55**	**10**	**334**	**103**	**61**
9	TAC-LP12-R-MU	Rupture 30 cm Dia	12.4	176	A,B,C	15.9	280	70	225	50	198	40	171	70	155	40	147	30	684	212	126
10	TAC-LP12-R-MN				D	53.9	347	60	297	40	273	35	156	70	140	45	132	30	202	63	37
11	TAC-LP12-R-MS				E,F	30.2	218	50	187	40	172	40	189	70	173	40	165	30	121	37	22
12	TAC-LP12-R-MA				**Average**	**100**	**297**	**59**	**252**	**42**	**231**	**37**	**168**	**70**	**152**	**43**	**144**	**30**	**254**	**79**	**47**
13	TAC-LP12-DR-MU	Double Rupture 43 cm Equ. Dia	6.1	363	A,B,C	15.9	329	70	292	60	276	60	235	100	214	60	203	40	841	260	154
14	TAC-LP12-DR-MN				D	53.9	404	70	339	50	228	50	214	100	192	70	182	50	841	260	154
15	TAC-LP12-DR-MS				E,F	30.2	243	60	205	40	187	40	261	90	239	60	228	40	143	44	26
16	TAC-LP12-DR-MA				**Average**	**100**	**343**	**67**	**291**	**49**	**223**	**49**	**232**	**97**	**210**	**65**	**199**	**45**	**630**	**195**	**115**
17	TAC-HP12-L-MU	Leak .5 cm Dia	56491	0.1	A,B,C	15.9	13.0	3.0	13.0	1.5	13.0	1.5	5.4	1.6	5.0	0.9	4.7	0.6	0	0	0
18	TAC-HP12-L-MN				D	53.9	1.1	0.6	0.8	0.5	0.6	0.4	4.6	1.6	3.9	1.0	3.8	0.6	0	0	0
19	TAC-HP12-L-MS				E,F	30.2	22.0	0.6	22.0	0.3	22.0	0.3	6.1	1.6	5.6	0.8	5.3	0.6	0	0	0
20	TAC-HP12-L-MA				**Average**	**100**	**9**	**1**	**9**	**1**	**9**	**1**	**5**	**2**	**5**	**1**	**4**	**1**	**0**	**0**	**0**
21	TAC-HP12-H-MU	Hole 10 cm Dia	141	47	A,B,C	15.9	205	42	182	29	181	25	94	35	86	22	82	16	447	138	82
22	TAC-HP12-H-MN				D	53.9	247	32	247	20	247	16	85	36	77	24	73	16	447	138	82
23	TAC-HP12-H-MS				E,F	30.2	167	36	149	29	140	27	103	34	94	20	90	15	447	138	82
24	TAC-HP12-H-MA				**Average**	**100**	**216**	**35**	**207**	**24**	**204**	**21**	**92**	**35**	**84**	**22**	**80**	**16**	**447**	**138**	**82**
25	TAC-HP12-R-MU	Rupture 30 cm Dia	15.7	423	A,B,C	15.9	351	75	309	60	288	60	252	100	229	70	217	50	921	285	169
26	TAC-HP12-R-MN				D	53.9	413	80	354	60	353	50	227	110	204	70	192	50	921	285	169
27	TAC-HP12-R-MS				E,F	30.2	249	60	210	45	191	45	276	100	252	60	240	40	921	285	169
28	TAC-HP12-R-MA				**Average**	**100**	**354**	**73**	**303**	**55**	**294**	**50**	**246**	**105**	**222**	**67**	**210**	**47**	**921**	**285**	**169**
29	TAC-HP12-DR-MU	Double Rupture 43 cm Equ. Dia	7.6	870	A,B,C	15.9	410	100	353	70	324	60	348	150	315	90	299	60	1134	351	208
30	TAC-HP12-DR-MN				D	53.9	463	100	394	70	394	60	313	150	280	100	264	80	1134	351	208
31	TAC-HP12-DR-MS				E,F	30.2	280	70	232	50	208	50	381	140	347	80	331	60	1134	351	208
32	TAC-HP12-DR-MA				**Average**	**100**	**399**	**91**	**339**	**64**	**327**	**57**	**339**	**147**	**306**	**92**	**290**	**71**	**1134**	**351**	**208**
33	TAC-VP12-L-MU	Leak .5 cm Dia	64422	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
34	TAC-VP12-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
35	TAC-VP12-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
36	TAC-VP12-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
37	TAC-VP12-H-MU	Hole 10 cm Dia	161	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	541	168	99
38	TAC-VP12-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	541	168	99
39	TAC-VP12-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
40	TAC-VP12-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**541**	**168**	**99**
41	TAC-VP12-R-MU	Rupture 30 cm Dia	17.9	752	A,B,C	15.9	520	190	424	160	375	160	324	140	294	80	279	60	311	96	57
42	TAC-VP12-R-MN				D	53.9	576	160	447	140	408	120	291	140	261	90	246	60	542	168	99
43	TAC-VP12-R-MS				E,F	30.2	525	210	413	180	355	180	354	120	323	80	308	60	291	90	53
44	TAC-VP12-R-MA				**Average**	**100**	**552**	**180**	**433**	**155**	**387**	**144**	**315**	**134**	**285**	**85**	**270**	**60**	**429**	**133**	**78**
45	TAC-VP12-DR-MU	Double Rupture 43 cm Equ. Dia	3.9	1545	A,B,C	15.9	642	240	512	210	447	210	447	200	404	120	384	100	367	114	68
46	TAC-VP12-DR-MN				D	53.9	695	210	571	180	508	180	402	200	359	130	339	100	427	132	78
47	TAC-VP12-DR-MS				E,F	30.2	674	300	525	250	448	250	489	190	445	120	424	90	355	110	65
48	TAC-VP12-DR-MA				**Average**	**100**	**680**	**242**	**548**	**206**	**480**	**206**	**435**	**197**	**392**	**125**	**372**	**97**	**396**	**122**	**72**

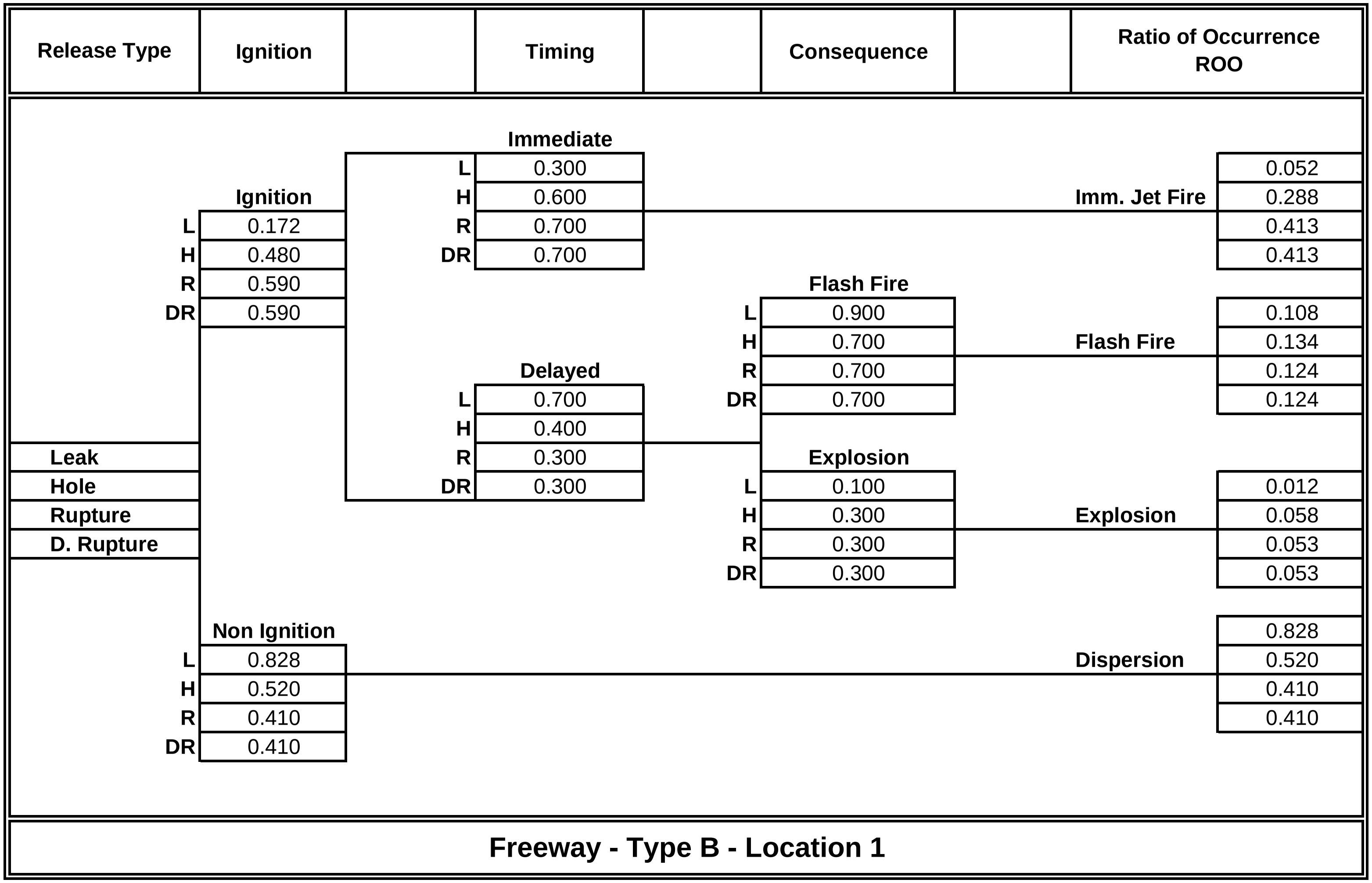


Figure C.2.1
Event Tree Freeway Location 1

Table C.3.1
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E h/day	Nt trip/day	Nd days/week	Nw weeks/year	L km/trip	V km/h	LISRF	IF	OF	Sfi	Sfo	ISRF
1	Freeway Type B	1	Daily Commuter	n/a	2	5	48	25	90	0.0153	0.95	0.05	0.1	1.0	0.00221
		2	Weekly Commuter	n/a	2	1	48	25	90	0.0031	0.90	0.10	0.1	1.0	0.00058
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
2	Arterial Type C,D	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.00199
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.00052
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
3	Collector Type E,F	1	Daily Commuter	n/a	2	5	48	15	70	0.0118	0.95	0.05	0.1	1.0	0.00171
		2	Weekly Commuter	n/a	2	1	48	15	70	0.0024	0.90	0.10	0.1	1.0	0.00045
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833
4	Local Type G,H,I,J	1	Daily Commuter	n/a	2	5	48	10	50	0.0110	0.95	0.05	0.1	1.0	0.00159
		2	Weekly Commuter	n/a	2	1	48	10	50	0.0022	0.90	0.10	0.1	1.0	0.00042
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.00751
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.08769
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.15833

Table C.3.2
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Freeway-Location 1																
GAS RELEASE	Leak	4.67E-04						-	-	-	-	-	-	-	-	-
	Hole	1.30E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.98E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.55E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.172	8.03E-05	0.1	4	0.25	1.61E-08	-	-	-	-	-	-	-	-
	Hole		0.480	6.24E-05	0.1	80	0.25	2.50E-07	2.49E-07	2.48E-07	2.37E-07	1.95E-07	-	-	-	-
	Rupture		0.590	1.76E-05	0.1	210	0.25	1.85E-07	1.85E-07	1.84E-07	1.83E-07	1.79E-07	1.29E-07	5.63E-08	-	-
	D Rupture		0.590	9.15E-06	0.1	290	0.25	1.33E-07	1.33E-07	1.33E-07	1.32E-07	1.31E-07	1.13E-07	9.60E-08	6.72E-08	-
FLASH FIRE - Transverse	Leak		0.108	5.04E-05	0.5	9	0.25	1.13E-07	9.44E-08	-	-	-	-	-	-	-
	Hole		0.134	1.74E-05	0.5	204	0.25	8.88E-07	8.88E-07	8.87E-07	8.82E-07	8.61E-07	6.02E-07	1.75E-07	-	-
	Rupture		0.124	3.70E-06	0.5	294	0.25	2.72E-07	2.72E-07	2.71E-07	2.71E-07	2.68E-07	2.34E-07	1.99E-07	1.43E-07	-
	D Rupture		0.124	1.92E-06	0.5	327	0.25	1.57E-07	1.57E-07	1.57E-07	1.57E-07	1.55E-07	1.40E-07	1.24E-07	1.01E-07	6.25E-08
FLASH FIRE - Parallel	Leak		0.108	5.04E-05	0.5	1	0.25	1.26E-08	-	-	-	-	-	-	-	-
	Hole		0.134	1.74E-05	0.5	21	0.25	9.15E-08	8.88E-08	8.04E-08	-	-	-	-	-	-
	Rupture		0.124	3.70E-06	0.5	50	0.25	4.62E-08	4.60E-08	4.53E-08	4.00E-08	0.00E+00	-	-	-	-
	D Rupture		0.124	1.92E-06	0.5	57	0.25	2.74E-08	2.73E-08	2.70E-08	2.46E-08	1.32E-08	-	-	-	-
EXPLOSION	Leak		0.012	5.60E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.058	7.54E-06	0.1	82	1.00	1.24E-07	1.23E-07	1.23E-07	1.18E-07	9.80E-08	-	-	-	-
	Rupture		0.053	1.58E-06	0.1	169	1.00	5.34E-08	5.34E-08	5.33E-08	5.28E-08	5.10E-08	2.46E-08	-	-	-
	D Rupture		0.053	8.22E-07	0.1	208	1.00	3.42E-08	3.42E-08	3.41E-08	3.39E-08	3.32E-08	2.37E-08	9.39E-09	-	-
DISPERSION	Leak		0.828	3.87E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.520	6.76E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.410	1.22E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.410	6.36E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.40E-06	2.35E-06	2.24E-06	2.13E-06	1.98E-06	1.27E-06	6.60E-07	3.11E-07	6.25E-08
			1	Daily Commuter Loc 1			0.0022	5.32E-09	5.20E-09	4.96E-09	4.72E-09	4.39E-09	2.80E-09	1.46E-09	6.89E-10	1.38E-10
			2	Weekly Commuter Loc 1			0.0006	1.39E-09	1.36E-09	1.30E-09	1.24E-09	1.15E-09	7.34E-10	3.83E-10	1.81E-10	3.63E-11
			3	Worker Loc1			0.0075	1.80E-08	1.76E-08	1.68E-08	1.60E-08	1.49E-08	9.51E-09	4.96E-09	2.34E-09	4.69E-10
			4	Resident Loc 1			0.0877	2.11E-07	2.06E-07	1.97E-07	1.87E-07	1.74E-07	1.11E-07	5.79E-08	2.73E-08	5.48E-09
TAC-HP12-MA-Freeway-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.48E-05	0.1	4	0.25	1.30E-08	-	-	-	-	-	-	-	-
	Hole		0.183	2.16E-05	0.1	80	0.25	8.64E-08	8.62E-08	8.57E-08	8.21E-08	6.74E-08	-	-	-	-
	Rupture		0.194	5.26E-06	0.1	210	0.25	5.52E-08	5.52E-08	5.51E-08	5.48E-08	5.36E-08	3.86E-08	1.68E-08	-	-
	D Rupture		0.194	2.74E-06	0.1	290	0.25	3.97E-08	3.97E-08	3.96E-08	3.95E-08	3.91E-08	3.39E-08	2.87E-08	2.01E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	204	0.25	7.82E-08	7.82E-08	7.81E-08	7.76E-08	7.58E-08	5.30E-08	1.54E-08	-	-
	Rupture		0.014	3.79E-07	0.5	294	0.25	2.79E-08	2.79E-08	2.79E-08	2.78E-08	2.75E-08	2.40E-08	2.04E-08	1.47E-08	-
	D Rupture		0.014	1.97E-07	0.5	327	0.25	1.61E-08	1.61E-08	1.61E-08	1.61E-08	1.59E-08	1.43E-08	1.28E-08	1.04E-08	6.42E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	21	0.25	8.05E-09	7.82E-09	7.08E-09	-	-	-	-	-	-
	Rupture		0.014	3.79E-07	0.5	50	0.25	4.74E-09	4.72E-09	4.65E-09	4.11E-09	0.00E+00	-	-	-	-
	D Rupture		0.014	1.97E-07	0.5	57	0.25	2.81E-09	2.80E-09	2.77E-09	2.53E-09	1.35E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.006	1.63E-07	0.1	169	1.00	5.50E-09	5.49E-09	5.49E-09	5.44E-09	5.25E-09	2.53E-09	-	-	-
	D Rupture		0.006	8.46E-08	0.1	208	1.00	3.52E-09	3.52E-09	3.52E-09	3.49E-09	3.42E-09	2.44E-09	9.67E-10	-	-
DISPERSION	Leak		0.848	3.61E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	9.64E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.806	2.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.806	1.14E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.66E-07	3.48E-07	3.36E-07	3.23E-07	2.97E-07	1.69E-07	9.51E-08	4.52E-08	6.42E-09
			4	Resident Loc 4			0.0877	3.21E-08	3.06E-08	2.94E-08	2.83E-08	2.61E-08	1.48E-08	8.34E-09	3.96E-09	5.63E-10

Table C.3.3
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Freeway-Location 2																
GAS RELEASE	Leak	4.59E-04						-	-	-	-	-	-	-	-	-
	Hole	1.27E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.93E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.53E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.170	7.80E-05	0.1	4	0.25	1.56E-08	-	-	-	-	-	-	-	-
	Hole		0.447	5.68E-05	0.1	80	0.25	2.27E-07	2.27E-07	2.25E-07	2.16E-07	1.77E-07	-	-	-	-
	Rupture		0.546	1.60E-05	0.1	210	0.25	1.68E-07	1.68E-07	1.68E-07	1.67E-07	1.63E-07	1.18E-07	5.12E-08	-	-
	D Rupture		0.546	8.35E-06	0.1	290	0.25	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.19E-07	1.04E-07	8.77E-08	6.14E-08	-
FLASH FIRE - Transverse	Leak		0.107	4.91E-05	0.5	9	0.25	1.11E-07	9.19E-08	-	-	-	-	-	-	-
	Hole		0.125	1.59E-05	0.5	204	0.25	8.10E-07	8.09E-07	8.09E-07	8.04E-07	7.85E-07	5.49E-07	1.60E-07	-	-
	Rupture		0.134	3.93E-06	0.5	294	0.25	2.89E-07	2.89E-07	2.88E-07	2.88E-07	2.84E-07	2.48E-07	2.12E-07	1.52E-07	-
	D Rupture		0.134	2.05E-06	0.5	327	0.25	1.68E-07	1.68E-07	1.68E-07	1.67E-07	1.66E-07	1.49E-07	1.33E-07	1.08E-07	6.67E-08
FLASH FIRE - Parallel	Leak		0.107	4.91E-05	0.5	1	0.25	1.23E-08	-	-	-	-	-	-	-	-
	Hole		0.125	1.59E-05	0.5	21	0.25	8.33E-08	8.09E-08	7.33E-08	-	-	-	-	-	-
	Rupture		0.134	3.93E-06	0.5	50	0.25	4.91E-08	4.88E-08	4.81E-08	4.25E-08	0.00E+00	-	-	-	-
	D Rupture		0.134	2.05E-06	0.5	57	0.25	2.92E-08	2.91E-08	2.88E-08	2.63E-08	1.40E-08	-	-	-	-
EXPLOSION	Leak		0.012	5.51E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.050	6.35E-06	0.1	82	1.00	1.04E-07	1.04E-07	1.03E-07	9.92E-08	8.25E-08	-	-	-	-
	Rupture		0.060	1.76E-06	0.1	169	1.00	5.94E-08	5.94E-08	5.93E-08	5.88E-08	5.68E-08	2.74E-08	-	-	-
	D Rupture		0.060	9.18E-07	0.1	208	1.00	3.82E-08	3.82E-08	3.81E-08	3.79E-08	3.71E-08	2.65E-08	1.05E-08	-	-
DISPERSION	Leak		0.832	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.586	7.44E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.498	1.46E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.498	7.62E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.28E-06	2.23E-06	2.13E-06	2.03E-06	1.89E-06	1.22E-06	6.53E-07	3.21E-07	6.67E-08
			1	Daily Commuter Loc 2			0.0022	5.05E-09	4.94E-09	4.71E-09	4.48E-09	4.17E-09	2.70E-09	1.45E-09	7.11E-10	1.48E-10
			2	Weekly Commuter Loc 2			0.0006	1.32E-09	1.30E-09	1.24E-09	1.18E-09	1.09E-09	7.08E-10	3.79E-10	1.86E-10	3.87E-11
			3	Worker Loc2			0.0075	1.71E-08	1.68E-08	1.60E-08	1.52E-08	1.42E-08	9.17E-09	4.90E-09	2.41E-09	5.01E-10
			4	Resident Loc 2			0.0877	2.00E-07	1.96E-07	1.87E-07	1.78E-07	1.65E-07	1.07E-07	5.73E-08	2.82E-08	5.85E-09
TAC-HP12-MA-Freeway-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.48E-05	0.1	4	0.25	1.30E-08	-	-	-	-	-	-	-	-
	Hole		0.183	2.16E-05	0.1	80	0.25	8.64E-08	8.62E-08	8.57E-08	8.21E-08	6.74E-08	-	-	-	-
	Rupture		0.194	5.26E-06	0.1	210	0.25	5.52E-08	5.52E-08	5.51E-08	5.48E-08	5.36E-08	3.86E-08	1.68E-08	-	-
	D Rupture		0.194	2.74E-06	0.1	290	0.25	3.97E-08	3.97E-08	3.96E-08	3.95E-08	3.91E-08	3.39E-08	2.87E-08	2.01E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	204	0.25	7.82E-08	7.82E-08	7.81E-08	7.76E-08	7.58E-08	5.30E-08	1.54E-08	-	-
	Rupture		0.014	3.79E-07	0.5	294	0.25	2.79E-08	2.79E-08	2.79E-08	2.78E-08	2.75E-08	2.40E-08	2.04E-08	1.47E-08	-
	D Rupture		0.014	1.97E-07	0.5	327	0.25	1.61E-08	1.61E-08	1.61E-08	1.61E-08	1.59E-08	1.43E-08	1.28E-08	1.04E-08	6.42E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	21	0.25	8.05E-09	7.82E-09	7.08E-09	-	-	-	-	-	-
	Rupture		0.014	3.79E-07	0.5	50	0.25	4.74E-09	4.72E-09	4.65E-09	4.11E-09	0.00E+00	-	-	-	-
	D Rupture		0.014	1.97E-07	0.5	57	0.25	2.81E-09	2.80E-09	2.77E-09	2.53E-09	1.35E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.006	1.63E-07	0.1	169	1.00	5.50E-09	5.49E-09	5.49E-09	5.44E-09	5.25E-09	2.53E-09	-	-	-
	D Rupture		0.006	8.46E-08	0.1	208	1.00	3.52E-09	3.52E-09	3.52E-09	3.49E-09	3.42E-09	2.44E-09	9.67E-10	-	-
DISPERSION	Leak		0.848	3.61E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	9.64E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.806	2.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.806	1.14E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.66E-07	3.48E-07	3.36E-07	3.23E-07	2.97E-07	1.69E-07	9.51E-08	4.52E-08	6.42E-09
			4	Resident Loc 4			0.0877	3.21E-08	3.06E-08	2.94E-08	2.83E-08	2.61E-08	1.48E-08	8.34E-09	3.96E-09	5.63E-10

Table C.3.4
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Freeway-Location 3																
GAS RELEASE	Leak	4.39E-04						-	-	-	-	-	-	-	-	-
	Hole	1.22E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.80E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.46E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.168	7.38E-05	0.1	4	0.25	1.48E-08	-	-	-	-	-	-	-	-
	Hole		0.414	5.05E-05	0.1	80	0.25	2.02E-07	2.02E-07	2.00E-07	1.92E-07	1.58E-07	-	-	-	-
	Rupture		0.502	1.41E-05	0.1	210	0.25	1.48E-07	1.48E-07	1.47E-07	1.47E-07	1.43E-07	1.03E-07	4.50E-08	-	-
	D Rupture		0.502	7.33E-06	0.1	290	0.25	1.06E-07	1.06E-07	1.06E-07	1.06E-07	1.05E-07	9.10E-08	7.70E-08	5.39E-08	-
FLASH FIRE - Transverse	Leak		0.106	4.65E-05	0.5	9	0.25	1.05E-07	8.71E-08	-	-	-	-	-	-	-
	Hole		0.116	1.42E-05	0.5	204	0.25	7.22E-07	7.22E-07	7.21E-07	7.16E-07	7.00E-07	4.89E-07	1.42E-07	-	-
	Rupture		0.141	3.95E-06	0.5	294	0.25	2.90E-07	2.90E-07	2.90E-07	2.89E-07	2.86E-07	2.50E-07	2.13E-07	1.53E-07	-
	D Rupture		0.141	2.06E-06	0.5	327	0.25	1.68E-07	1.68E-07	1.68E-07	1.68E-07	1.66E-07	1.50E-07	1.33E-07	1.08E-07	6.70E-08
FLASH FIRE - Parallel	Leak		0.106	4.65E-05	0.5	1	0.25	1.16E-08	-	-	-	-	-	-	-	-
	Hole		0.116	1.42E-05	0.5	21	0.25	7.43E-08	7.22E-08	6.53E-08	-	-	-	-	-	-
	Rupture		0.141	3.95E-06	0.5	50	0.25	4.94E-08	4.91E-08	4.84E-08	4.27E-08	0.00E+00	-	-	-	-
	D Rupture		0.141	2.06E-06	0.5	57	0.25	2.93E-08	2.92E-08	2.89E-08	2.64E-08	1.41E-08	-	-	-	-
EXPLOSION	Leak		0.012	5.27E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.050	6.10E-06	0.1	82	1.00	1.00E-07	9.99E-08	9.93E-08	9.53E-08	7.93E-08	-	-	-	-
	Rupture		0.060	1.68E-06	0.1	169	1.00	5.68E-08	5.68E-08	5.67E-08	5.62E-08	5.42E-08	2.62E-08	-	-	-
	D Rupture		0.060	8.76E-07	0.1	208	1.00	3.64E-08	3.64E-08	3.64E-08	3.62E-08	3.54E-08	2.52E-08	1.00E-08	-	-
DISPERSION	Leak		0.832	3.65E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.586	7.15E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.498	1.39E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.498	7.27E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.11E-06	2.07E-06	1.97E-06	1.87E-06	1.74E-06	1.13E-06	6.20E-07	3.15E-07	6.70E-08
			1	Daily Commuter Loc 3			0.0022	4.68E-09	4.57E-09	4.36E-09	4.15E-09	3.85E-09	2.51E-09	1.37E-09	6.97E-10	1.48E-10
			2	Weekly Commuter Loc 3			0.0006	1.23E-09	1.20E-09	1.14E-09	1.09E-09	1.01E-09	6.58E-10	3.60E-10	1.83E-10	3.88E-11
			3	Worker Loc 3			0.0075	1.59E-08	1.55E-08	1.48E-08	1.41E-08	1.31E-08	8.51E-09	4.66E-09	2.37E-09	5.03E-10
			4	Resident Loc 3			0.0877	1.85E-07	1.81E-07	1.73E-07	1.64E-07	1.53E-07	9.94E-08	5.44E-08	2.76E-08	5.87E-09
TAC-HP12-MA-Freeway-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.48E-05	0.1	4	0.25	1.30E-08	-	-	-	-	-	-	-	-
	Hole		0.183	2.16E-05	0.1	80	0.25	8.64E-08	8.62E-08	8.57E-08	8.21E-08	6.74E-08	-	-	-	-
	Rupture		0.194	5.26E-06	0.1	210	0.25	5.52E-08	5.52E-08	5.51E-08	5.48E-08	5.36E-08	3.86E-08	1.68E-08	-	-
	D Rupture		0.194	2.74E-06	0.1	290	0.25	3.97E-08	3.97E-08	3.96E-08	3.95E-08	3.91E-08	3.39E-08	2.87E-08	2.01E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	204	0.25	7.82E-08	7.82E-08	7.81E-08	7.76E-08	7.58E-08	5.30E-08	1.54E-08	-	-
	Rupture		0.014	3.79E-07	0.5	294	0.25	2.79E-08	2.79E-08	2.79E-08	2.78E-08	2.75E-08	2.40E-08	2.04E-08	1.47E-08	-
	D Rupture		0.014	1.97E-07	0.5	327	0.25	1.61E-08	1.61E-08	1.61E-08	1.61E-08	1.59E-08	1.43E-08	1.28E-08	1.04E-08	6.42E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.013	1.53E-06	0.5	21	0.25	8.05E-09	7.82E-09	7.08E-09	-	-	-	-	-	-
	Rupture		0.014	3.79E-07	0.5	50	0.25	4.74E-09	4.72E-09	4.65E-09	4.11E-09	0.00E+00	-	-	-	-
	D Rupture		0.014	1.97E-07	0.5	57	0.25	2.81E-09	2.80E-09	2.77E-09	2.53E-09	1.35E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.006	1.63E-07	0.1	169	1.00	5.50E-09	5.49E-09	5.49E-09	5.44E-09	5.25E-09	2.53E-09	-	-	-
	D Rupture		0.006	8.46E-08	0.1	208	1.00	3.52E-09	3.52E-09	3.52E-09	3.49E-09	3.42E-09	2.44E-09	9.67E-10	-	-
DISPERSION	Leak		0.848	3.61E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	9.64E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.806	2.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.806	1.14E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.66E-07	3.48E-07	3.36E-07	3.23E-07	2.97E-07	1.69E-07	9.51E-08	4.52E-08	6.42E-09
			4	Resident Loc 4			0.0877	3.21E-08	3.06E-08	2.94E-08	2.83E-08	2.61E-08	1.48E-08	8.34E-09	3.96E-09	5.63E-10

Table C.3.5
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Arterial-Location 1																
GAS RELEASE	Leak	4.67E-04						-	-	-	-	-	-	-	-	-
	Hole	1.30E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.98E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.55E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	7.57E-05	0.1	4	0.25	1.51E-08	-	-	-	-	-	-	-	-
	Hole		0.336	4.37E-05	0.1	80	0.25	1.75E-07	1.74E-07	1.73E-07	1.66E-07	1.36E-07	-	-	-	-
	Rupture		0.397	1.18E-05	0.1	210	0.25	1.24E-07	1.24E-07	1.24E-07	1.23E-07	1.21E-07	8.69E-08	3.79E-08	-	-
	D Rupture		0.397	6.15E-06	0.1	290	0.25	8.92E-08	8.92E-08	8.92E-08	8.89E-08	8.79E-08	7.64E-08	6.46E-08	4.52E-08	-
FLASH FIRE - Transverse	Leak		0.102	4.76E-05	0.5	9	0.25	1.07E-07	8.91E-08	-	-	-	-	-	-	-
	Hole		0.094	1.22E-05	0.5	204	0.25	6.23E-07	6.23E-07	6.22E-07	6.19E-07	6.04E-07	4.22E-07	1.23E-07	-	-
	Rupture		0.083	2.47E-06	0.5	294	0.25	1.82E-07	1.82E-07	1.82E-07	1.81E-07	1.79E-07	1.56E-07	1.33E-07	9.57E-08	-
	D Rupture		0.083	1.29E-06	0.5	327	0.25	1.05E-07	1.05E-07	1.05E-07	1.05E-07	1.04E-07	9.35E-08	8.32E-08	6.78E-08	4.18E-08
FLASH FIRE - Parallel	Leak		0.102	4.76E-05	0.5	1	0.25	1.19E-08	-	-	-	-	-	-	-	-
	Hole		0.094	1.22E-05	0.5	21	0.25	6.42E-08	6.23E-08	5.64E-08	-	-	-	-	-	-
	Rupture		0.083	2.47E-06	0.5	50	0.25	3.09E-08	3.08E-08	3.03E-08	2.68E-08	0.00E+00	-	-	-	-
	D Rupture		0.083	1.29E-06	0.5	57	0.25	1.83E-08	1.83E-08	1.80E-08	1.65E-08	8.80E-09	-	-	-	-
EXPLOSION	Leak		0.011	5.14E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.040	5.20E-06	0.1	82	1.00	8.53E-08	8.51E-08	8.46E-08	8.12E-08	6.76E-08	-	-	-	-
	Rupture		0.036	1.07E-06	0.1	169	1.00	3.63E-08	3.62E-08	3.62E-08	3.59E-08	3.46E-08	1.67E-08	-	-	-
	D Rupture		0.036	5.58E-07	0.1	208	1.00	2.32E-08	2.32E-08	2.32E-08	2.30E-08	2.25E-08	1.61E-08	6.38E-09	-	-
DISPERSION	Leak		0.838	3.91E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	8.63E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	1.80E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	9.35E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	1.69E-06	1.64E-06	1.54E-06	1.47E-06	1.37E-06	8.68E-07	4.48E-07	2.09E-07	4.18E-08
			1	Daily Commuter Loc 1			0.0022	3.74E-09	3.64E-09	3.42E-09	3.24E-09	3.02E-09	1.92E-09	9.92E-10	4.62E-10	9.26E-11
			2	Weekly Commuter Loc 1			0.0006	9.81E-10	9.53E-10	8.96E-10	8.50E-10	7.92E-10	5.04E-10	2.60E-10	1.21E-10	2.43E-11
			3	Worker Loc 1			0.0075	1.27E-08	1.23E-08	1.16E-08	1.10E-08	1.03E-08	6.52E-09	3.37E-09	1.57E-09	3.14E-10
			4	Resident Loc 1			0.0877	1.48E-07	1.44E-07	1.35E-07	1.29E-07	1.20E-07	7.61E-08	3.93E-08	1.83E-08	3.67E-09
TAC-HP12-MA-Arterial-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.43E-05	0.1	4	0.25	1.29E-08	-	-	-	-	-	-	-	-
	Hole		0.169	1.99E-05	0.1	80	0.25	7.98E-08	7.96E-08	7.91E-08	7.58E-08	6.23E-08	-	-	-	-
	Rupture		0.175	4.74E-06	0.1	210	0.25	4.98E-08	4.98E-08	4.97E-08	4.94E-08	4.84E-08	3.49E-08	1.52E-08	-	-
	D Rupture		0.175	2.47E-06	0.1	290	0.25	3.58E-08	3.58E-08	3.58E-08	3.56E-08	3.52E-08	3.06E-08	2.59E-08	1.81E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.012	1.42E-06	0.5	204	0.25	7.22E-08	7.22E-08	7.21E-08	7.17E-08	7.00E-08	4.89E-08	1.42E-08	-	-
	Rupture		0.012	3.25E-07	0.5	294	0.25	2.39E-08	2.39E-08	2.39E-08	2.38E-08	2.36E-08	2.06E-08	1.75E-08	1.26E-08	-
	D Rupture		0.012	1.69E-07	0.5	327	0.25	1.38E-08	1.38E-08	1.38E-08	1.38E-08	1.37E-08	1.23E-08	1.09E-08	8.92E-09	5.50E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.012	1.42E-06	0.5	21	0.25	7.43E-09	7.22E-09	6.54E-09	-	-	-	-	-	-
	Rupture		0.012	3.25E-07	0.5	50	0.25	4.07E-09	4.04E-09	3.98E-09	3.52E-09	0.00E+00	-	-	-	-
	D Rupture		0.012	1.69E-07	0.5	57	0.25	2.41E-09	2.40E-09	2.37E-09	2.17E-09	1.16E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.005	1.36E-07	0.1	169	1.00	4.58E-09	4.58E-09	4.57E-09	4.53E-09	4.37E-09	2.11E-09	-	-	-
	D Rupture		0.005	7.05E-08	0.1	208	1.00	2.93E-09	2.93E-09	2.93E-09	2.91E-09	2.85E-09	2.03E-09	8.06E-10	-	-
DISPERSION	Leak		0.849	3.62E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	9.81E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	2.24E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.16E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.34E-07	3.17E-07	3.04E-07	2.92E-07	2.69E-07	1.51E-07	8.46E-08	3.96E-08	5.50E-09
			4	Resident Loc 4			0.0877	2.93E-08	2.78E-08	2.67E-08	2.56E-08	2.36E-08	1.33E-08	7.42E-09	3.47E-09	4.83E-10

Table C.3.6
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Collector-Location 1																
GAS RELEASE	Leak	4.67E-04						-	-	-	-	-	-	-	-	-
	Hole	1.30E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.98E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.55E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.158	7.38E-05	0.1	4	0.25	1.48E-08	-	-	-	-	-	-	-	-
	Hole		0.227	2.95E-05	0.1	80	0.25	1.18E-07	1.18E-07	1.17E-07	1.12E-07	9.21E-08	-	-	-	-
	Rupture		0.320	9.54E-06	0.1	210	0.25	1.00E-07	1.00E-07	1.00E-07	9.94E-08	9.72E-08	7.01E-08	3.05E-08	-	-
	D Rupture		0.320	4.96E-06	0.1	290	0.25	7.19E-08	7.19E-08	7.19E-08	7.17E-08	7.08E-08	6.16E-08	5.21E-08	3.64E-08	-
FLASH FIRE - Transverse	Leak		0.100	4.67E-05	0.5	9	0.25	1.05E-07	8.74E-08	-	-	-	-	-	-	-
	Hole		0.078	1.01E-05	0.5	204	0.25	5.17E-07	5.17E-07	5.17E-07	5.13E-07	5.01E-07	3.50E-07	1.02E-07	-	-
	Rupture		0.067	2.00E-06	0.5	294	0.25	1.47E-07	1.47E-07	1.47E-07	1.46E-07	1.45E-07	1.26E-07	1.08E-07	7.72E-08	-
	D Rupture		0.067	1.04E-06	0.5	327	0.25	8.49E-08	8.49E-08	8.49E-08	8.46E-08	8.39E-08	7.54E-08	6.72E-08	5.47E-08	3.38E-08
FLASH FIRE - Parallel	Leak		0.100	4.67E-05	0.5	1	0.25	1.17E-08	-	-	-	-	-	-	-	-
	Hole		0.078	1.01E-05	0.5	21	0.25	5.32E-08	5.17E-08	4.68E-08	-	-	-	-	-	-
	Rupture		0.067	2.00E-06	0.5	50	0.25	2.50E-08	2.48E-08	2.45E-08	2.16E-08	0.00E+00	-	-	-	-
	D Rupture		0.067	1.04E-06	0.5	57	0.25	1.48E-08	1.47E-08	1.46E-08	1.33E-08	7.11E-09	-	-	-	-
EXPLOSION	Leak		0.011	5.14E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.033	4.29E-06	0.1	82	1.00	7.04E-08	7.02E-08	6.98E-08	6.70E-08	5.58E-08	-	-	-	-
	Rupture		0.029	8.64E-07	0.1	169	1.00	2.92E-08	2.92E-08	2.92E-08	2.89E-08	2.79E-08	1.35E-08	-	-	-
	D Rupture		0.029	4.50E-07	0.1	208	1.00	1.87E-08	1.87E-08	1.87E-08	1.86E-08	1.82E-08	1.30E-08	5.14E-09	-	-
DISPERSION	Leak		0.842	3.93E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.723	9.40E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.680	2.03E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.680	1.05E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	1.38E-06	1.34E-06	1.24E-06	1.18E-06	1.10E-06	7.10E-07	3.64E-07	1.68E-07	3.38E-08
			1	Daily Commuter Loc 1			0.0022	3.06E-09	2.95E-09	2.75E-09	2.60E-09	2.43E-09	1.57E-09	8.06E-10	3.73E-10	7.48E-11
			2	Weekly Commuter Loc 1			0.0006	8.01E-10	7.74E-10	7.19E-10	6.82E-10	6.37E-10	4.12E-10	2.11E-10	9.77E-11	1.96E-11
			3	Worker Loc 1			0.0075	1.04E-08	1.00E-08	9.32E-09	8.84E-09	8.25E-09	5.33E-09	2.74E-09	1.26E-09	2.54E-10
			4	Resident Loc 1			0.0877	1.21E-07	1.17E-07	1.09E-07	1.03E-07	9.64E-08	6.23E-08	3.20E-08	1.48E-08	2.96E-09
TAC-HP12-MA-Collector-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.43E-05	0.1	4	0.25	1.29E-08	-	-	-	-	-	-	-	-
	Hole		0.163	1.92E-05	0.1	80	0.25	7.69E-08	7.68E-08	7.63E-08	7.31E-08	6.01E-08	-	-	-	-
	Rupture		0.167	4.53E-06	0.1	210	0.25	4.75E-08	4.75E-08	4.75E-08	4.72E-08	4.62E-08	3.33E-08	1.45E-08	-	-
	D Rupture		0.167	2.35E-06	0.1	290	0.25	3.41E-08	3.41E-08	3.41E-08	3.40E-08	3.36E-08	2.92E-08	2.47E-08	1.73E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.011	1.30E-06	0.5	204	0.25	6.62E-08	6.62E-08	6.61E-08	6.57E-08	6.42E-08	4.49E-08	1.30E-08	-	-
	Rupture		0.012	3.25E-07	0.5	294	0.25	2.39E-08	2.39E-08	2.39E-08	2.38E-08	2.36E-08	2.06E-08	1.75E-08	1.26E-08	-
	D Rupture		0.012	1.69E-07	0.5	327	0.25	1.38E-08	1.38E-08	1.38E-08	1.38E-08	1.37E-08	1.23E-08	1.09E-08	8.92E-09	5.50E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.011	1.30E-06	0.5	21	0.25	6.81E-09	6.62E-09	5.99E-09	-	-	-	-	-	-
	Rupture		0.012	3.25E-07	0.5	50	0.25	4.07E-09	4.04E-09	3.98E-09	3.52E-09	0.00E+00	-	-	-	-
	D Rupture		0.012	1.69E-07	0.5	57	0.25	2.41E-09	2.40E-09	2.37E-09	2.17E-09	1.16E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.005	1.36E-07	0.1	169	1.00	4.58E-09	4.58E-09	4.57E-09	4.53E-09	4.37E-09	2.11E-09	-	-	-
	D Rupture		0.005	7.05E-08	0.1	208	1.00	2.93E-09	2.93E-09	2.93E-09	2.91E-09	2.85E-09	2.03E-09	8.06E-10	-	-
DISPERSION	Leak		0.849	3.62E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.837	9.88E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.833	2.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.833	1.17E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.21E-07	3.04E-07	2.91E-07	2.80E-07	2.57E-07	1.44E-07	8.15E-08	3.88E-08	5.50E-09
			4	Resident Loc 4			0.0877	2.81E-08	2.66E-08	2.55E-08	2.45E-08	2.26E-08	1.27E-08	7.15E-09	3.40E-09	4.83E-10

Table C.3.7
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-HP12-MA-Local-Location 1																
GAS RELEASE	Leak	4.67E-04						-	-	-	-	-	-	-	-	-
	Hole	1.30E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.98E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.55E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	7.05E-05	0.1	4	0.25	1.41E-08	-	-	-	-	-	-	-	-
	Hole		0.168	2.18E-05	0.1	80	0.25	8.74E-08	8.72E-08	8.67E-08	8.30E-08	6.82E-08	-	-	-	-
	Rupture		0.174	5.19E-06	0.1	210	0.25	5.44E-08	5.44E-08	5.44E-08	5.41E-08	5.29E-08	3.81E-08	1.66E-08	-	-
	D Rupture		0.174	2.70E-06	0.1	290	0.25	3.91E-08	3.91E-08	3.91E-08	3.90E-08	3.85E-08	3.35E-08	2.83E-08	1.98E-08	-
FLASH FIRE - Transverse	Leak		0.095	4.44E-05	0.5	9	0.25	9.98E-08	8.30E-08	-	-	-	-	-	-	-
	Hole		0.047	6.11E-06	0.5	204	0.25	3.12E-07	3.12E-07	3.11E-07	3.09E-07	3.02E-07	2.11E-07	6.14E-08	-	-
	Rupture		0.036	1.07E-06	0.5	294	0.25	7.89E-08	7.88E-08	7.88E-08	7.86E-08	7.77E-08	6.78E-08	5.78E-08	4.15E-08	-
	D Rupture		0.036	5.58E-07	0.5	327	0.25	4.56E-08	4.56E-08	4.56E-08	4.55E-08	4.51E-08	4.05E-08	3.61E-08	2.94E-08	1.82E-08
FLASH FIRE - Parallel	Leak		0.095	4.44E-05	0.5	1	0.25	1.11E-08	-	-	-	-	-	-	-	-
	Hole		0.047	6.11E-06	0.5	21	0.25	3.21E-08	3.12E-08	2.82E-08	-	-	-	-	-	-
	Rupture		0.036	1.07E-06	0.5	50	0.25	1.34E-08	1.33E-08	1.31E-08	1.16E-08	0.00E+00	-	-	-	-
	D Rupture		0.036	5.58E-07	0.5	57	0.25	7.95E-09	7.92E-09	7.83E-09	7.15E-09	3.82E-09	-	-	-	-
EXPLOSION	Leak		0.011	5.14E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.020	2.60E-06	0.1	82	1.00	4.26E-08	4.26E-08	4.23E-08	4.06E-08	3.38E-08	-	-	-	-
	Rupture		0.016	4.77E-07	0.1	169	1.00	1.61E-08	1.61E-08	1.61E-08	1.59E-08	1.54E-08	7.42E-09	-	-	-
	D Rupture		0.016	2.48E-07	0.1	208	1.00	1.03E-08	1.03E-08	1.03E-08	1.02E-08	1.00E-08	7.15E-09	2.83E-09	-	-
DISPERSION	Leak		0.849	3.96E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.832	1.08E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.826	2.46E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.826	1.28E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	8.65E-07	8.21E-07	7.34E-07	6.95E-07	6.48E-07	4.06E-07	2.03E-07	9.07E-08	1.82E-08
			1	Daily Commuter Loc 1			0.0022	1.91E-09	1.82E-09	1.62E-09	1.54E-09	1.43E-09	8.98E-10	4.49E-10	2.01E-10	4.02E-11
			2	Weekly Commuter Loc 1			0.0006	5.01E-10	4.76E-10	4.26E-10	4.03E-10	3.76E-10	2.35E-10	1.18E-10	5.26E-11	1.05E-11
			3	Worker Loc 1			0.0075	6.49E-09	6.17E-09	5.51E-09	5.22E-09	4.86E-09	3.05E-09	1.52E-09	6.81E-10	1.36E-10
			4	Resident Loc 1			0.0877	7.58E-08	7.20E-08	6.43E-08	6.09E-08	5.68E-08	3.56E-08	1.78E-08	7.96E-09	1.59E-09
TAC-HP12-MA-Local-Location 4																
GAS RELEASE	Leak	4.26E-04						-	-	-	-	-	-	-	-	-
	Hole	1.18E-04						-	-	-	-	-	-	-	-	-
	Rupture	2.71E-05						-	-	-	-	-	-	-	-	-
	D Rupture	1.41E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.150	6.39E-05	0.1	4	0.25	1.28E-08	-	-	-	-	-	-	-	-
	Hole		0.152	1.79E-05	0.1	80	0.25	7.17E-08	7.16E-08	7.12E-08	6.82E-08	5.60E-08	-	-	-	-
	Rupture		0.152	4.12E-06	0.1	210	0.25	4.33E-08	4.32E-08	4.32E-08	4.29E-08	4.20E-08	3.03E-08	1.32E-08	-	-
	D Rupture		0.152	2.14E-06	0.1	290	0.25	3.11E-08	3.11E-08	3.11E-08	3.10E-08	3.06E-08	2.66E-08	2.25E-08	1.57E-08	-
FLASH FIRE - Transverse	Leak		0.014	5.96E-06	0.5	9	0.25	1.34E-08	1.12E-08	-	-	-	-	-	-	-
	Hole		0.011	1.30E-06	0.5	204	0.25	6.62E-08	6.62E-08	6.61E-08	6.57E-08	6.42E-08	4.49E-08	1.30E-08	-	-
	Rupture		0.011	2.98E-07	0.5	294	0.25	2.19E-08	2.19E-08	2.19E-08	2.18E-08	2.16E-08	1.88E-08	1.61E-08	1.15E-08	-
	D Rupture		0.011	1.55E-07	0.5	327	0.25	1.27E-08	1.27E-08	1.27E-08	1.26E-08	1.25E-08	1.13E-08	1.00E-08	8.17E-09	5.05E-09
FLASH FIRE - Parallel	Leak		0.014	5.96E-06	0.5	1	0.25	1.49E-09	-	-	-	-	-	-	-	-
	Hole		0.011	1.30E-06	0.5	21	0.25	6.81E-09	6.62E-09	5.99E-09	-	-	-	-	-	-
	Rupture		0.011	2.98E-07	0.5	50	0.25	3.73E-09	3.71E-09	3.65E-09	3.23E-09	0.00E+00	-	-	-	-
	D Rupture		0.011	1.55E-07	0.5	57	0.25	2.21E-09	2.20E-09	2.18E-09	1.99E-09	1.06E-09	-	-	-	-
EXPLOSION	Leak		0.002	8.52E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	5.90E-07	0.1	82	1.00	9.68E-09	9.66E-09	9.60E-09	9.22E-09	7.67E-09	-	-	-	-
	Rupture		0.005	1.36E-07	0.1	169	1.00	4.58E-09	4.58E-09	4.57E-09	4.53E-09	4.37E-09	2.11E-09	-	-	-
	D Rupture		0.005	7.05E-08	0.1	208	1.00	2.93E-09	2.93E-09	2.93E-09	2.91E-09	2.85E-09	2.03E-09	8.06E-10	-	-
DISPERSION	Leak		0.850	3.62E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.848	1.00E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.848	2.30E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.848	1.20E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.04E-07	2.88E-07	2.75E-07	2.64E-07	2.43E-07	1.36E-07	7.56E-08	3.55E-08	5.05E-09
			4	Resident Loc 4			0.0877	2.67E-08	2.52E-08	2.41E-08	2.32E-08	2.13E-08	1.19E-08	6.63E-09	3.11E-09	4.42E-10

Table C.3.8
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	270
TAC-HP08-MA-Freeway-Location 1																
GAS RELEASE	Leak	4.92E-04						-	-	-	-	-	-	-	-	-
	Hole	1.84E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.172	8.46E-05	0.1	4	0.25	1.69E-08	-	-	-	-	-	-	-	-
	Hole		0.480	8.83E-05	0.1	80	0.25	3.53E-07	3.53E-07	3.51E-07	3.36E-07	2.76E-07	-	-	-	-
	Rupture		0.590	2.49E-05	0.1	147	0.25	1.83E-07	1.83E-07	1.83E-07	1.80E-07	1.72E-07	-	-	-	-
	D Rupture		0.590	1.30E-05	0.1	198	0.25	1.29E-07	1.28E-07	1.28E-07	1.27E-07	1.24E-07	8.39E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.108	5.31E-05	0.5	9	0.25	1.20E-07	9.94E-08	-	-	-	-	-	-	-
	Hole		0.134	2.47E-05	0.5	204	0.25	1.26E-06	1.26E-06	1.26E-06	1.25E-06	1.22E-06	8.52E-07	2.48E-07	-	-
	Rupture		0.124	5.23E-06	0.5	253	0.25	3.31E-07	3.31E-07	3.31E-07	3.29E-07	3.24E-07	2.67E-07	2.03E-07	5.08E-08	-
	D Rupture		0.124	2.73E-06	0.5	287	0.25	1.96E-07	1.96E-07	1.96E-07	1.95E-07	1.93E-07	1.67E-07	1.40E-07	9.61E-08	6.64E-08
FLASH FIRE - Parallel	Leak		0.108	5.31E-05	0.5	1	0.25	1.33E-08	-	-	-	-	-	-	-	-
	Hole		0.134	2.47E-05	0.5	21	0.25	1.29E-07	1.26E-07	1.14E-07	-	-	-	-	-	-
	Rupture		0.124	5.23E-06	0.5	42	0.25	5.49E-08	5.46E-08	5.34E-08	4.42E-08	-	-	-	-	-
	D Rupture		0.124	2.73E-06	0.5	48	0.25	3.27E-08	3.26E-08	3.20E-08	2.79E-08	-	-	-	-	-
EXPLOSION	Leak		0.012	5.90E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.058	1.07E-05	0.1	82	1.00	1.75E-07	1.75E-07	1.74E-07	1.67E-07	1.39E-07	-	-	-	-
	Rupture		0.053	2.24E-06	0.1	129	1.00	5.77E-08	5.77E-08	5.75E-08	5.66E-08	5.32E-08	-	-	-	-
	D Rupture		0.053	1.17E-06	0.1	157	1.00	3.66E-08	3.66E-08	3.65E-08	3.61E-08	3.47E-08	1.08E-08	-	-	-
DISPERSION	Leak		0.828	4.07E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.520	9.57E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.410	1.73E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.410	9.02E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.09E-06	3.03E-06	2.91E-06	2.75E-06	2.54E-06	1.38E-06	5.91E-07	1.47E-07	6.64E-08
			1	Daily Commuter Loc 1			0.0022	6.83E-09	6.70E-09	6.44E-09	6.08E-09	5.61E-09	3.05E-09	1.31E-09	3.25E-10	1.47E-10
			2	Weekly Commuter Loc 1			0.0006	1.79E-09	1.76E-09	1.69E-09	1.59E-09	1.47E-09	8.01E-10	3.43E-10	8.52E-11	3.85E-11
			3	Worker Loc1			0.0075	2.32E-08	2.27E-08	2.19E-08	2.06E-08	1.90E-08	1.04E-08	4.44E-09	1.10E-09	4.98E-10
			4	Resident Loc 1			0.0877	2.71E-07	2.66E-07	2.55E-07	2.41E-07	2.22E-07	1.21E-07	5.18E-08	1.29E-08	5.82E-09
TAC-HP08-MA-Freeway-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.86E-05	0.1	4	0.25	1.37E-08	-	-	-	-	-	-	-	-
	Hole		0.183	3.15E-05	0.1	80	0.25	1.26E-07	1.26E-07	1.25E-07	1.20E-07	9.83E-08	-	-	-	-
	Rupture		0.194	7.66E-06	0.1	210	0.25	8.05E-08	8.04E-08	8.04E-08	7.99E-08	7.81E-08	5.63E-08	2.45E-08	-	-
	D Rupture		0.194	4.00E-06	0.1	290	0.25	5.79E-08	5.79E-08	5.79E-08	5.77E-08	5.71E-08	4.96E-08	4.20E-08	2.94E-08	2.11E-08
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	9	0.25	1.42E-08	1.18E-08	-	-	-	-	-	-	-
	Hole		0.013	2.24E-06	0.5	204	0.25	1.14E-07	1.14E-07	1.14E-07	1.13E-07	1.11E-07	7.73E-08	2.25E-08	-	-
	Rupture		0.014	5.53E-07	0.5	294	0.25	4.06E-08	4.06E-08	4.06E-08	4.05E-08	4.01E-08	3.50E-08	2.98E-08	2.14E-08	1.61E-08
	D Rupture		0.014	2.88E-07	0.5	327	0.25	2.36E-08	2.36E-08	2.36E-08	2.35E-08	2.33E-08	2.09E-08	1.87E-08	1.52E-08	1.33E-08
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	1	0.25	1.58E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.24E-06	0.5	21	0.25	1.17E-08	1.14E-08	1.03E-08	-	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	50	0.25	6.91E-09	6.88E-09	6.77E-09	5.99E-09	0.00E+00	-	-	-	-
	D Rupture		0.014	2.88E-07	0.5	57	0.25	4.11E-09	4.09E-09	4.05E-09	3.69E-09	1.97E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	8.60E-07	0.1	82	1.00	1.41E-08	1.41E-08	1.40E-08	1.34E-08	1.12E-08	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	169	1.00	8.01E-09	8.01E-09	8.00E-09	7.92E-09	7.65E-09	3.69E-09	-	-	-
	D Rupture		0.006	1.24E-07	0.1	208	1.00	5.14E-09	5.14E-09	5.14E-09	5.10E-09	4.99E-09	3.56E-09	1.41E-09	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.41E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.806	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.806	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.22E-07	5.04E-07	4.90E-07	4.71E-07	4.33E-07	2.46E-07	1.39E-07	6.60E-08	5.05E-08
			4	Resident Loc 4			0.0877	4.58E-08	4.42E-08	4.29E-08	4.13E-08	3.80E-08	2.16E-08	1.22E-08	5.78E-09	4.43E-09

Table C.3.9
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	270
TAC-HP08-MA-Arterial-Location 1																
GAS RELEASE	Leak	4.92E-04						-	-	-	-	-	-	-	-	-
	Hole	1.84E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	7.97E-05	0.1	4	0.25	1.59E-08	-	-	-	-	-	-	-	-
	Hole		0.336	6.18E-05	0.1	80	0.25	2.47E-07	2.47E-07	2.45E-07	2.35E-07	1.93E-07	-	-	-	-
	Rupture		0.397	1.68E-05	0.1	147	0.25	1.23E-07	1.23E-07	1.23E-07	1.21E-07	1.16E-07	-	-	-	-
	D Rupture		0.397	8.73E-06	0.1	198	0.25	8.65E-08	8.64E-08	8.64E-08	8.58E-08	8.37E-08	5.64E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.102	5.02E-05	0.5	9	0.25	1.13E-07	9.39E-08	-	-	-	-	-	-	-
	Hole		0.094	1.73E-05	0.5	204	0.25	8.82E-07	8.82E-07	8.81E-07	8.75E-07	8.55E-07	5.98E-07	1.74E-07	-	-
	Rupture		0.083	3.50E-06	0.5	253	0.25	2.22E-07	2.21E-07	2.21E-07	2.20E-07	2.17E-07	1.78E-07	1.36E-07	3.40E-08	-
	D Rupture		0.083	1.83E-06	0.5	287	0.25	1.31E-07	1.31E-07	1.31E-07	1.31E-07	1.29E-07	1.12E-07	9.40E-08	6.43E-08	4.44E-08
FLASH FIRE - Parallel	Leak		0.102	5.02E-05	0.5	1	0.25	1.25E-08	-	-	-	-	-	-	-	-
	Hole		0.094	1.73E-05	0.5	21	0.25	9.08E-08	8.82E-08	7.98E-08	-	-	-	-	-	-
	Rupture		0.083	3.50E-06	0.5	42	0.25	3.68E-08	3.65E-08	3.57E-08	2.96E-08	-	-	-	-	-
	D Rupture		0.083	1.83E-06	0.5	48	0.25	2.19E-08	2.18E-08	2.14E-08	1.87E-08	-	-	-	-	-
EXPLOSION	Leak		0.011	5.41E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.040	7.36E-06	0.1	82	1.00	1.21E-07	1.20E-07	1.20E-07	1.15E-07	9.57E-08	-	-	-	-
	Rupture		0.036	1.52E-06	0.1	129	1.00	3.92E-08	3.92E-08	3.91E-08	3.85E-08	3.61E-08	-	-	-	-
	D Rupture		0.036	7.92E-07	0.1	157	1.00	2.49E-08	2.49E-08	2.48E-08	2.46E-08	2.36E-08	7.34E-09	-	-	-
DISPERSION	Leak		0.838	4.12E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	1.22E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	2.54E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	1.33E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.17E-06	2.12E-06	2.01E-06	1.89E-06	1.75E-06	9.52E-07	4.03E-07	9.84E-08	4.44E-08
			1	Daily Commuter Loc 1			0.0022	4.80E-09	4.68E-09	4.45E-09	4.19E-09	3.87E-09	2.11E-09	8.93E-10	2.18E-10	9.83E-11
			2	Weekly Commuter Loc 1			0.0006	1.26E-09	1.23E-09	1.16E-09	1.10E-09	1.01E-09	5.52E-10	2.34E-10	5.70E-11	2.58E-11
			3	Worker Loc 1			0.0075	1.63E-08	1.59E-08	1.51E-08	1.42E-08	1.31E-08	7.15E-09	3.03E-09	7.39E-10	3.34E-10
			4	Resident Loc 1			0.0877	1.90E-07	1.86E-07	1.76E-07	1.66E-07	1.53E-07	8.35E-08	3.54E-08	8.63E-09	3.90E-09
TAC-HP08-MA-Arterial-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	4	0.25	1.36E-08	-	-	-	-	-	-	-	-
	Hole		0.169	2.91E-05	0.1	80	0.25	1.16E-07	1.16E-07	1.15E-07	1.10E-07	9.08E-08	-	-	-	-
	Rupture		0.175	6.91E-06	0.1	210	0.25	7.26E-08	7.26E-08	7.25E-08	7.21E-08	7.05E-08	5.08E-08	2.21E-08	-	-
	D Rupture		0.175	3.61E-06	0.1	290	0.25	5.23E-08	5.23E-08	5.22E-08	5.21E-08	5.15E-08	4.47E-08	3.79E-08	2.65E-08	1.91E-08
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	9	0.25	1.42E-08	1.18E-08	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	204	0.25	1.05E-07	1.05E-07	1.05E-07	1.04E-07	1.02E-07	7.13E-08	2.07E-08	-	-
	Rupture		0.012	4.74E-07	0.5	294	0.25	3.48E-08	3.48E-08	3.48E-08	3.47E-08	3.43E-08	3.00E-08	2.55E-08	1.83E-08	1.38E-08
	D Rupture		0.012	2.47E-07	0.5	327	0.25	2.02E-08	2.02E-08	2.02E-08	2.01E-08	2.00E-08	1.80E-08	1.60E-08	1.30E-08	1.14E-08
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	1	0.25	1.58E-09	-	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	21	0.25	1.08E-08	1.05E-08	9.53E-09	-	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	50	0.25	5.93E-09	5.90E-09	5.81E-09	5.13E-09	0.00E+00	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	57	0.25	3.52E-09	3.51E-09	3.47E-09	3.17E-09	1.69E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	8.60E-07	0.1	82	1.00	1.41E-08	1.41E-08	1.40E-08	1.34E-08	1.12E-08	-	-	-	-
	Rupture		0.005	1.98E-07	0.1	169	1.00	6.68E-09	6.67E-09	6.66E-09	6.60E-09	6.38E-09	3.08E-09	-	-	-
	D Rupture		0.005	1.03E-07	0.1	208	1.00	4.28E-09	4.28E-09	4.28E-09	4.25E-09	4.16E-09	2.97E-09	1.18E-09	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	1.43E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	3.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.70E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	4.76E-07	4.58E-07	4.44E-07	4.27E-07	3.93E-07	2.21E-07	1.23E-07	5.79E-08	4.43E-08
			4	Resident Loc 4			0.0877	4.18E-08	4.02E-08	3.89E-08	3.74E-08	3.44E-08	1.94E-08	1.08E-08	5.07E-09	3.88E-09

Table C.3.10
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	270
TAC-HP08-MA-Collector-Location 1																
GAS RELEASE	Leak	4.92E-04						-	-	-	-	-	-	-	-	-
	Hole	1.84E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.158	7.77E-05	0.1	4	0.25	1.55E-08	-	-	-	-	-	-	-	-
	Hole		0.227	4.18E-05	0.1	80	0.25	1.67E-07	1.67E-07	1.66E-07	1.59E-07	1.30E-07	-	-	-	-
	Rupture		0.320	1.35E-05	0.1	147	0.25	9.93E-08	9.92E-08	9.90E-08	9.78E-08	9.33E-08	-	-	-	-
	D Rupture		0.320	7.04E-06	0.1	198	0.25	6.97E-08	6.97E-08	6.96E-08	6.91E-08	6.74E-08	4.55E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.100	4.92E-05	0.5	9	0.25	1.11E-07	9.20E-08	-	-	-	-	-	-	-
	Hole		0.078	1.44E-05	0.5	204	0.25	7.32E-07	7.32E-07	7.31E-07	7.26E-07	7.10E-07	4.96E-07	1.44E-07	-	-
	Rupture		0.067	2.83E-06	0.5	253	0.25	1.79E-07	1.79E-07	1.79E-07	1.78E-07	1.75E-07	1.44E-07	1.10E-07	2.75E-08	-
	D Rupture		0.067	1.47E-06	0.5	287	0.25	1.06E-07	1.06E-07	1.06E-07	1.05E-07	1.04E-07	9.02E-08	7.59E-08	5.19E-08	3.59E-08
FLASH FIRE - Parallel	Leak		0.100	4.92E-05	0.5	1	0.25	1.23E-08	-	-	-	-	-	-	-	-
	Hole		0.078	1.44E-05	0.5	21	0.25	7.53E-08	7.32E-08	6.63E-08	-	-	-	-	-	-
	Rupture		0.067	2.83E-06	0.5	42	0.25	2.97E-08	2.95E-08	2.88E-08	2.39E-08	-	-	-	-	-
	D Rupture		0.067	1.47E-06	0.5	48	0.25	1.77E-08	1.76E-08	1.73E-08	1.51E-08	-	-	-	-	-
EXPLOSION	Leak		0.011	5.41E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.032	5.89E-06	0.1	82	1.00	9.66E-08	9.64E-08	9.58E-08	9.20E-08	7.65E-08	-	-	-	-
	Rupture		0.032	1.35E-06	0.1	129	1.00	3.48E-08	3.48E-08	3.47E-08	3.42E-08	3.21E-08	-	-	-	-
	D Rupture		0.032	7.04E-07	0.1	157	1.00	2.21E-08	2.21E-08	2.21E-08	2.18E-08	2.10E-08	6.53E-09	-	-	-
DISPERSION	Leak		0.842	4.14E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.735	1.35E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.697	2.94E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.697	1.53E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	1.77E-06	1.72E-06	1.61E-06	1.52E-06	1.41E-06	7.82E-07	3.30E-07	7.94E-08	3.59E-08
			1	Daily Commuter Loc 1			0.0022	3.91E-09	3.80E-09	3.57E-09	3.37E-09	3.12E-09	1.73E-09	7.29E-10	1.76E-10	7.94E-11
			2	Weekly Commuter Loc 1			0.0006	1.03E-09	9.96E-10	9.37E-10	8.83E-10	8.18E-10	4.54E-10	1.91E-10	4.61E-11	2.08E-11
			3	Worker Loc 1			0.0075	1.33E-08	1.29E-08	1.21E-08	1.14E-08	1.06E-08	5.87E-09	2.48E-09	5.96E-10	2.69E-10
			4	Resident Loc 1			0.0877	1.55E-07	1.51E-07	1.42E-07	1.33E-07	1.24E-07	6.86E-08	2.89E-08	6.96E-09	3.14E-09
TAC-HP08-MA-Collector-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	4	0.25	1.36E-08	-	-	-	-	-	-	-	-
	Hole		0.163	2.80E-05	0.1	80	0.25	1.12E-07	1.12E-07	1.11E-07	1.07E-07	8.75E-08	-	-	-	-
	Rupture		0.167	6.60E-06	0.1	210	0.25	6.93E-08	6.92E-08	6.92E-08	6.88E-08	6.73E-08	4.85E-08	2.11E-08	-	-
	D Rupture		0.167	3.44E-06	0.1	290	0.25	4.99E-08	4.99E-08	4.99E-08	4.97E-08	4.91E-08	4.27E-08	3.61E-08	2.53E-08	1.82E-08
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	9	0.25	1.42E-08	1.18E-08	-	-	-	-	-	-	-
	Hole		0.011	1.89E-06	0.5	204	0.25	9.65E-08	9.65E-08	9.64E-08	9.58E-08	9.35E-08	6.54E-08	1.90E-08	-	-
	Rupture		0.012	4.74E-07	0.5	294	0.25	3.48E-08	3.48E-08	3.48E-08	3.47E-08	3.43E-08	3.00E-08	2.55E-08	1.83E-08	1.38E-08
	D Rupture		0.012	2.47E-07	0.5	327	0.25	2.02E-08	2.02E-08	2.02E-08	2.01E-08	2.00E-08	1.80E-08	1.60E-08	1.30E-08	1.14E-08
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	1	0.25	1.58E-09	-	-	-	-	-	-	-	-
	Hole		0.011	1.89E-06	0.5	21	0.25	9.93E-09	9.65E-09	8.73E-09	-	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	50	0.25	5.93E-09	5.90E-09	5.81E-09	5.13E-09	0.00E+00	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	57	0.25	3.52E-09	3.51E-09	3.47E-09	3.17E-09	1.69E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	8.60E-07	0.1	82	1.00	1.41E-08	1.41E-08	1.40E-08	1.34E-08	1.12E-08	-	-	-	-
	Rupture		0.005	1.98E-07	0.1	169	1.00	6.68E-09	6.67E-09	6.66E-09	6.60E-09	6.38E-09	3.08E-09	-	-	-
	D Rupture		0.005	1.03E-07	0.1	208	1.00	4.28E-09	4.28E-09	4.28E-09	4.25E-09	4.16E-09	2.97E-09	1.18E-09	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.837	1.44E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.833	3.29E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.833	1.72E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	4.57E-07	4.38E-07	4.25E-07	4.08E-07	3.75E-07	2.11E-07	1.19E-07	5.66E-08	4.34E-08
			4	Resident Loc 4			0.0877	4.00E-08	3.84E-08	3.72E-08	3.58E-08	3.29E-08	1.85E-08	1.04E-08	4.97E-09	3.81E-09

Table C.3.11
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	270
TAC-HP08-MA-Local-Location 1																
GAS RELEASE	Leak	4.92E-04						-	-	-	-	-	-	-	-	-
	Hole	1.84E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	7.43E-05	0.1	4	0.25	1.49E-08	-	-	-	-	-	-	-	-
	Hole		0.168	3.09E-05	0.1	80	0.25	1.24E-07	1.23E-07	1.23E-07	1.17E-07	9.65E-08	-	-	-	-
	Rupture		0.174	7.34E-06	0.1	147	0.25	5.40E-08	5.39E-08	5.38E-08	5.32E-08	5.08E-08	-	-	-	-
	D Rupture		0.174	3.83E-06	0.1	198	0.25	3.79E-08	3.79E-08	3.78E-08	3.76E-08	3.67E-08	2.47E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.095	4.67E-05	0.5	9	0.25	1.05E-07	8.74E-08	-	-	-	-	-	-	-
	Hole		0.047	8.65E-06	0.5	204	0.25	4.41E-07	4.41E-07	4.41E-07	4.38E-07	4.28E-07	2.99E-07	8.69E-08	-	-
	Rupture		0.036	1.52E-06	0.5	253	0.25	9.61E-08	9.61E-08	9.60E-08	9.56E-08	9.42E-08	7.74E-08	5.88E-08	1.48E-08	-
	D Rupture		0.036	7.92E-07	0.5	287	0.25	5.68E-08	5.68E-08	5.68E-08	5.66E-08	5.60E-08	4.84E-08	4.08E-08	2.79E-08	1.93E-08
FLASH FIRE - Parallel	Leak		0.095	4.67E-05	0.5	1	0.25	1.17E-08	-	-	-	-	-	-	-	-
	Hole		0.047	8.65E-06	0.5	21	0.25	4.54E-08	4.41E-08	3.99E-08	-	-	-	-	-	-
	Rupture		0.036	1.52E-06	0.5	42	0.25	1.60E-08	1.58E-08	1.55E-08	1.28E-08	-	-	-	-	-
	D Rupture		0.036	7.92E-07	0.5	48	0.25	9.50E-09	9.45E-09	9.30E-09	8.11E-09	-	-	-	-	-
EXPLOSION	Leak		0.011	5.41E-06	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.020	3.68E-06	0.1	82	1.00	6.04E-08	6.02E-08	5.99E-08	5.75E-08	4.78E-08	-	-	-	-
	Rupture		0.016	6.75E-07	0.1	129	1.00	1.74E-08	1.74E-08	1.74E-08	1.71E-08	1.61E-08	-	-	-	-
	D Rupture		0.016	3.52E-07	0.1	157	1.00	1.11E-08	1.10E-08	1.10E-08	1.09E-08	1.05E-08	3.26E-09	-	-	-
DISPERSION	Leak		0.849	4.18E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.832	1.53E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.826	3.49E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.826	1.82E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	1.10E-06	1.05E-06	9.61E-07	9.05E-07	8.36E-07	4.53E-07	1.87E-07	4.27E-08	1.93E-08
			1	Daily Commuter Loc 1			0.0022	2.44E-09	2.33E-09	2.13E-09	2.00E-09	1.85E-09	1.00E-09	4.13E-10	9.44E-11	4.26E-11
			2	Weekly Commuter Loc 1			0.0006	6.38E-10	6.12E-10	5.57E-10	5.25E-10	4.85E-10	2.63E-10	1.08E-10	2.47E-11	1.12E-11
			3	Worker Loc 1			0.0075	8.27E-09	7.92E-09	7.21E-09	6.79E-09	6.28E-09	3.40E-09	1.40E-09	3.20E-10	1.45E-10
			4	Resident Loc 1			0.0877	9.65E-08	9.25E-08	8.42E-08	7.93E-08	7.33E-08	3.97E-08	1.64E-08	3.74E-09	1.69E-09
TAC-HP08-MA-local-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.150	6.77E-05	0.1	4	0.25	1.35E-08	-	-	-	-	-	-	-	-
	Hole		0.152	2.61E-05	0.1	80	0.25	1.05E-07	1.04E-07	1.04E-07	9.93E-08	8.16E-08	-	-	-	-
	Rupture		0.152	6.00E-06	0.1	210	0.25	6.30E-08	6.30E-08	6.30E-08	6.26E-08	6.12E-08	4.41E-08	1.92E-08	-	-
	D Rupture		0.152	3.13E-06	0.1	290	0.25	4.54E-08	4.54E-08	4.54E-08	4.52E-08	4.47E-08	3.89E-08	3.29E-08	2.30E-08	1.66E-08
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	9	0.25	1.42E-08	1.18E-08	-	-	-	-	-	-	-
	Hole		0.011	1.89E-06	0.5	204	0.25	9.65E-08	9.65E-08	9.64E-08	9.58E-08	9.35E-08	6.54E-08	1.90E-08	-	-
	Rupture		0.011	4.35E-07	0.5	294	0.25	3.19E-08	3.19E-08	3.19E-08	3.18E-08	3.15E-08	2.75E-08	2.34E-08	1.68E-08	1.26E-08
	D Rupture		0.011	2.27E-07	0.5	327	0.25	1.85E-08	1.85E-08	1.85E-08	1.85E-08	1.83E-08	1.65E-08	1.47E-08	1.19E-08	1.05E-08
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	1	0.25	1.58E-09	-	-	-	-	-	-	-	-
	Hole		0.011	1.89E-06	0.5	21	0.25	9.93E-09	9.65E-09	8.73E-09	-	-	-	-	-	-
	Rupture		0.011	4.35E-07	0.5	50	0.25	5.43E-09	5.40E-09	5.32E-09	4.70E-09	0.00E+00	-	-	-	-
	D Rupture		0.011	2.27E-07	0.5	57	0.25	3.23E-09	3.22E-09	3.18E-09	2.90E-09	1.55E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	0	1.00	-	-	-	-	-	-	-	-	-
	Hole		0.005	8.60E-07	0.1	82	1.00	1.41E-08	1.41E-08	1.40E-08	1.34E-08	1.12E-08	-	-	-	-
	Rupture		0.005	1.98E-07	0.1	169	1.00	6.68E-09	6.67E-09	6.66E-09	6.60E-09	6.38E-09	3.08E-09	-	-	-
	D Rupture		0.005	1.03E-07	0.1	208	1.00	4.28E-09	4.28E-09	4.28E-09	4.25E-09	4.16E-09	2.97E-09	1.18E-09	-	-
DISPERSION	Leak		0.850	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.848	1.46E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.848	3.35E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.848	1.75E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	4.33E-07	4.15E-07	4.01E-07	3.85E-07	3.54E-07	1.98E-07	1.10E-07	5.18E-08	3.97E-08
			4	Resident Loc 4			0.0877	3.80E-08	3.64E-08	3.52E-08	3.38E-08	3.11E-08	1.74E-08	9.68E-09	4.54E-09	3.48E-09

Table C.3.12
Collective Risk Exposure Numbers

Nr	Road Type	ADDT	Hazard	V	Spacing		Number of cars		Number of People	
		cars/day max	m	km/h min	Day m	Night m	Day	Night	Day	Night
1	Freeway Type B	10000	300	90	108	432	2.78	0.69	6	2
2	Arterial Type C,D	5000	300	80	192	768	1.56	0.39	4	1
3	Collector Type E,F	3000	300	70	280	1120	1.07	0.27	3	1
4	Local Type G,H,I,J	300	300	50	2000	8000	0.15	0.04	1	1

Table C.3.13
Automobile Occupant IRI Calculation

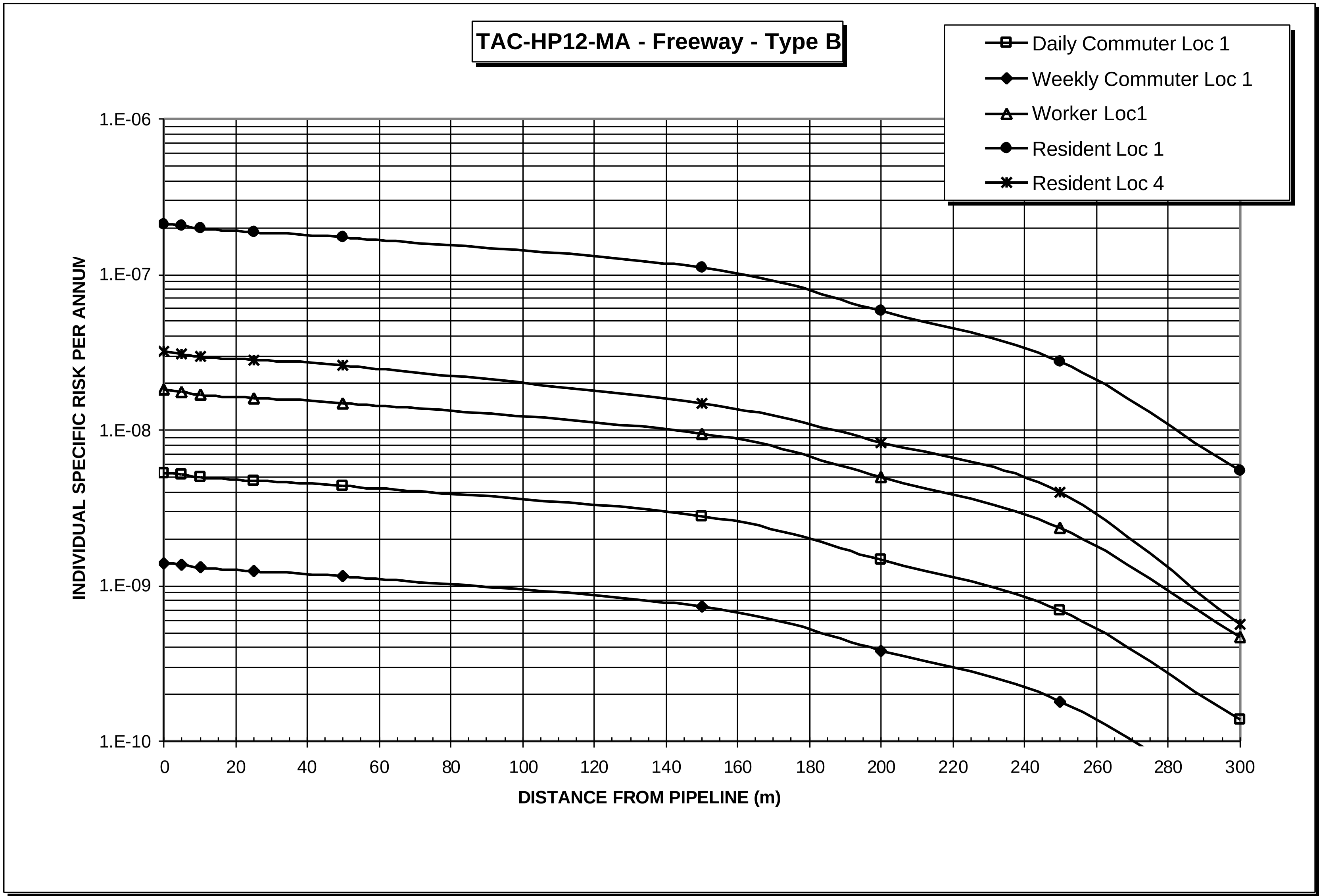
Scenario	FLASH FIRE				JET FIRE				EXPLOSION			
Release type	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**
Releases [per km-year]	4.92E-04	1.84E-04	4.22E-05	2.20E-05	4.92E-04	1.84E-04	4.22E-05	2.20E-05	4.92E-04	1.84E-04	4.22E-05	2.20E-05
Interactive Length [km]	10											
Releases [per year]	4.92E-03	1.84E-03	4.22E-04	2.20E-04	4.92E-03	1.84E-03	4.22E-04	2.20E-04	4.92E-03	1.84E-03	4.22E-04	2.20E-04
ROO	0.172	0.480	0.590	0.590	0.108	0.134	0.124	0.124	0.012	0.058	0.053	0.053
Probability [per year]	8.46E-04	8.81E-04	2.49E-04	1.30E-04	5.33E-04	2.47E-04	5.23E-05	2.73E-05	5.92E-05	1.06E-04	2.24E-05	1.17E-05
Probability of Fatality	0.50				0.10				0.10			
Sheild Factor	0.10				0.10				0.10			
P-Footprint Factor	0.12				0.25				0.80			
Individual Risk Intensity	5.08E-06	5.29E-06	1.49E-06	7.80E-07	1.33E-06	6.17E-07	1.31E-07	6.82E-08	4.74E-07	8.46E-07	1.79E-07	9.35E-08
Hazard Distance [m]	9.0	204.0	294.0	327.0	4.0	8.0	210.0	290.0	0.0	82.0	169.0	208.0

Table C.3.14
Calculated Probabilities of Fatalities for Freeway

Location	Time	Distance [m]	IRI	OCR Factor	Directional Factor	Dynamic Factor	N Footprint Factor	N [ppl]	N in Footprint [ppl]	Annual Chance of N Fatalities
Road	Night	100	8.00E-06	0.50	0.5	0.06	0.50	1	0.50	1.20E-07
		200	3.00E-06	0.50	0.5	0.12	0.50	1	0.50	9.00E-08
		300	2.00E-06	0.50	0.5	0.18	0.50	2	1.00	9.00E-08
	Day	100	8.00E-06	0.50	0.5	0.06	0.50	2	1.00	1.20E-07
		200	3.00E-06	0.50	0.5	0.12	0.50	4	2.00	9.00E-08
		300	2.00E-06	0.50	0.5	0.18	0.50	6	3.00	9.00E-08

N in Footprint [ppl]	Annual Chance of N Fatalities	Annual Chance of N or more Fatalities
1	4.20E-07	6.00E-07
2	9.00E-08	1.80E-07
3	9.00E-08	9.00E-08

OCR	Outdor Collective Risk factor
Dinamic Factor	Amount of time as % of 60 sec in the footprint



TAC-HP12-MA - Freeway - Type B
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc1
Resident Loc 1
Resident Loc 4
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
INDIVIDUAL SPECIFIC RISK PER ANNUM
DISTANCE FROM PIPELINE (m)

Figure C.3.2

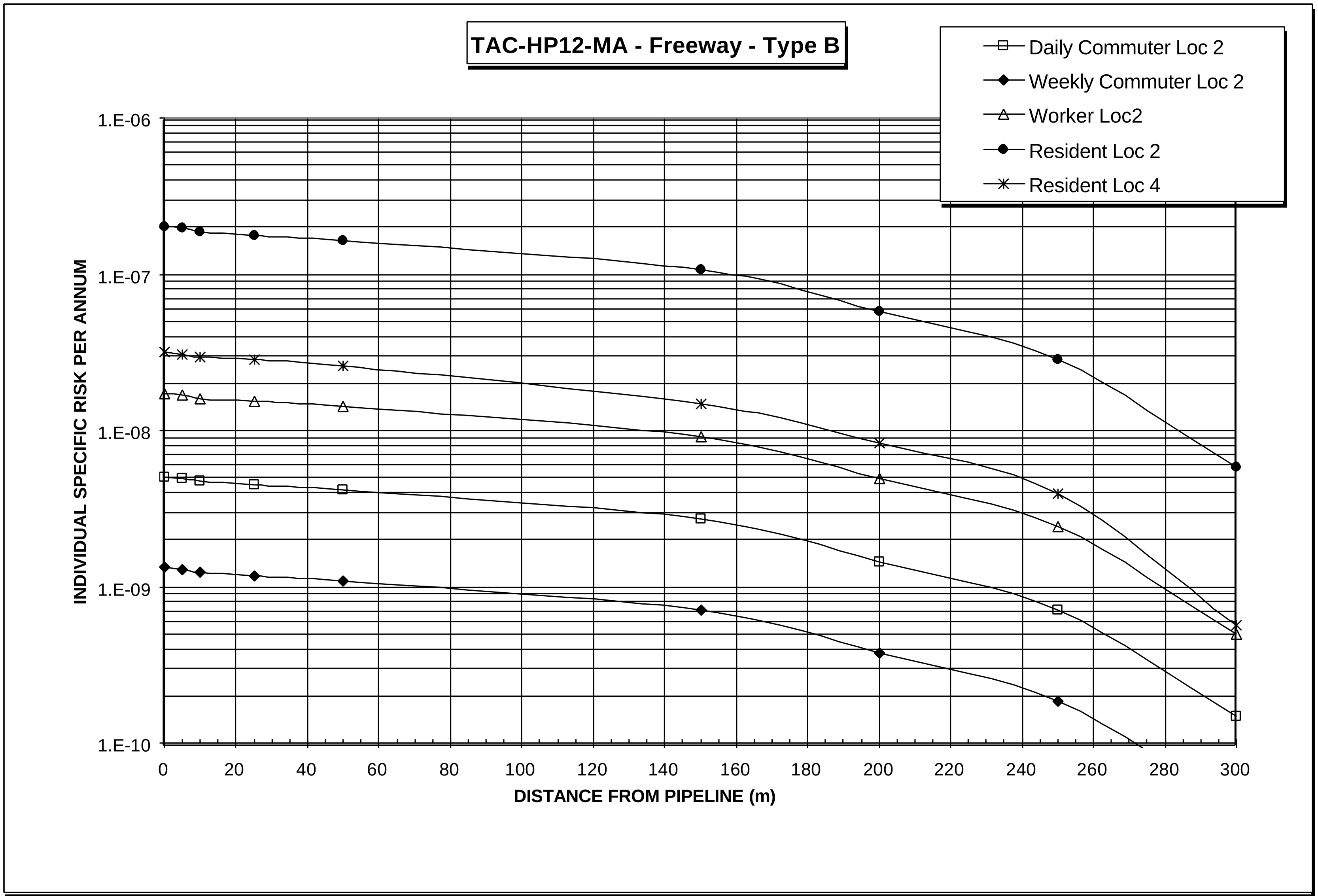
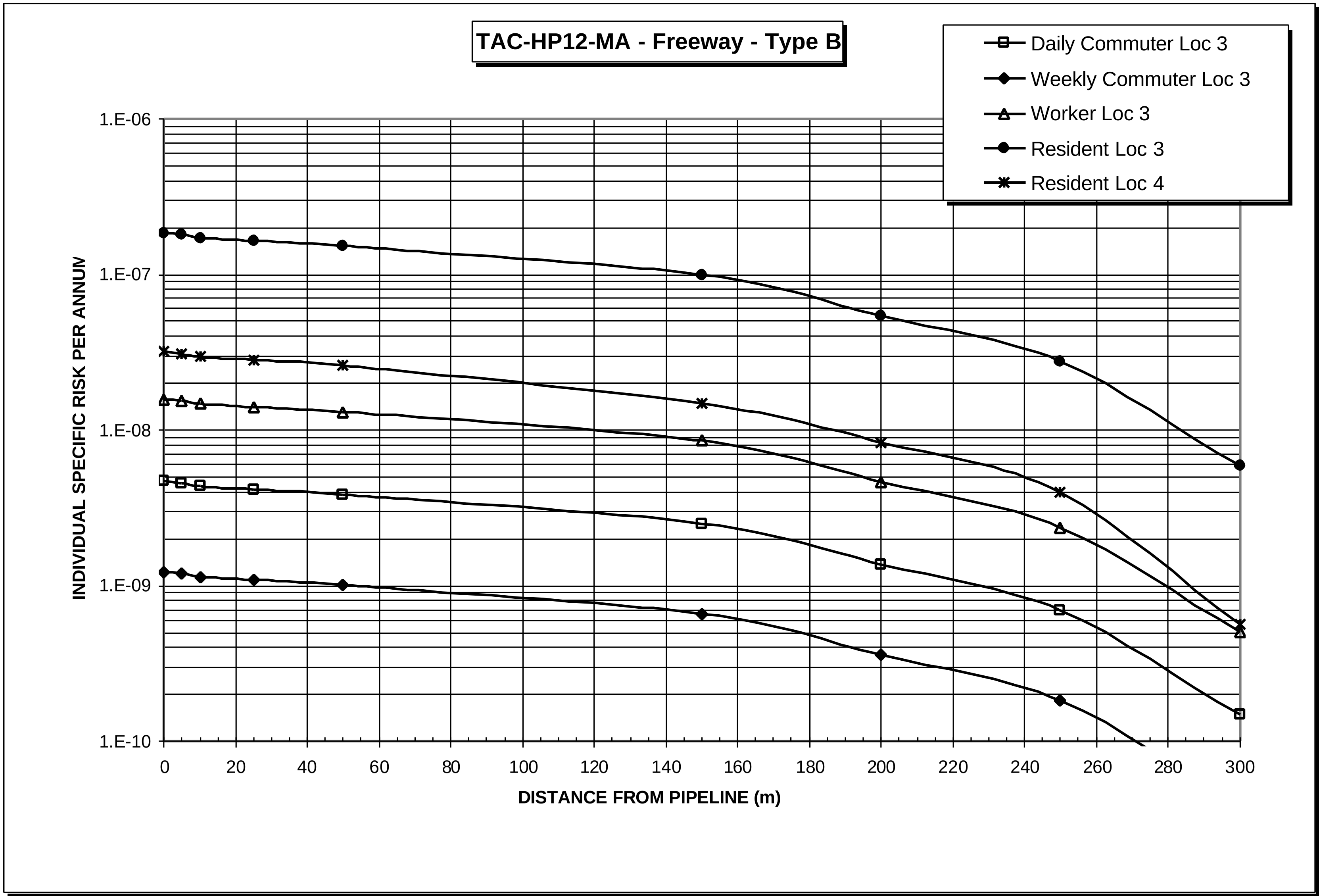

TAC-HP12-MA - Freeway - Type B
Daily Commuter Loc 2
Weekly Commuter Loc 2
Worker Loc2
Resident Loc 2
Resident Loc 4
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
INDIVIDUAL SPECIFIC RISK PER ANNUM
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
DISTANCE FROM PIPELINE (m)

Figure C.3.3



TAC-HP12-MA - Freeway - Type B
Daily Commuter Loc 3
Weekly Commuter Loc 3
Worker Loc 3
Resident Loc 3
Resident Loc 4
INDIVIDUAL SPECIFIC RISK PER ANNUM
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
DISTANCE FROM PIPELINE (m)

Figure C.3.4

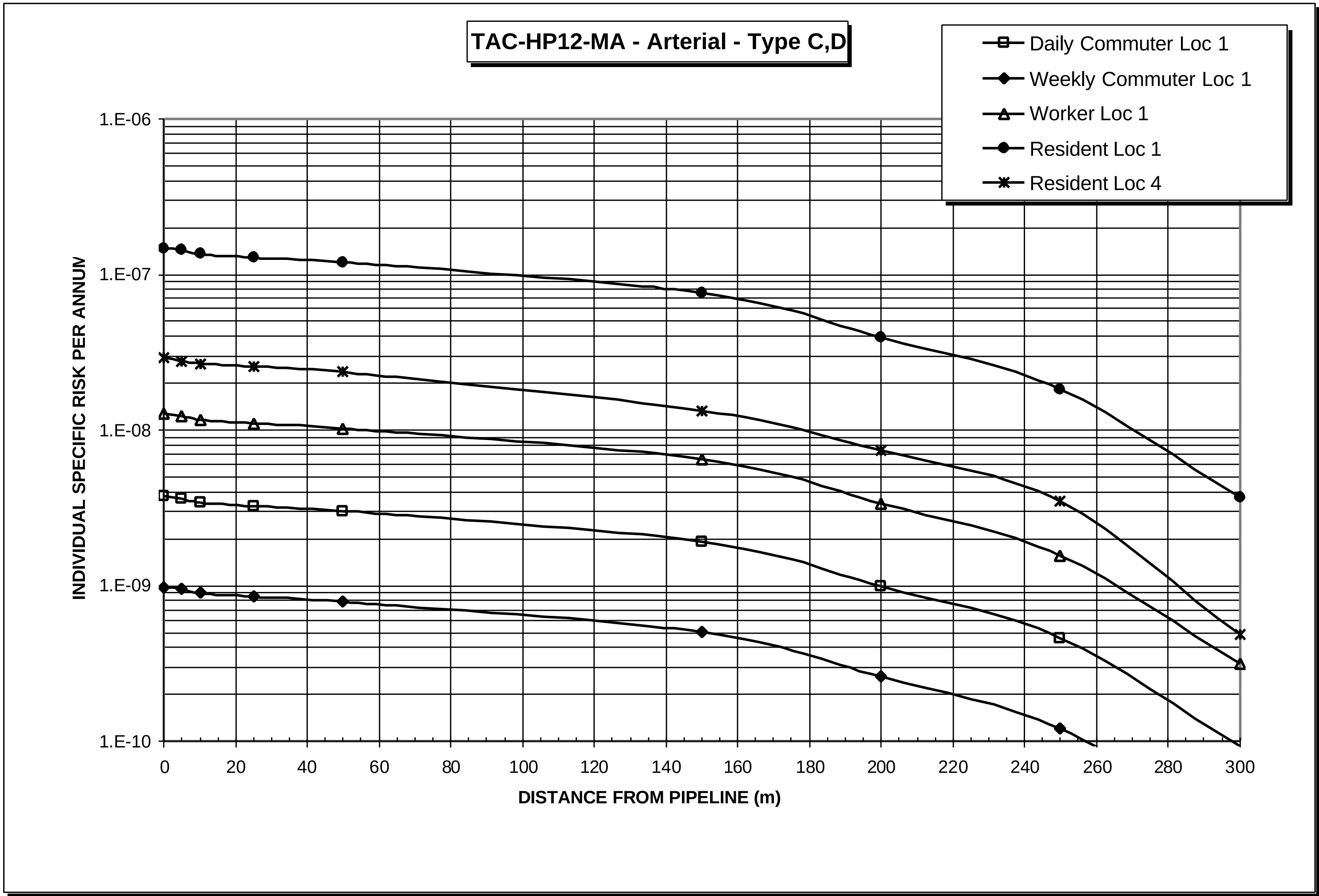
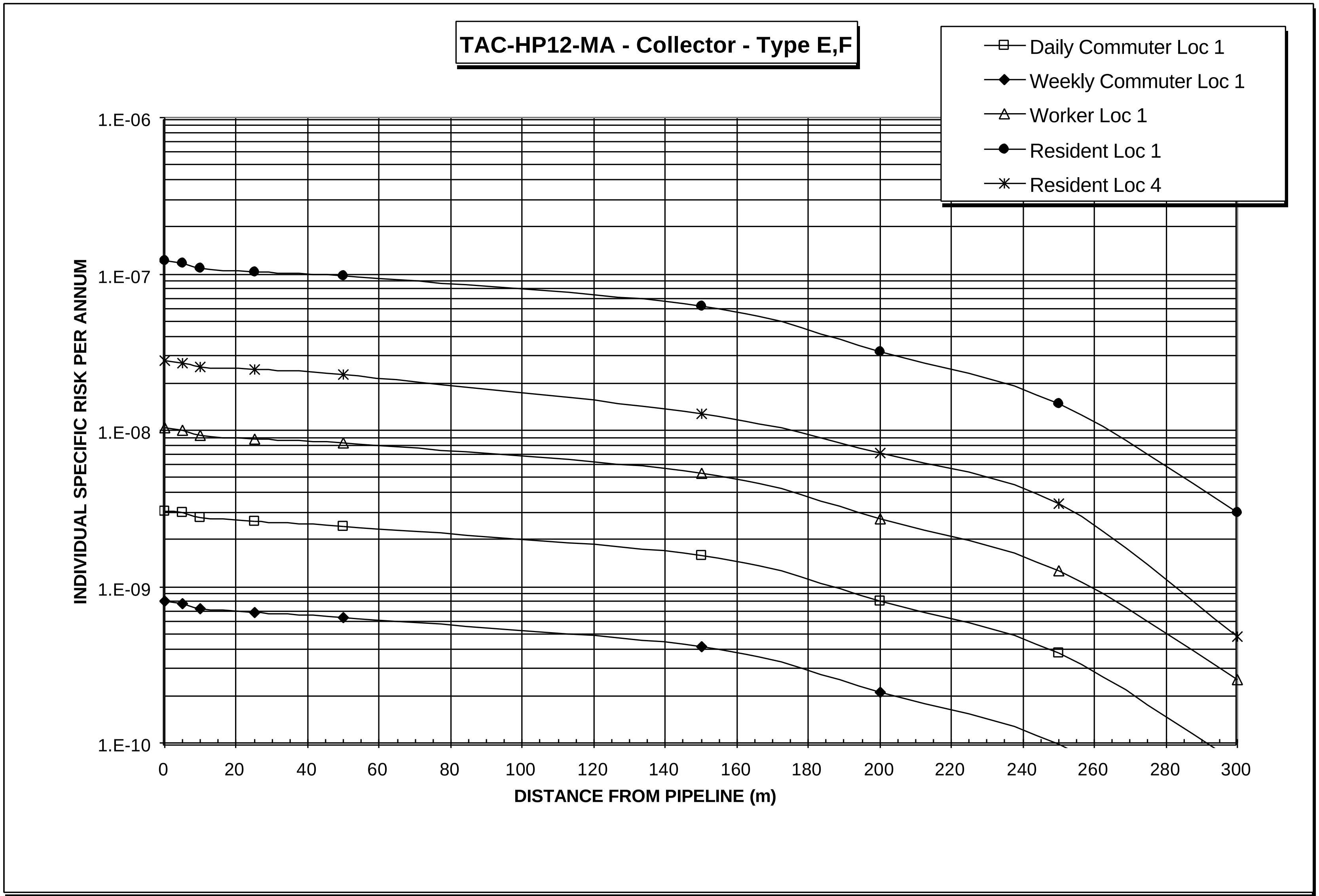

TAC-HP12-MA - Arterial - Type C,D
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
INDIVIDUAL SPECIFIC RISK PER ANNUM
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
DISTANCE FROM PIPELINE (m)

Figure C.3.5



TAC-HP12-MA - Collector - Type E,F
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
INDIVIDUAL SPECIFIC RISK PER ANNUM
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
DISTANCE FROM PIPELINE (m)

Figure C.3.6

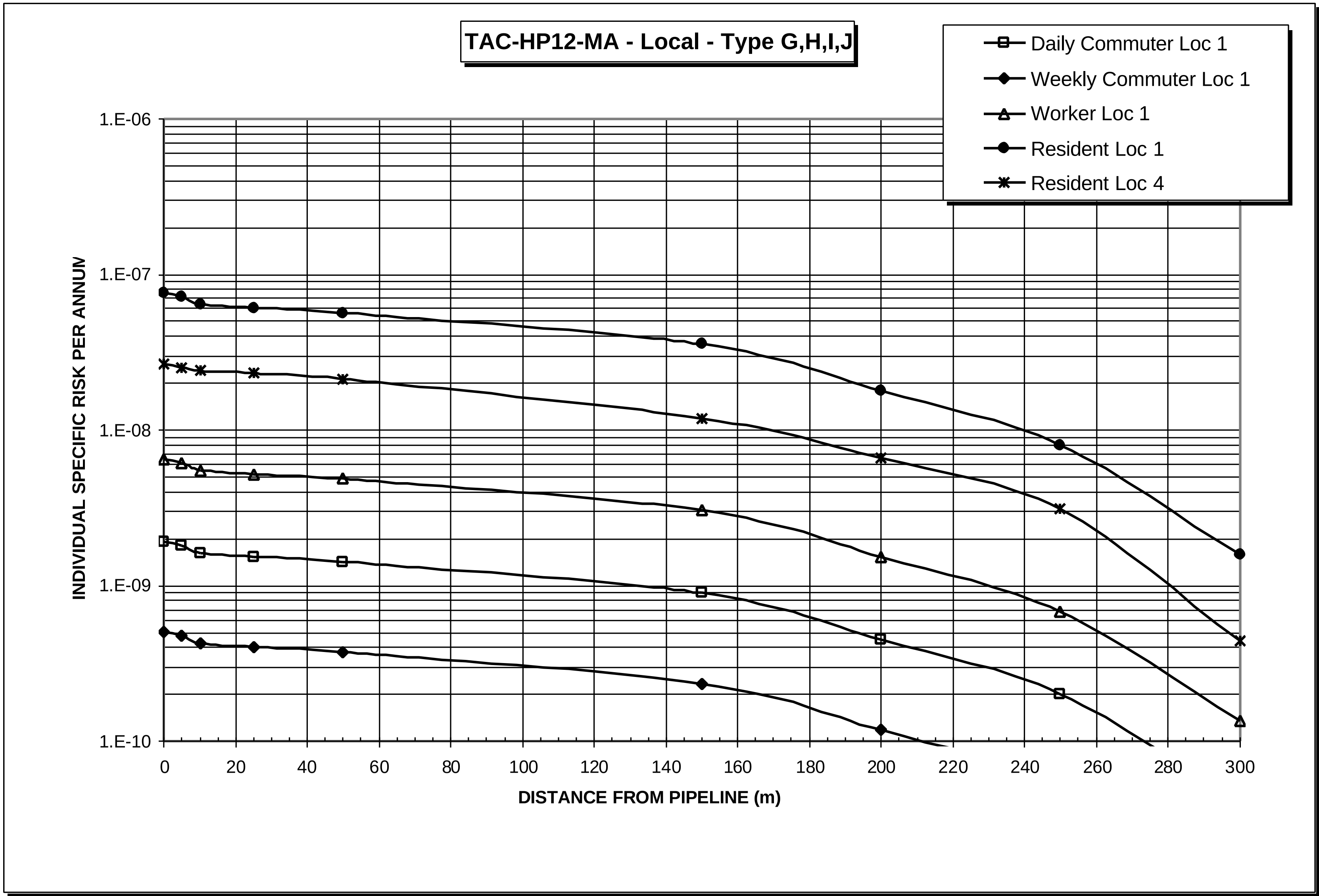
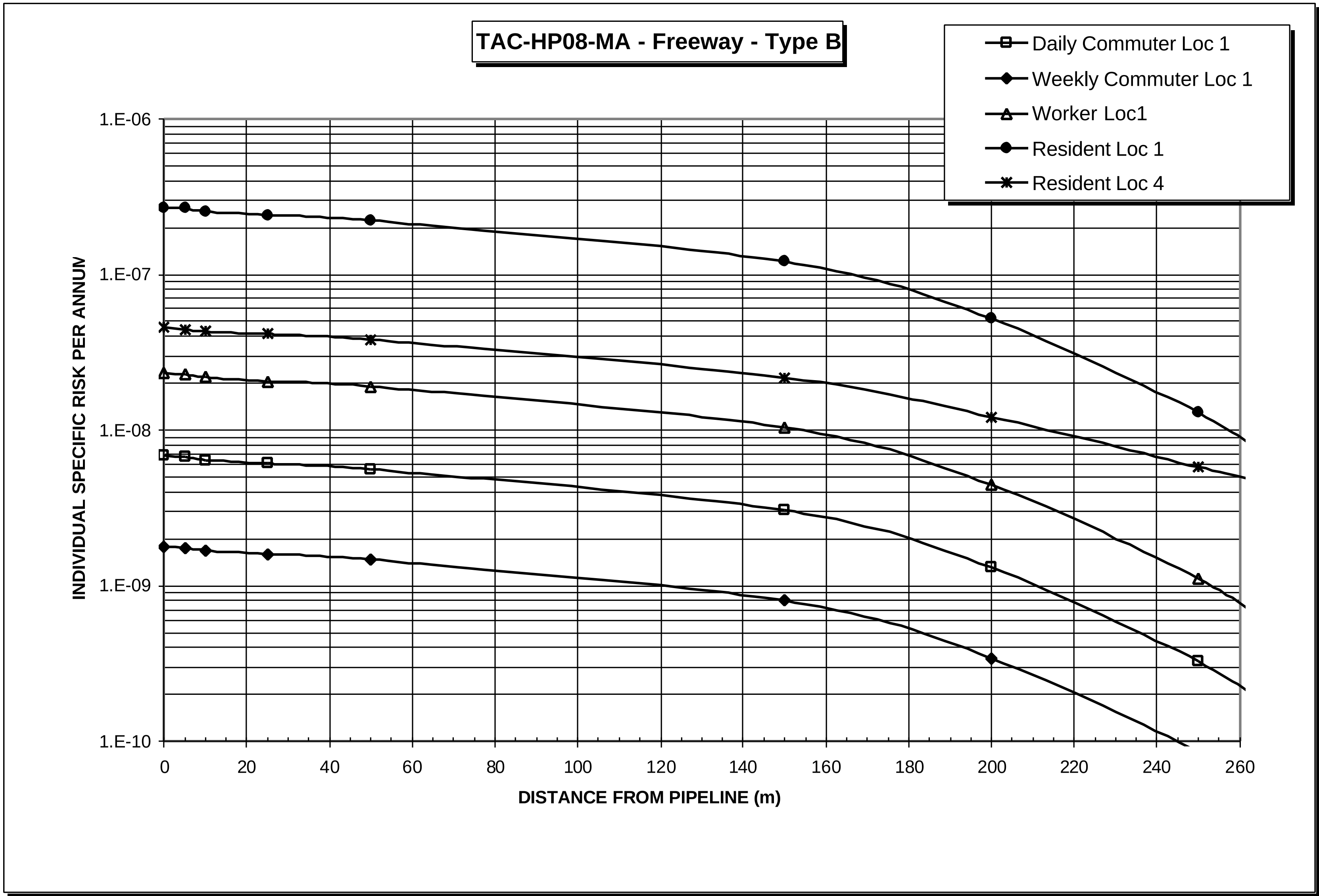

TAC-HP12-MA - Local - Type G,H,I,J
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
INDIVIDUAL SPECIFIC RISK PER ANNUM
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
DISTANCE FROM PIPELINE (m)

Figure C.3.7



TAC-HP08-MA - Freeway - Type B
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc1
Resident Loc 1
Resident Loc 4
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
INDIVIDUAL SPECIFIC RISK PER ANNUM
0
20
40
60
80
100
120
140
160
180
200
220
240
260
DISTANCE FROM PIPELINE (m)

Figure C.3.8

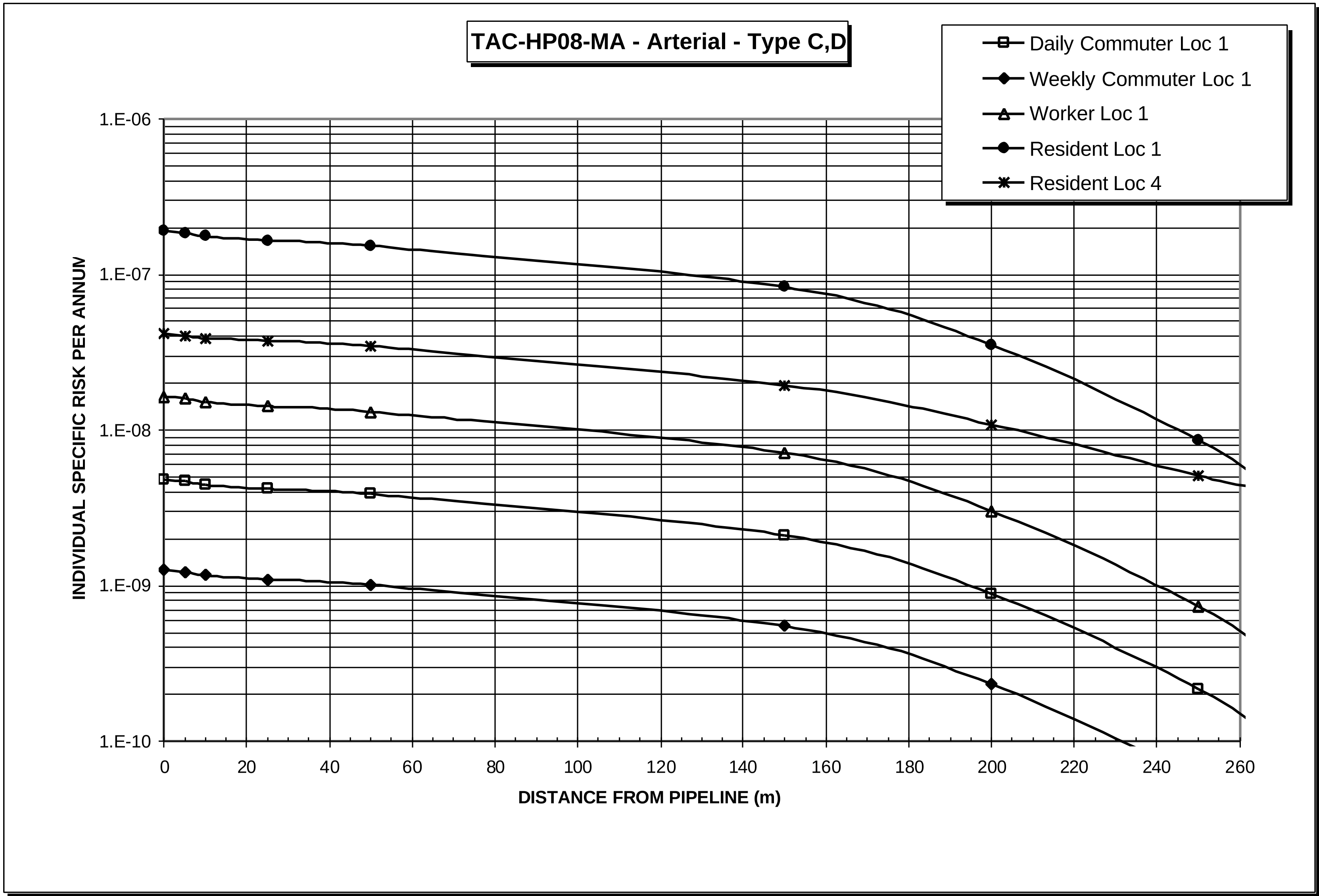

TAC-HP08-MA - Arterial - Type C,D
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
INDIVIDUAL SPECIFIC RISK PER ANNUM
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
DISTANCE FROM PIPELINE (m)

Figure C.3.9

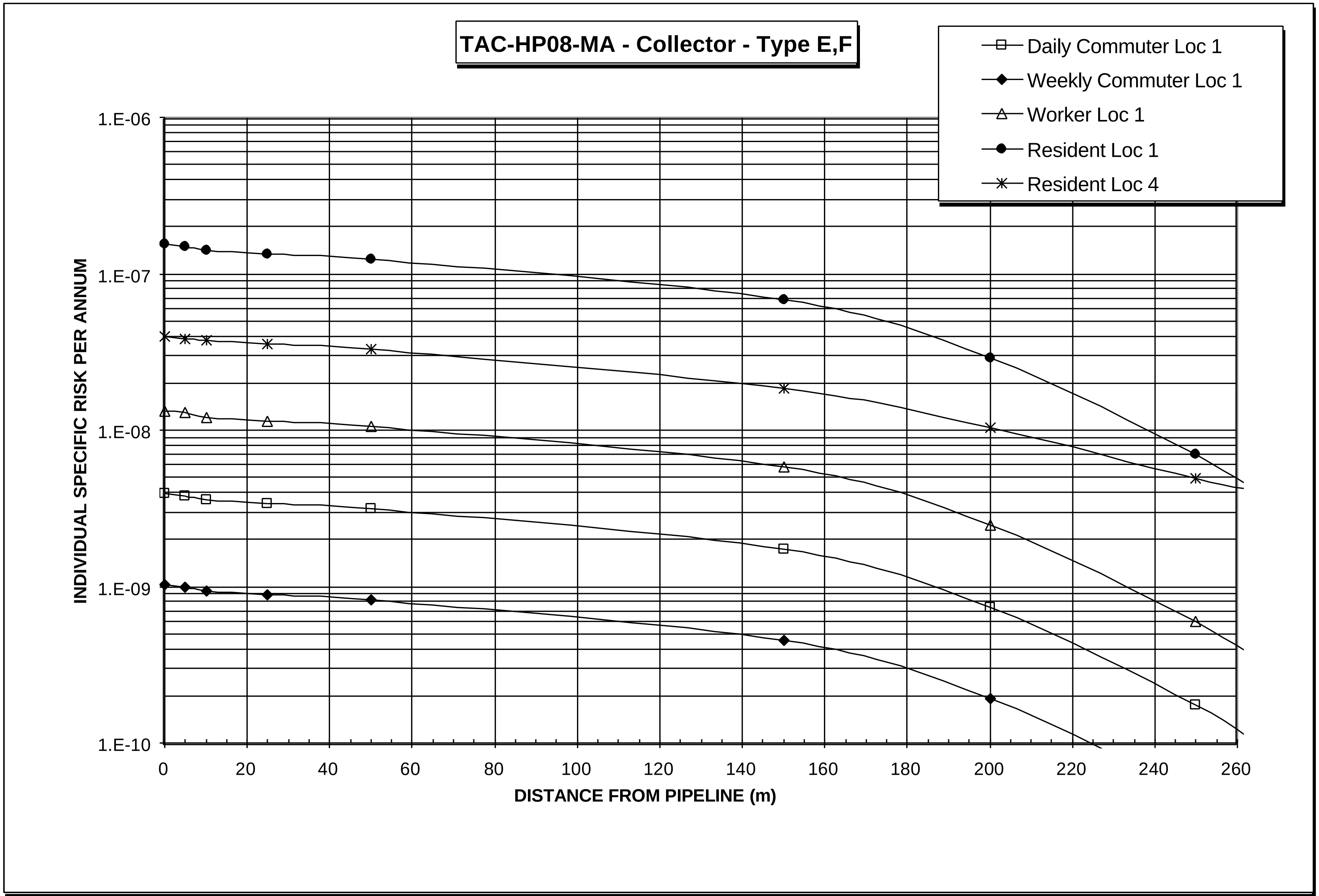
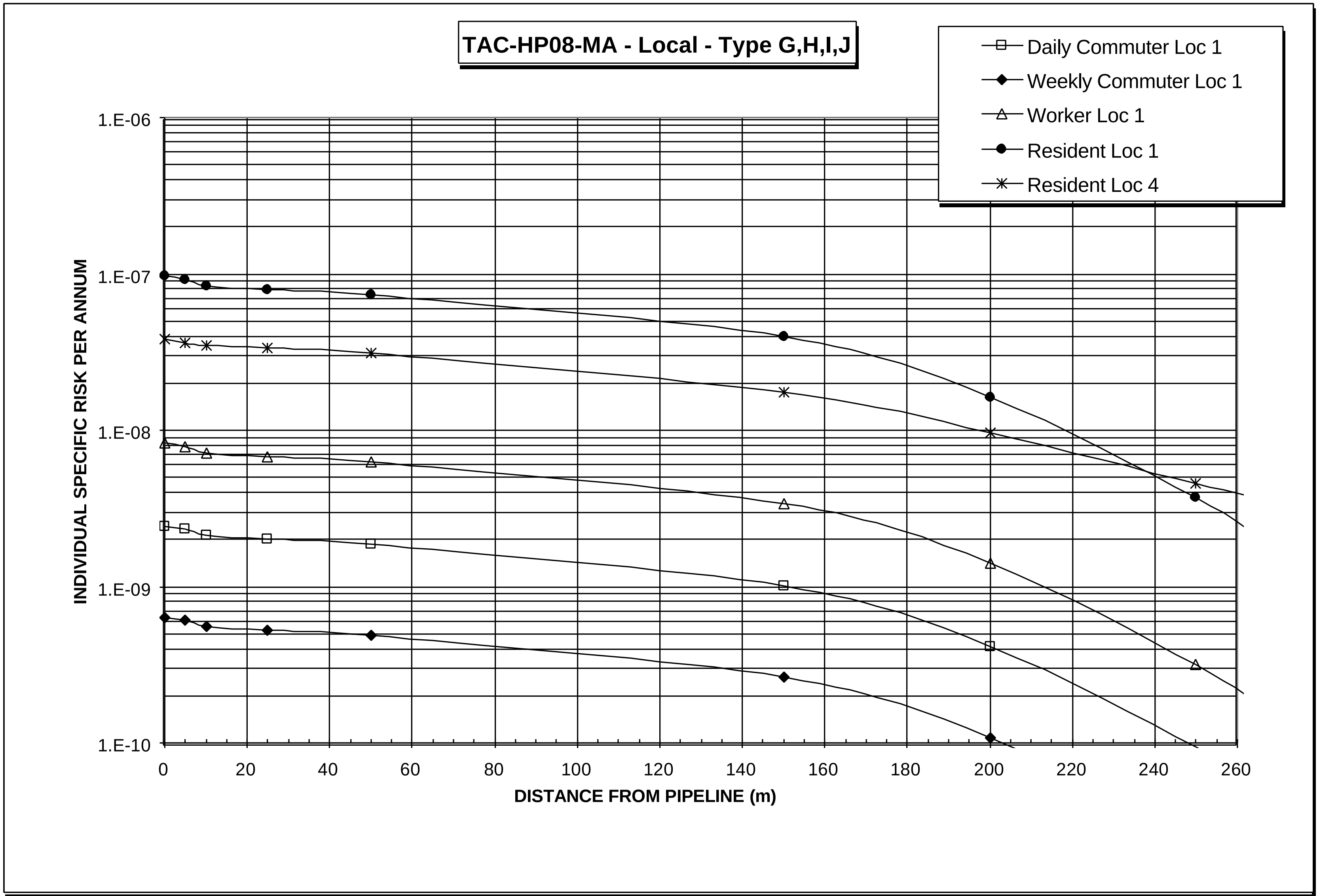

TAC-HP08-MA - Collector - Type E,F
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
INDIVIDUAL SPECIFIC RISK PER ANNUM
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
DISTANCE FROM PIPELINE (m)

Figure C.3.10



TAC-HP08-MA - Local - Type G,H,I,J
Daily Commuter Loc 1
Weekly Commuter Loc 1
Worker Loc 1
Resident Loc 1
Resident Loc 4
INDIVIDUAL SPECIFIC RISK PER ANNUM
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
DISTANCE FROM PIPELINE (m)

Figure C.3.11

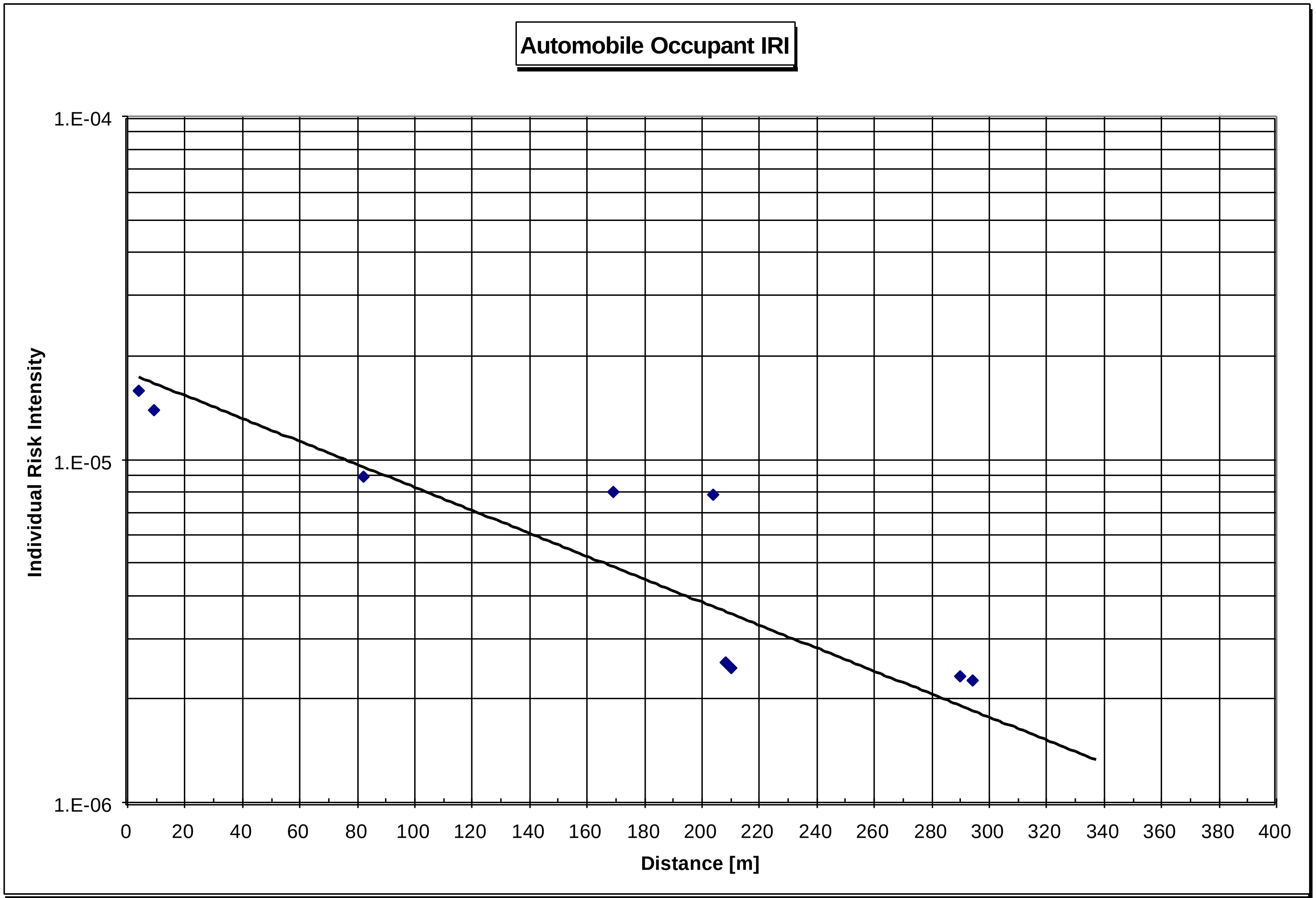
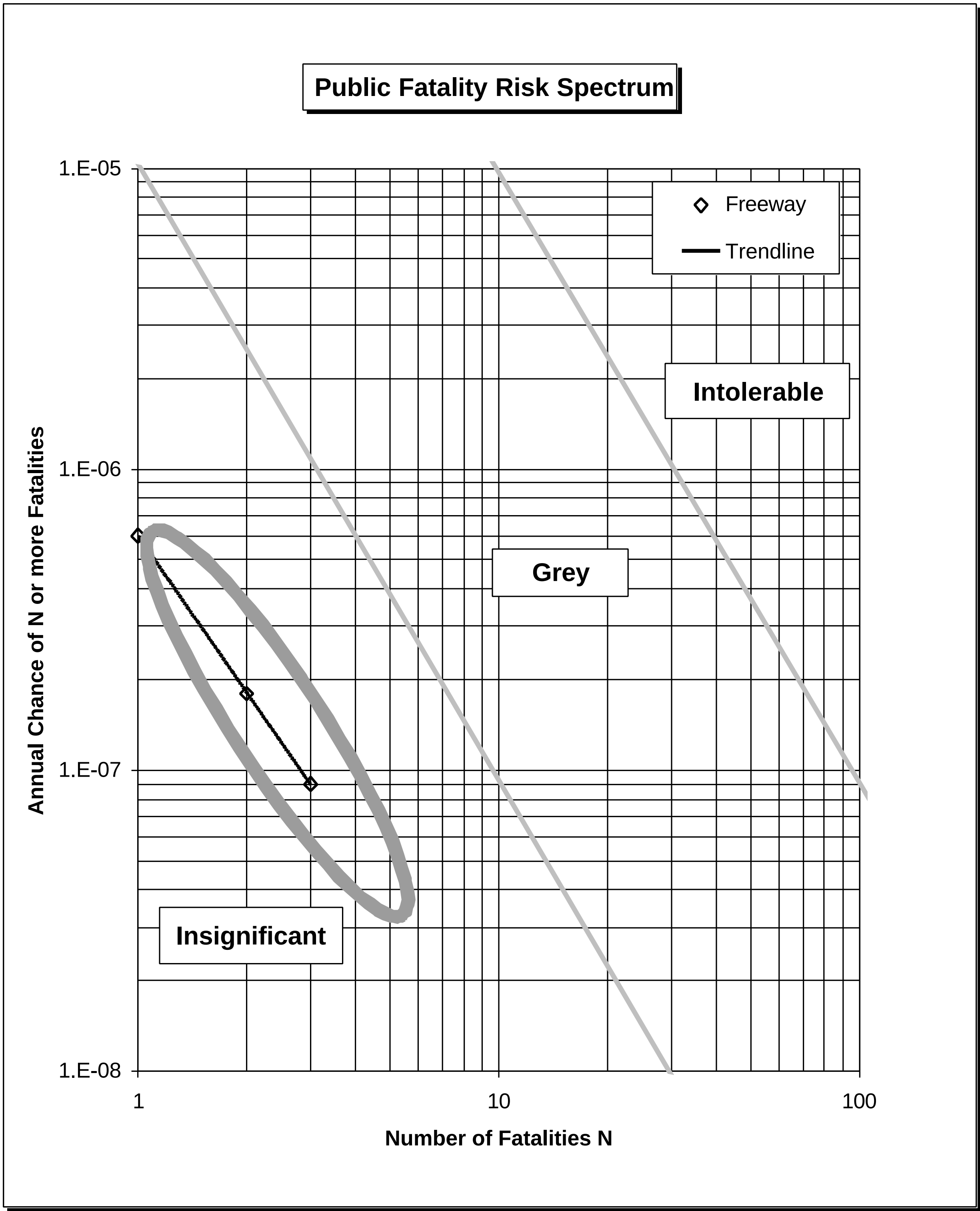

Automobile Occupant IRI
1.E-04
1.E-05
1.E-06
Individual Risk Intensity
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Distance [m]

Figure C.3.13



Public Fatality Risk Spectrum
Freeway
Trendline
Intolerable
Grey
Insignificant
1.E-05
1.E-06
1.E-07
1.E-08
1
10
100
Annual Chance of N or more Fatalities
Number of Fatalities N

Figure C.3.14

APPENDIX D

Case Study #1

Table D.1.1
P/L 08(06)" Leak Failure Rates

AEUB LEAK CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08 DISTRIBUTION (%)	PL HP08 FAILURE RATE [per km-yr]
CORROSION	**52.4**	**4.21E-04**	**61.7**	**20.1**	**35.7**	**1.61E-04**
Internal	25.6	2.06E-04	75.0	6.4	11.4	5.14E-05
External	26.3	2.11E-04	50.0	13.2	23.4	1.06E-04
Girth/Filet Weld	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
EXTERNAL FORCES	**15.1**	**1.21E-04**	**43.1**	**8.6**	**15.3**	**6.90E-05**
Construction Damage	5.1	4.10E-05	70.7	1.5	2.7	1.20E-05
Third Party Damage	8.8	7.07E-05	25.0	6.6	11.8	5.30E-05
Earth Movement	1.2	9.64E-06	58.5	0.5	0.9	4.00E-06
WELD FAILURES	**10.6**	**8.51E-05**	**0.0**	**10.6**	**18.9**	**8.51E-05**
Girth Weld	6.2	4.98E-05	0.0	6.2	11.0	4.98E-05
Other	2.8	2.25E-05	0.0	2.8	5.0	2.25E-05
Seam Rupture	1.6	1.28E-05	0.0	1.6	2.8	1.28E-05
JOINT FAILURES	**5.6**	**4.50E-05**	**0.0**	**5.6**	**10.0**	**4.50E-05**
Mechanical	5.0	4.02E-05	0.0	5.0	8.9	4.02E-05
Miscellaneous	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
SURFACE EQUIPMENT FAILURE	**5.0**	**4.02E-05**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	4.02E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	4.5	3.61E-05	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**11.3**	**9.07E-05**	**0.0**	**11.3**	**20.1**	**9.07E-05**
Pipe Failure	5.3	4.26E-05	0.0	5.3	9.4	4.26E-05
Overpressure	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
Operator Error	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
Miscellaneous	2.0	1.61E-05	0.0	2.0	3.6	1.61E-05
Unknown	2.9	2.33E-05	0.0	2.9	5.2	2.33E-05
TOTALS	**100.0**	**8.03E-04**	**43.9**	**56.1**	**100.0**	**4.51E-04**

Table D.1.2
P/L 08(06)" Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08 DISTRIBUTION (%)	PL HP08 FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**2.8**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	0.8	1.78E-06
External	3.2	9.50E-06	50.0	1.6	2.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**21.9**	**62.6**	**80.1**	**1.86E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	6.5	1.51E-05
Third Party Damage	70.1	2.08E-04	25.0	52.6	67.3	1.56E-04
Earth Movement	4.9	1.46E-05	0.0	4.9	6.3	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**3.5**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	1.5	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	1.9	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**1.5**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**12.0**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	5.6	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**21.9**	**78.1**	**100.0**	**2.32E-04**

Table D.1.5
Case Study 1 - Roadway Effects on Pipeline Failure Rate

CS1 ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**7.94E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							1.04E-05
		Unknown Total							**1.04E-05**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07

Table D.1.5
Case Study 1 - Roadway Effects on Pipeline Failure Rate

Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity Value	Hazard Quantity Unit	P/L Damage Probability per Unit	P/L Damage Probability Total	Failure Rate Change [per km-year]
		CS1 ROAD TYPE G							
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
								Third Party DamageTotal	**5.92E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
								Earth Movement Total	**2.33E-05**
	Unknown	Other							8.36E-06
								Unknown Total	**8.36E-06**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
								External Corrosion Total	**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
								Third Party DamageTotal	**9.25E-06**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
								Earth Movement Total	**2.33E-05**
	Unknown	Other							3.36E-06
								Unknown Total	**3.36E-06**

Table D.1.6
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

CS1 ROAD TYPE G Pipeline 08(06)								
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.97E-05	2.49E-04	119.0
		Leak	5.30E-05	Leak	36	2.86E-05	8.16E-05	153.9
		Rupture	1.56E-04	Rupture	14	1.11E-05	1.67E-04	107.1
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.19E-06	3.14E-05	119.8
		Leak	2.33E-05	Leak	36	3.74E-06	2.70E-05	116.1
		Rupture	2.97E-06	Rupture	14	1.45E-06	4.42E-06	148.9
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	2.96E-05	2.39E-04	114.2
		Leak	5.30E-05	Leak	36	2.13E-05	7.43E-05	140.2
		Rupture	1.56E-04	Rupture	14	8.29E-06	1.64E-04	105.3
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	4.18E-06	3.04E-05	115.9
		Leak	2.33E-05	Leak	36	3.01E-06	2.63E-05	112.9
		Rupture	2.97E-06	Rupture	14	1.17E-06	4.14E-06	139.4
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.62E-06	2.14E-04	102.2
		Leak	5.30E-05	Leak	36	3.33E-06	5.64E-05	106.3
		Rupture	1.56E-04	Rupture	14	1.29E-06	1.57E-04	100.8
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.68E-06	2.79E-05	106.4
		Leak	2.33E-05	Leak	36	1.21E-06	2.45E-05	105.2
		Rupture	2.97E-06	Rupture	14	4.71E-07	3.44E-06	115.9

Table D.1.8 Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS1 ROAD TYPE G Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**1.06E-04**	**9.88E-05**	**8.08E-05**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	8.16E-05	7.43E-05	5.64E-05	5.30E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.45E-05**	**9.37E-05**	**9.20E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	2.63E-05	2.45E-05	2.33E-05
TOTALS	**4.51E-04**	**4.92E-04**	**4.84E-04**	**4.64E-04**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS1 ROAD TYPE G Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**2.00E-04**	**1.97E-04**	**1.90E-04**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.67E-04	1.64E-04	1.57E-04	1.56E-04
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**2.91E-05**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.42E-06	4.14E-06	3.44E-06	2.97E-06
TOTALS	**2.32E-04**	**2.48E-04**	**2.45E-04**	**2.37E-04**	**2.32E-04**

Table D.1.10
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS1 ROAD TYPE G							
	Pipeline 08(06)"							
Base Leak	73.0%	**4.92E-04**	73.0%	**4.84E-04**	73.0%	**4.64E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**2.48E-04**	27.0%	**2.45E-04**	27.0%	**2.37E-04**	27.0%	**2.32E-04**
Leak	73.0%	4.92E-04	73.0%	4.84E-04	73.0%	4.64E-04	73.0%	4.51E-04
Hole	20.0%	1.84E-04	20.0%	1.81E-04	20.0%	1.76E-04	20.0%	1.72E-04
Rupture	4.6%	4.22E-05	4.6%	4.17E-05	4.6%	4.04E-05	4.6%	3.95E-05
D Rupture	2.4%	2.20E-05	2.4%	2.18E-05	2.4%	2.11E-05	2.4%	2.06E-05

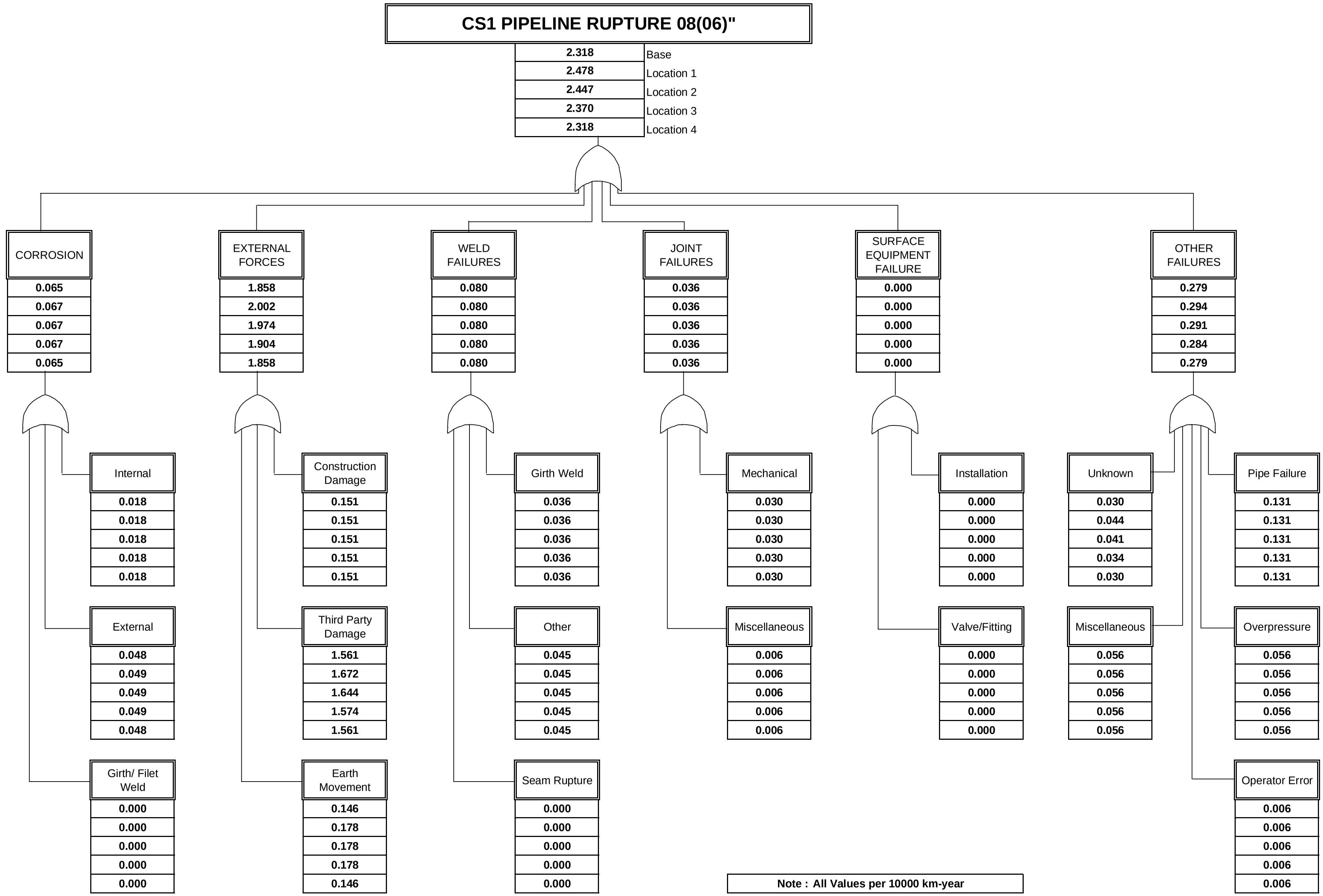


Figure D.1.1 Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

Table D.2.1 Ignition Probability Calculation

Ignition Probability Calculation - Case 1								
Release Type	ADDT	Speed [km/h]	Cloud Length [m]	Cloud Probability	Ignition per Vehicle	Probability of Autoign.	Location Factor	Probability of Ignition
Type G - Location 1								
Leak	5000	80	10	0.95	0.50	0.15	1.00	**0.162**
Hole	5000	80	150	0.95	0.50	0.15	1.00	**0.336**
Rupture	5000	80	200	0.95	0.50	0.15	1.00	**0.397**
D Rupture	5000	80	200	0.95	0.50	0.15	1.00	**0.397**
Type G - Location 1								
Leak	5000	80	10	0.95	0.50	0.15	0.90	**0.161**
Hole	5000	80	150	0.95	0.50	0.15	0.90	**0.317**
Rupture	5000	80	200	0.95	0.50	0.15	0.90	**0.373**
D Rupture	5000	80	200	0.95	0.50	0.15	0.90	**0.373**
Type G - Location 1								
Leak	5000	80	10	0.95	0.50	0.15	0.80	**0.160**
Hole	5000	80	150	0.95	0.50	0.15	0.80	**0.298**
Rupture	5000	80	200	0.95	0.50	0.15	0.80	**0.348**
D Rupture	5000	80	200	0.95	0.50	0.15	0.80	**0.348**
Type G - Location 1								
Leak	5000	80	10	0.95	0.50	0.15	0.10	**0.151**
Hole	5000	80	150	0.95	0.50	0.15	0.10	**0.169**
Rupture	5000	80	200	0.95	0.50	0.15	0.10	**0.175**
D Rupture	5000	80	200	0.95	0.50	0.15	0.10	**0.175**

Table D.2.2 Event Tree Database

Event Tree Database - for All Scenarios											
Release Type	Ignition		Timing		Consequence			Ratio of Occurrence ROO			
	Yes	No	Imm.	Del.	F Fire	Expl.	Imm. J Fire	J Fire	F Fire	Expl.	Disp.
Type G - Location 1											
Leak	0.162	0.838	0.300	0.700	0.900	0.100	0.049	0.162	0.102	0.011	0.838
Hole	0.336	0.664	0.600	0.400	0.700	0.300	0.201	0.336	0.094	0.040	0.664
Rupture	0.397	0.603	0.700	0.300	0.700	0.300	0.278	0.397	0.083	0.036	0.603
D Rupture	0.397	0.603	0.700	0.300	0.700	0.300	0.278	0.397	0.083	0.036	0.603
Type G - Location 1											
Leak	0.161	0.839	0.300	0.700	0.900	0.100	0.048	0.161	0.102	0.011	0.839
Hole	0.317	0.683	0.600	0.400	0.700	0.300	0.190	0.317	0.089	0.038	0.683
Rupture	0.373	0.627	0.650	0.350	0.700	0.300	0.242	0.373	0.091	0.039	0.627
D Rupture	0.373	0.627	0.650	0.350	0.700	0.300	0.242	0.373	0.091	0.039	0.627
Type G - Location 1											
Leak	0.160	0.840	0.300	0.700	0.900	0.100	0.048	0.160	0.101	0.011	0.840
Hole	0.298	0.702	0.600	0.400	0.700	0.300	0.179	0.298	0.084	0.036	0.702
Rupture	0.348	0.652	0.600	0.400	0.700	0.300	0.209	0.348	0.097	0.042	0.652
D Rupture	0.348	0.652	0.600	0.400	0.700	0.300	0.209	0.348	0.097	0.042	0.652
Type G - Location 1											
Leak	0.151	0.849	0.900	0.100	0.900	0.100	0.136	0.151	0.014	0.002	0.849
Hole	0.169	0.831	0.900	0.100	0.700	0.300	0.152	0.169	0.012	0.005	0.831
Rupture	0.175	0.825	0.900	0.100	0.700	0.300	0.157	0.175	0.012	0.005	0.825
D Rupture	0.175	0.825	0.900	0.100	0.700	0.300	0.157	0.175	0.012	0.005	0.825

Table D.2.3
06" Pipeline Consequence Modelling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m]						Max Isopleth Distance [m]						Max Isopleth Distance [m]		
							Flash Fire, Thermal Radiation Flux [W/m2]						Jet Fire, Thermal Radiation Flux [W/m2]						Explosion Overpressure [Pa]		
							12500		25000		37500		12500		25000		37500		6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-VP06-L-MU	Leak .5 cm Dia	7772	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
2	TAC-VP06-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
3	TAC-VP06-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
4	TAC-VP06-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
5	TAC-VP06-H-MU	Hole 10 cm Dia	19.4	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	231	71	42
6	TAC-VP06-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	142	44	26
7	TAC-VP06-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
8	TAC-VP06-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**277**	**86**	**51**
9	TAC-VP06-R-MU	Rupture 15 cm Dia			A,B,C	15.9	280	70	251	50	250	50	174	70	158	40	150	30	686	212	126
10	TAC-VP06-R-MN				D	53.9	352	70	305	40	298	30	157	70	141	50	134	30	686	212	126
11	TAC-VP06-R-MS				E,F	30.2	344	130	278	120	244	120	190	70	174	40	166	30	187	58	34
12	TAC-VP06-R-MA				**Average**	**100**	**338**	**88**	**288**	**66**	**274**	**60**	**170**	**70**	**154**	**45**	**146**	**30**	**535**	**165**	**98**
13	TAC-VP06-DR-MU	Double Rupture 21.2 cm Equ. Dia			A,B,C	15.9	417	140	348	120	313	120	237	100	215	60	205	50	509	158	93
14	TAC-VP06-DR-MN				D	53.9	491	120	387	100	340	80	213	100	192	60	181	50	380	118	70
15	TAC-VP06-DR-MS				E,F	30.2	424	160	338	140	294	140	259	90	237	60	226	40	217	67	40
16	TAC-VP06-DR-MA				**Average**	**100**	**459**	**135**	**366**	**115**	**322**	**104**	**231**	**97**	**209**	**60**	**198**	**47**	**351**	**109**	**65**

Table D.3.1
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E h/day	Nt trip/day	Nd days/week	Nw weeks/year	L km/trip	V km/h	LISRF	IF	OF	Sfi	Sfo	ISRF
1	CS 1 Type G	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.0020
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.0005
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.0075
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.0877
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.1583

Table D.3.2
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS1-Location 1																
GAS RELEASE	Leak	4.92E-04						-	-	-	-	-	-	-	-	-
	Hole	1.84E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	7.97E-05	0.1	6	0.25	2.39E-08	1.32E-08	-	-	-	-	-	-	-
	Hole		0.336	6.17E-05	0.1	102	0.25	3.15E-07	3.14E-07	3.13E-07	3.05E-07	2.74E-07	-	-	-	-
	Rupture		0.397	1.68E-05	0.1	146	0.25	1.22E-07	1.22E-07	1.22E-07	1.21E-07	1.15E-07	-	-	-	-
	D Rupture		0.397	8.75E-06	0.1	198	0.25	8.66E-08	8.66E-08	8.65E-08	8.59E-08	8.38E-08	5.65E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.102	5.02E-05	0.5	12	0.25	1.51E-07	1.37E-07	8.32E-08	-	-	-	-	-	-
	Hole		0.094	1.73E-05	0.5	236	0.25	1.02E-06	1.02E-06	1.02E-06	1.01E-06	9.95E-07	7.86E-07	5.40E-07	-	-
	Rupture		0.083	3.50E-06	0.5	274	0.25	2.40E-07	2.40E-07	2.40E-07	2.39E-07	2.36E-07	2.01E-07	1.64E-07	9.82E-08	-
	D Rupture		0.083	1.83E-06	0.5	322	0.25	1.47E-07	1.47E-07	1.47E-07	1.47E-07	1.45E-07	1.30E-07	1.15E-07	9.28E-08	5.35E-08
FLASH FIRE - Parallel	Leak		0.102	5.02E-05	0.5	2	0.25	2.51E-08	-	-	-	-	-	-	-	-
	Hole		0.094	1.73E-05	0.5	47	0.25	2.03E-07	2.02E-07	1.98E-07	1.72E-07	-	-	-	-	-
	Rupture		0.083	3.50E-06	0.5	60	0.25	5.26E-08	5.24E-08	5.18E-08	4.78E-08	2.91E-08	-	-	-	-
	D Rupture		0.083	1.83E-06	0.5	104	0.25	4.75E-08	4.75E-08	4.73E-08	4.61E-08	4.17E-08	-	-	-	-
EXPLOSION	Leak		0.011	5.41E-06	0.1	2	1.00	2.16E-09	-	-	-	-	-	-	-	-
	Hole		0.040	7.34E-06	0.1	51	1.00	7.49E-08	7.45E-08	7.34E-08	6.53E-08	1.48E-08	-	-	-	-
	Rupture		0.036	1.52E-06	0.1	98	1.00	2.98E-08	2.98E-08	2.96E-08	2.88E-08	2.56E-08	-	-	-	-
	D Rupture		0.036	7.93E-07	0.1	65	1.00	1.03E-08	1.03E-08	1.02E-08	9.52E-09	6.59E-09	-	-	-	-
DISPERSION	Leak		0.838	4.12E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	1.22E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	2.55E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	1.33E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.55E-06	2.49E-06	2.42E-06	2.28E-06	1.97E-06	1.17E-06	8.20E-07	1.91E-07	5.35E-08
			1	Daily Commuter Loc 1			0.0020	5.08E-09	4.97E-09	4.82E-09	4.54E-09	3.92E-09	2.34E-09	1.63E-09	3.80E-10	1.07E-10
			2	Weekly Commuter Loc 1			0.0005	1.33E-09	1.30E-09	1.26E-09	1.19E-09	1.03E-09	6.13E-10	4.28E-10	9.97E-11	2.79E-11
			3	Worker Loc1			0.0075	1.91E-08	1.87E-08	1.82E-08	1.71E-08	1.48E-08	8.81E-09	6.16E-09	1.43E-09	4.02E-10
			4	Resident Loc 1			0.0877	2.23E-07	2.19E-07	2.12E-07	2.00E-07	1.72E-07	1.03E-07	7.19E-08	1.68E-08	4.69E-09
TAC-VP06-MA-CS1-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	6	0.25	2.04E-08	1.13E-08	-	-	-	-	-	-	-
	Hole		0.169	2.90E-05	0.1	102	0.25	1.48E-07	1.48E-07	1.47E-07	1.43E-07	1.29E-07	-	-	-	-
	Rupture		0.175	6.91E-06	0.1	146	0.25	5.05E-08	5.04E-08	5.03E-08	4.97E-08	4.74E-08	-	-	-	-
	D Rupture		0.175	3.61E-06	0.1	198	0.25	3.57E-08	3.57E-08	3.57E-08	3.54E-08	3.45E-08	2.33E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	236	0.25	1.22E-07	1.22E-07	1.21E-07	1.21E-07	1.19E-07	9.39E-08	6.45E-08	-	-
	Rupture		0.012	4.74E-07	0.5	274	0.25	3.25E-08	3.25E-08	3.24E-08	3.23E-08	3.19E-08	2.72E-08	2.22E-08	1.33E-08	-
	D Rupture		0.012	2.47E-07	0.5	322	0.25	1.99E-08	1.99E-08	1.99E-08	1.98E-08	1.97E-08	1.76E-08	1.56E-08	1.25E-08	7.23E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	47	0.25	2.42E-08	2.41E-08	2.37E-08	2.05E-08	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	60	0.25	7.11E-09	7.08E-09	7.01E-09	6.46E-09	3.93E-09	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	104	0.25	6.43E-09	6.42E-09	6.40E-09	6.24E-09	5.64E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.005	8.59E-07	0.1	51	1.00	8.76E-09	8.72E-09	8.59E-09	7.63E-09	1.73E-09	-	-	-	-
	Rupture		0.005	1.97E-07	0.1	98	1.00	3.87E-09	3.87E-09	3.85E-09	3.74E-09	3.33E-09	-	-	-	-
	D Rupture		0.005	1.03E-07	0.1	65	1.00	1.34E-09	1.34E-09	1.32E-09	1.24E-09	8.56E-10	-	-	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	1.43E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	3.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.70E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.03E-07	4.88E-07	4.68E-07	4.48E-07	3.97E-07	1.62E-07	1.02E-07	2.58E-08	7.23E-09
			4	Resident Loc 4			0.0877	4.41E-08	4.28E-08	4.11E-08	3.92E-08	3.48E-08	1.42E-08	8.97E-09	2.27E-09	6.34E-10

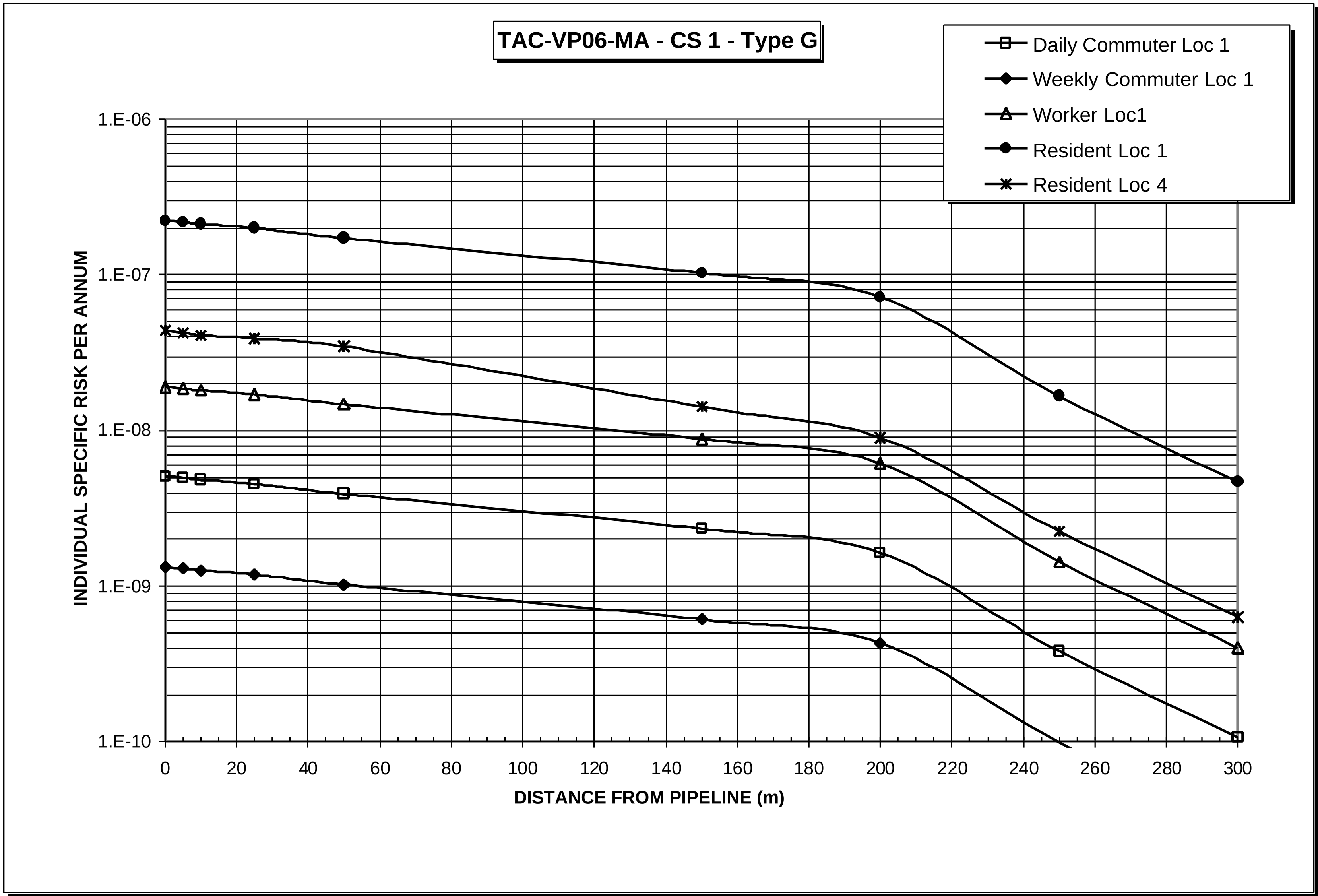


Figure D.3.2 – Transects CS1 VP06 Loc 1(4)

Table D.3.3
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS1-Location 2																
GAS RELEASE	Leak	4.84E-04						-	-	-	-	-	-	-	-	-
	Hole	1.81E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.17E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.18E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	7.84E-05	0.1	6	0.25	2.35E-08	1.30E-08	-	-	-	-	-	-	-
	Hole		0.336	6.08E-05	0.1	102	0.25	3.10E-07	3.10E-07	3.09E-07	3.01E-07	2.70E-07	-	-	-	-
	Rupture		0.397	1.66E-05	0.1	146	0.25	1.21E-07	1.21E-07	1.21E-07	1.19E-07	1.14E-07	-	-	-	-
	D Rupture		0.397	8.65E-06	0.1	198	0.25	8.57E-08	8.57E-08	8.56E-08	8.50E-08	8.29E-08	5.59E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.102	4.94E-05	0.5	12	0.25	1.48E-07	1.35E-07	8.19E-08	-	-	-	-	-	-
	Hole		0.094	1.70E-05	0.5	236	0.25	1.00E-06	1.00E-06	1.00E-06	9.98E-07	9.81E-07	7.75E-07	5.33E-07	-	-
	Rupture		0.083	3.46E-06	0.5	274	0.25	2.37E-07	2.37E-07	2.37E-07	2.36E-07	2.33E-07	1.98E-07	1.62E-07	9.70E-08	-
	D Rupture		0.083	1.81E-06	0.5	322	0.25	1.46E-07	1.46E-07	1.46E-07	1.45E-07	1.44E-07	1.29E-07	1.14E-07	9.18E-08	5.29E-08
FLASH FIRE - Parallel	Leak		0.102	4.94E-05	0.5	2	0.25	2.47E-08	-	-	-	-	-	-	-	-
	Hole		0.094	1.70E-05	0.5	47	0.25	2.00E-07	1.99E-07	1.95E-07	1.69E-07	-	-	-	-	-
	Rupture		0.083	3.46E-06	0.5	60	0.25	5.19E-08	5.17E-08	5.12E-08	4.72E-08	2.87E-08	-	-	-	-
	D Rupture		0.083	1.81E-06	0.5	104	0.25	4.70E-08	4.70E-08	4.68E-08	4.57E-08	4.13E-08	-	-	-	-
EXPLOSION	Leak		0.011	5.32E-06	0.1	2	1.00	2.13E-09	-	-	-	-	-	-	-	-
	Hole		0.040	7.24E-06	0.1	51	1.00	7.38E-08	7.35E-08	7.24E-08	6.44E-08	1.46E-08	-	-	-	-
	Rupture		0.036	1.50E-06	0.1	98	1.00	2.94E-08	2.94E-08	2.93E-08	2.85E-08	2.53E-08	-	-	-	-
	D Rupture		0.036	7.85E-07	0.1	65	1.00	1.02E-08	1.02E-08	1.01E-08	9.42E-09	6.52E-09	-	-	-	-
DISPERSION	Leak		0.838	4.06E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	1.20E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	2.51E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	1.31E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.51E-06	2.46E-06	2.39E-06	2.25E-06	1.94E-06	1.16E-06	8.09E-07	1.89E-07	5.29E-08
			1	Daily Commuter Loc 2			0.0020	5.01E-09	4.90E-09	4.75E-09	4.48E-09	3.87E-09	2.31E-09	1.61E-09	3.76E-10	1.05E-10
			2	Weekly Commuter Loc 2			0.0005	1.31E-09	1.28E-09	1.25E-09	1.17E-09	1.01E-09	6.05E-10	4.22E-10	9.86E-11	2.76E-11
			3	Worker Loc2			0.0075	1.89E-08	1.85E-08	1.79E-08	1.69E-08	1.46E-08	8.70E-09	6.08E-09	1.42E-09	3.97E-10
			4	Resident Loc 2			0.0877	2.20E-07	2.16E-07	2.09E-07	1.97E-07	1.70E-07	1.02E-07	7.10E-08	1.66E-08	4.64E-09
TAC-VP06-MA-CS1-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	6	0.25	2.04E-08	1.13E-08	-	-	-	-	-	-	-
	Hole		0.169	2.90E-05	0.1	102	0.25	1.48E-07	1.48E-07	1.47E-07	1.43E-07	1.29E-07	-	-	-	-
	Rupture		0.175	6.91E-06	0.1	146	0.25	5.05E-08	5.04E-08	5.03E-08	4.97E-08	4.74E-08	-	-	-	-
	D Rupture		0.175	3.61E-06	0.1	198	0.25	3.57E-08	3.57E-08	3.57E-08	3.54E-08	3.45E-08	2.33E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	236	0.25	1.22E-07	1.22E-07	1.21E-07	1.21E-07	1.19E-07	9.39E-08	6.45E-08	-	-
	Rupture		0.012	4.74E-07	0.5	274	0.25	3.25E-08	3.25E-08	3.24E-08	3.23E-08	3.19E-08	2.72E-08	2.22E-08	1.33E-08	-
	D Rupture		0.012	2.47E-07	0.5	322	0.25	1.99E-08	1.99E-08	1.99E-08	1.98E-08	1.97E-08	1.76E-08	1.56E-08	1.25E-08	7.23E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	47	0.25	2.42E-08	2.41E-08	2.37E-08	2.05E-08	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	60	0.25	7.11E-09	7.08E-09	7.01E-09	6.46E-09	3.93E-09	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	104	0.25	6.43E-09	6.42E-09	6.40E-09	6.24E-09	5.64E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.005	8.59E-07	0.1	51	1.00	8.76E-09	8.72E-09	8.59E-09	7.63E-09	1.73E-09	-	-	-	-
	Rupture		0.005	1.97E-07	0.1	98	1.00	3.87E-09	3.87E-09	3.85E-09	3.74E-09	3.33E-09	-	-	-	-
	D Rupture		0.005	1.03E-07	0.1	65	1.00	1.34E-09	1.34E-09	1.32E-09	1.24E-09	8.56E-10	-	-	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	1.43E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	3.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.70E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.03E-07	4.88E-07	4.68E-07	4.48E-07	3.97E-07	1.62E-07	1.02E-07	2.58E-08	7.23E-09
			4	Resident Loc 4			0.0877	4.41E-08	4.28E-08	4.11E-08	3.92E-08	3.48E-08	1.42E-08	8.97E-09	2.27E-09	6.34E-10

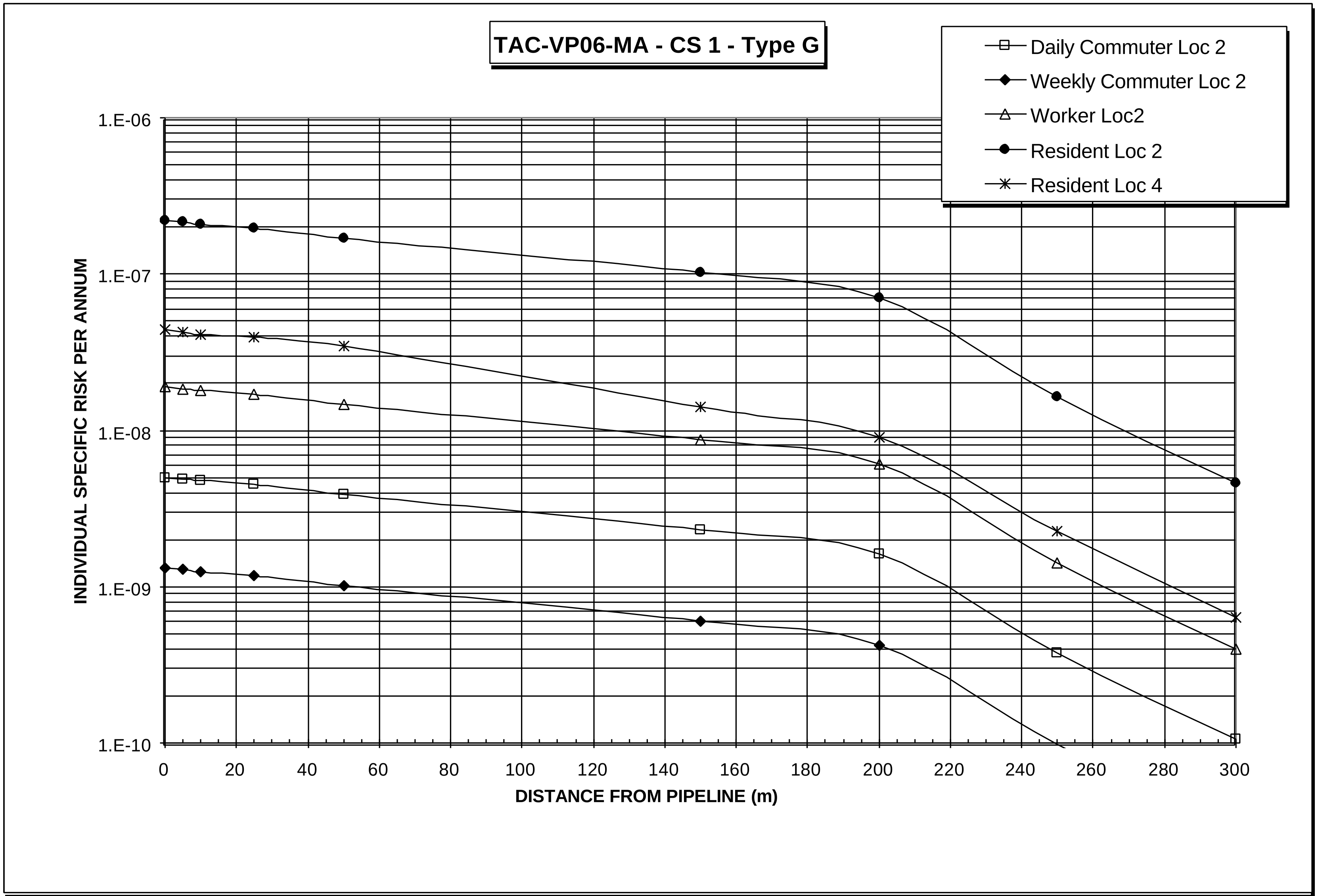


Figure D.3.3 – Transects CS1 VP06 Loc 2(4)

Table D.1.5U
Case Study 1 - Roadway Effects on Pipeline Failure Rate

CS1U ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	External Corrosion	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
								External Corrosion Total	**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
								Third Party DamageTotal	**7.94E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
								Earth Movement Total	**2.33E-05**
	Unknown	Other							1.04E-05
								Unknown Total	**1.04E-05**
2	External Corrosion	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
								External Corrosion Total	**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	10	25	25	km	5.00E-01	1.25E+01	5.00E-02
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06

Table D.1.5U
Case Study 1 - Roadway Effects on Pipeline Failure Rate

CS1U ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		Third Party DamageTotal							**5.00E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							5.01E-03
		Unknown Total							**5.01E-03**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**9.25E-06**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							3.36E-06
		Unknown Total							**3.36E-06**

Table D.1.6U
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

CS1U ROAD TYPE G Pipeline 08(06)									
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.97E-05	2.49E-04	119.0
		Leak	5.30E-05	Leak	36	2.86E-05	8.16E-05	153.9
		Rupture	1.56E-04	Rupture	14	1.11E-05	1.67E-04	107.1
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.19E-06	3.14E-05	119.8
		Leak	2.33E-05	Leak	36	3.74E-06	2.70E-05	116.0
		Rupture	2.97E-06	Rupture	14	1.45E-06	4.42E-06	148.9
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	2.50E-02	2.52E-02	12064.0
		Leak	5.30E-05	Leak	36	1.80E-02	1.81E-02	34072.9
		Rupture	1.56E-04	Rupture	14	7.01E-03	7.16E-03	4587.8
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	2.50E-03	2.53E-03	9633.4
		Leak	2.33E-05	Leak	36	1.80E-03	1.83E-03	7839.5
		Rupture	2.97E-06	Rupture	14	7.01E-04	7.04E-04	23699.0
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.62E-06	2.14E-04	102.2
		Leak	5.30E-05	Leak	36	3.33E-06	5.64E-05	106.3
		Rupture	1.56E-04	Rupture	14	1.29E-06	1.57E-04	100.8
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.40E-06	1.24E-05	310.1
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.68E-06	2.79E-05	106.4
		Leak	2.33E-05	Leak	36	1.21E-06	2.45E-05	105.2
		Rupture	2.97E-06	Rupture	14	4.71E-07	3.44E-06	115.9

Table D.1.8U Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS1U ROAD TYPE G Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**1.06E-04**	**1.81E-02**	**8.08E-05**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	8.16E-05	1.81E-02	5.64E-05	5.30E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.45E-05**	**1.89E-03**	**9.20E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	1.83E-03	2.45E-05	2.33E-05
TOTALS	**4.51E-04**	**4.92E-04**	**2.03E-02**	**4.64E-04**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS1U ROAD TYPE G Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**2.00E-04**	**7.19E-03**	**1.90E-04**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.67E-04	7.16E-03	1.57E-04	1.56E-04
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**7.29E-04**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.42E-06	7.04E-04	3.44E-06	2.97E-06
TOTALS	**2.32E-04**	**2.48E-04**	**7.94E-03**	**2.37E-04**	**2.32E-04**

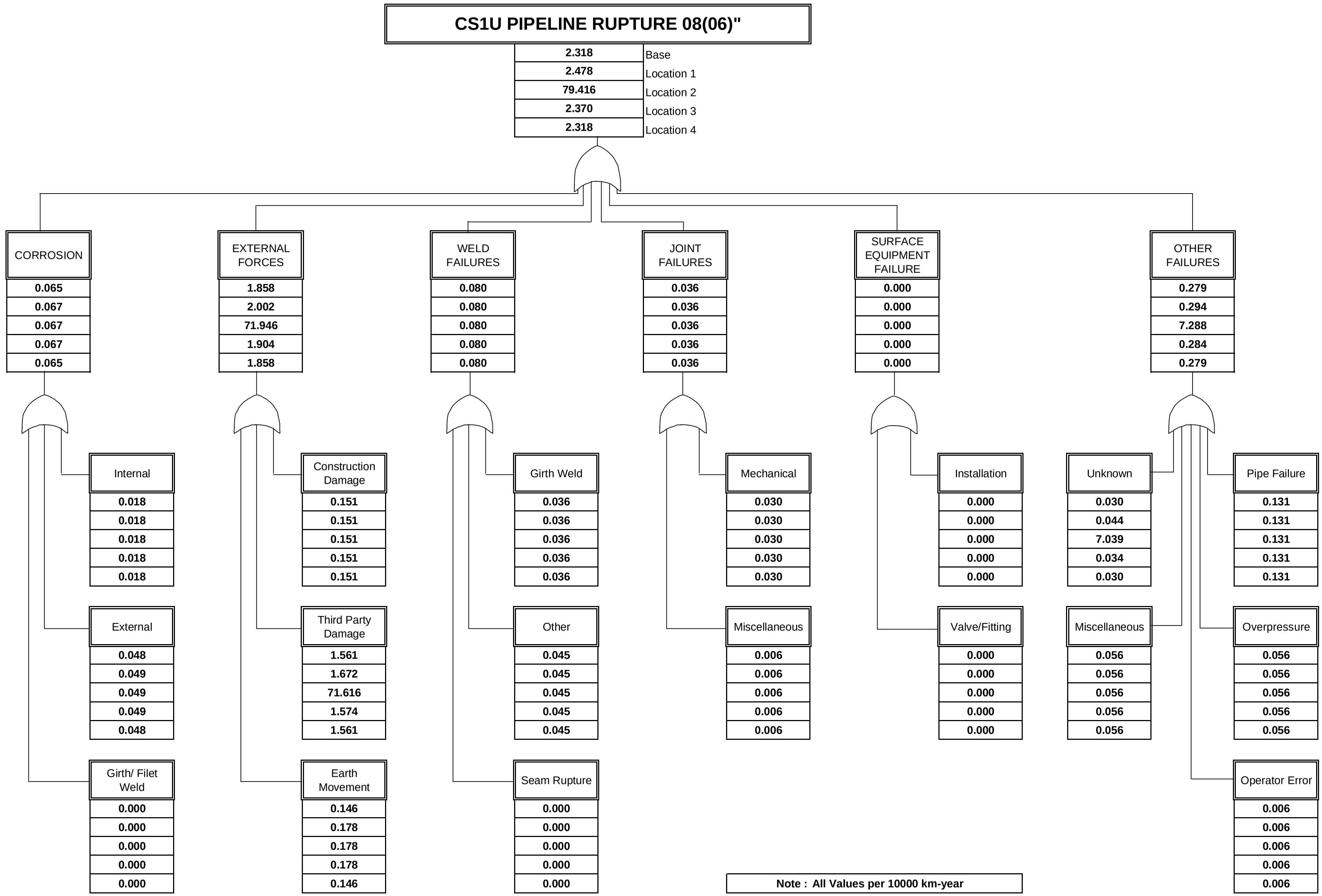


Figure D.1.1U Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

Table D.1.10U
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS1U ROAD TYPE G							
	Pipeline 08(06)"							
Base Leak	73.0%	**4.92E-04**	73.0%	**2.03E-02**	73.0%	**4.64E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**2.48E-04**	27.0%	**7.94E-03**	27.0%	**2.37E-04**	27.0%	**2.32E-04**
Leak	73.0%	4.92E-04	73.0%	2.03E-02	73.0%	4.64E-04	73.0%	4.51E-04
Hole	20.0%	1.84E-04	20.0%	5.88E-03	20.0%	1.76E-04	20.0%	1.72E-04
Rupture	4.6%	4.22E-05	4.6%	1.35E-03	4.6%	4.04E-05	4.6%	3.95E-05
D Rupture	2.4%	2.20E-05	2.4%	7.06E-04	2.4%	2.11E-05	2.4%	2.06E-05

Table D.3.1U
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E	Nt	Nd	Nw	L	V	LISRF	IF	OF	Sfi	Sfo	ISRF
				h/day	trip/day	days/week	weeks/year	km/trip	km/h						
1	CS 1 Type G	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.0020
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.0005
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.0075
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.0877
		5	Ditcher Operator	10	n/a	5	50	n/a	n/a	0.2862	0.00	1.00	0.1	1.0	0.2862
		6	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.1583

Table D.3.3U
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS1U-Location 2																
GAS RELEASE	Leak	2.03E-02						-	-	-	-	-	-	-	-	-
	Hole	5.88E-03						-	-	-	-	-	-	-	-	-
	Rupture	1.35E-03						-	-	-	-	-	-	-	-	-
	D Rupture	7.06E-04						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	3.29E-03	0.1	6	0.25	9.87E-07	5.45E-07	-	-	-	-	-	-	-
	Hole		0.336	1.98E-03	0.1	102	0.25	1.01E-05	1.01E-05	1.00E-05	9.77E-06	8.78E-06	-	-	-	-
	Rupture		0.397	5.36E-04	0.1	146	0.25	3.91E-06	3.91E-06	3.90E-06	3.85E-06	3.68E-06	-	-	-	-
	D Rupture		0.397	2.80E-04	0.1	198	0.25	2.77E-06	2.77E-06	2.77E-06	2.75E-06	2.68E-06	1.81E-06	-	-	-
FLASH FIRE - Transverse	Leak		0.102	2.07E-03	0.5	12	0.25	6.21E-06	5.65E-06	3.43E-06	-	-	-	-	-	-
	Hole		0.094	5.53E-04	0.5	236	0.25	3.26E-05	3.26E-05	3.26E-05	3.24E-05	3.19E-05	2.52E-05	1.73E-05	-	-
	Rupture		0.083	1.12E-04	0.5	274	0.25	7.68E-06	7.67E-06	7.67E-06	7.64E-06	7.55E-06	6.42E-06	5.25E-06	3.14E-06	-
	D Rupture		0.083	5.86E-05	0.5	322	0.25	4.72E-06	4.72E-06	4.71E-06	4.70E-06	4.66E-06	4.17E-06	3.70E-06	2.97E-06	1.71E-06
FLASH FIRE - Parallel	Leak		0.102	2.07E-03	0.5	2	0.25	1.04E-06	-	-	-	-	-	-	-	-
	Hole		0.094	5.53E-04	0.5	47	0.25	6.49E-06	6.46E-06	6.35E-06	5.50E-06	-	-	-	-	-
	Rupture		0.083	1.12E-04	0.5	60	0.25	1.68E-06	1.67E-06	1.66E-06	1.53E-06	9.29E-07	-	-	-	-
	D Rupture		0.083	5.86E-05	0.5	104	0.25	1.52E-06	1.52E-06	1.52E-06	1.48E-06	1.34E-06	-	-	-	-
EXPLOSION	Leak		0.011	2.23E-04	0.1	2	1.00	8.93E-08	-	-	-	-	-	-	-	-
	Hole		0.040	2.35E-04	0.1	51	1.00	2.40E-06	2.39E-06	2.35E-06	2.09E-06	4.73E-07	-	-	-	-
	Rupture		0.036	4.86E-05	0.1	98	1.00	9.53E-07	9.51E-07	9.48E-07	9.21E-07	8.19E-07	-	-	-	-
	D Rupture		0.036	2.54E-05	0.1	65	1.00	3.30E-07	3.29E-07	3.26E-07	3.05E-07	2.11E-07	-	-	-	-
DISPERSION	Leak		0.838	1.70E-02	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	3.90E-03	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	8.14E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	4.26E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	8.35E-05	8.13E-05	7.82E-05	7.30E-05	6.30E-05	3.76E-05	2.63E-05	6.11E-06	1.71E-06
			1	Daily Commuter Loc 2			0.0020	1.66E-07	1.62E-07	1.56E-07	1.45E-07	1.25E-07	7.49E-08	5.23E-08	1.22E-08	3.41E-09
			2	Weekly Commuter Loc 2			0.0005	4.36E-08	4.24E-08	4.08E-08	3.81E-08	3.29E-08	1.96E-08	1.37E-08	3.19E-09	8.95E-10
			3	Worker Loc 2			0.0075	6.27E-07	6.10E-07	5.88E-07	5.48E-07	4.73E-07	2.82E-07	1.97E-07	4.59E-08	1.29E-08
			4	Resident Loc 2			0.0877	7.32E-06	7.13E-06	6.86E-06	6.40E-06	5.52E-06	3.30E-06	2.30E-06	5.36E-07	1.50E-07
			5	Ditcher Operator			0.2862	2.39E-05	2.33E-05	2.24E-05	2.09E-05	1.80E-05	1.08E-05	7.51E-06	1.75E-06	4.90E-07
TAC-VP06-MA-CS1U-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	6	0.25	2.04E-08	1.13E-08	-	-	-	-	-	-	-
	Hole		0.169	2.90E-05	0.1	102	0.25	1.48E-07	1.48E-07	1.47E-07	1.43E-07	1.29E-07	-	-	-	-
	Rupture		0.175	6.91E-06	0.1	146	0.25	5.05E-08	5.04E-08	5.03E-08	4.97E-08	4.74E-08	-	-	-	-
	D Rupture		0.175	3.61E-06	0.1	198	0.25	3.57E-08	3.57E-08	3.57E-08	3.54E-08	3.45E-08	2.33E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	236	0.25	1.22E-07	1.22E-07	1.21E-07	1.21E-07	1.19E-07	9.39E-08	6.45E-08	-	-
	Rupture		0.012	4.74E-07	0.5	274	0.25	3.25E-08	3.25E-08	3.24E-08	3.23E-08	3.19E-08	2.72E-08	2.22E-08	1.33E-08	-
	D Rupture		0.012	2.47E-07	0.5	322	0.25	1.99E-08	1.99E-08	1.99E-08	1.98E-08	1.97E-08	1.76E-08	1.56E-08	1.25E-08	7.23E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	47	0.25	2.42E-08	2.41E-08	2.37E-08	2.05E-08	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	60	0.25	7.11E-09	7.08E-09	7.01E-09	6.46E-09	3.93E-09	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	104	0.25	6.43E-09	6.42E-09	6.40E-09	6.24E-09	5.64E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.005	8.59E-07	0.1	51	1.00	8.76E-09	8.72E-09	8.59E-09	7.63E-09	1.73E-09	-	-	-	-
	Rupture		0.005	1.97E-07	0.1	98	1.00	3.87E-09	3.87E-09	3.85E-09	3.74E-09	3.33E-09	-	-	-	-
	D Rupture		0.005	1.03E-07	0.1	65	1.00	1.34E-09	1.34E-09	1.32E-09	1.24E-09	8.56E-10	-	-	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	1.43E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	3.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.70E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.03E-07	4.88E-07	4.68E-07	4.48E-07	3.97E-07	1.62E-07	1.02E-07	2.58E-08	7.23E-09
			4	Resident Loc 4			0.0877	4.41E-08	4.28E-08	4.11E-08	3.92E-08	3.48E-08	1.42E-08	8.97E-09	2.27E-09	6.34E-10

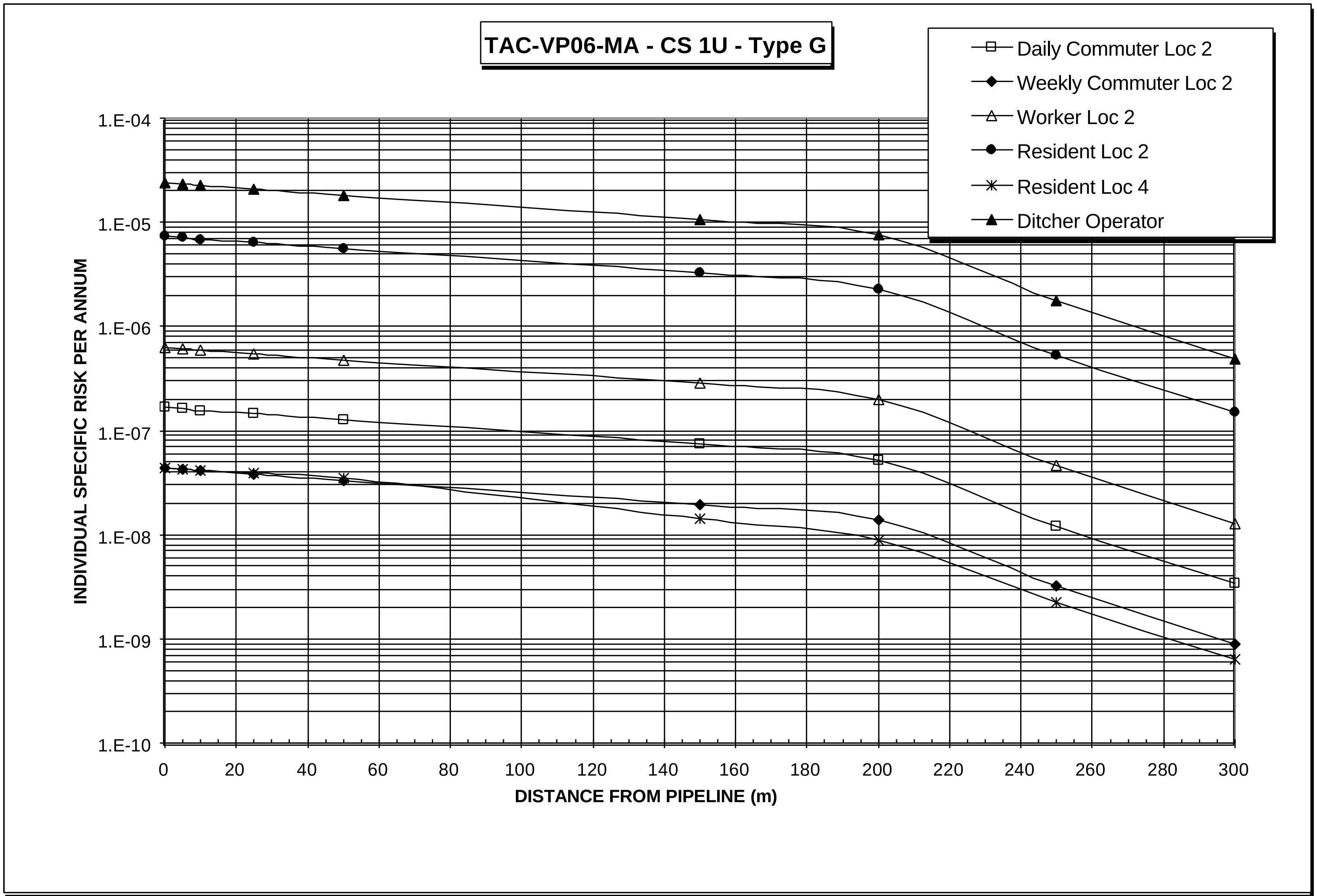


Figure D.3.3U – Transects CS1 VP06 Loc 2(4)

Table D.3.12
Collective Risk Exposure Numbers CS1

Nr	Road Type	ADDT	Hazard	V	Spacing		Number of cars		Number of People	
		cars/day max	m	km/h min	Day m	Night m	Day	Night	Day	Night
1	CS1 Type G	5000	300	80	192	768	1.56	0.39	4	1

Table D.3.13
Automobile Occupant IRI Calculation CS1

Scenario	FLASH FIRE				JET FIRE				EXPLOSION			
Release type	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**
Releases [per km-year]	2.03E-02	5.88E-03	1.35E-03	7.06E-04	2.03E-02	5.88E-03	1.35E-03	7.06E-04	2.03E-02	5.88E-03	1.35E-03	7.06E-04
Interactive Length [km]	10											
Releases [per year]	2.03E-01	5.88E-02	1.35E-02	7.06E-03	2.03E-01	5.88E-02	1.35E-02	7.06E-03	2.03E-01	5.88E-02	1.35E-02	7.06E-03
ROO	0.172	0.480	0.590	0.590	0.108	0.134	0.124	0.124	0.012	0.058	0.053	0.053
Probability [per year]	3.49E-02	2.82E-02	7.96E-03	4.16E-03	2.20E-02	7.90E-03	1.67E-03	8.74E-04	2.44E-03	3.39E-03	7.17E-04	3.75E-04
Probability of Fatality	0.50				0.10				0.10			
Sheild Factor	0.10				0.10				0.10			
P-Footprint Factor	0.12				0.25				0.80			
Individual Risk Intensity	2.09E-04	1.69E-04	4.78E-05	2.50E-05	5.50E-05	1.98E-05	4.18E-06	2.19E-06	1.96E-05	2.71E-05	5.73E-06	3.00E-06
Hazard Distance [m]	9.0	204.0	294.0	327.0	4.0	8.0	210.0	290.0	0.0	82.0	169.0	208.0

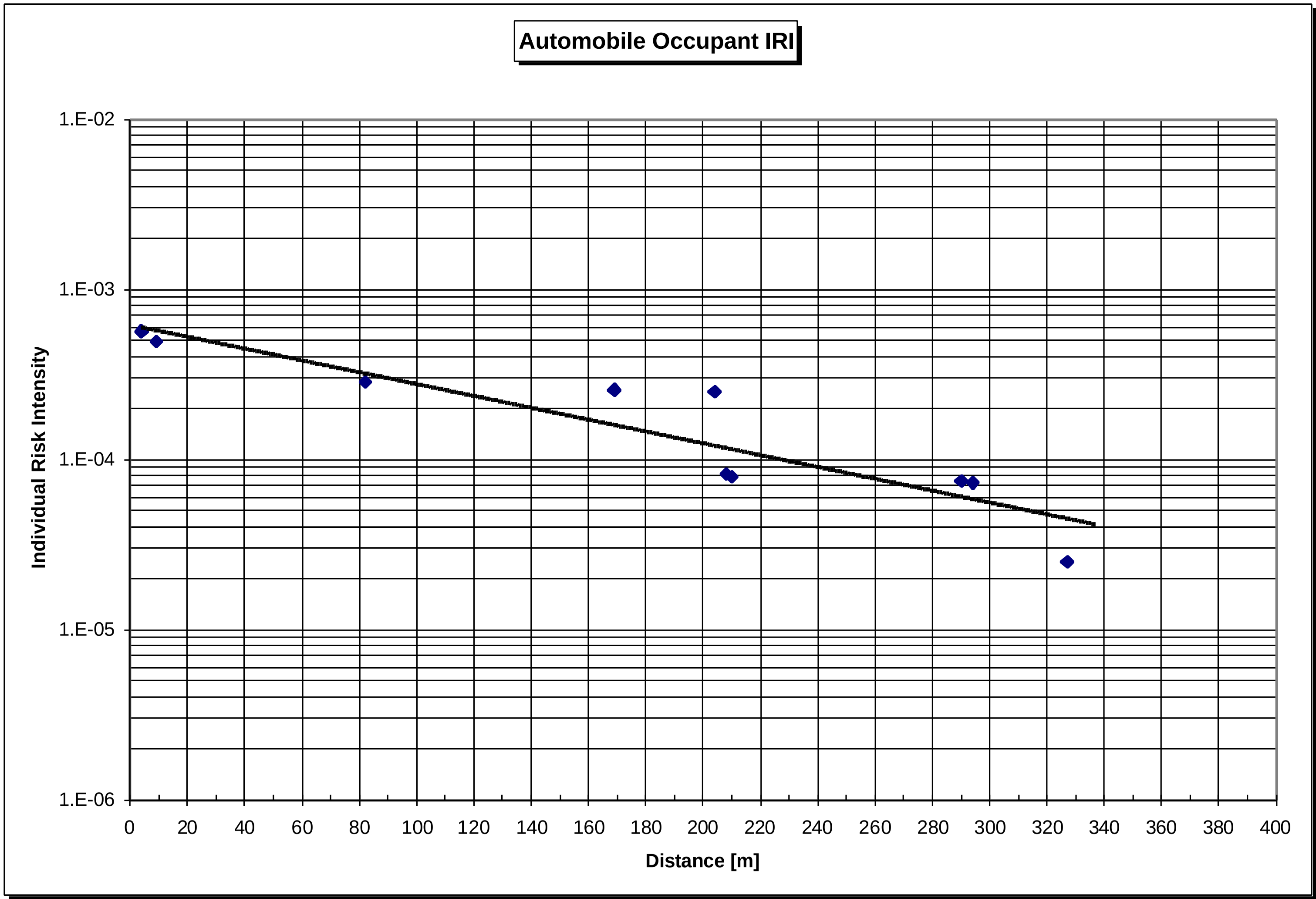


Figure D.3.13 – CS1 – Automobile Occupant IRI

Table D.3.14
Calculated Probabilities of Fatalities for CS1

Location	Time	Distance [m]	IRI	OCR Factor	Directional Factor	Dynamic Factor	N Footprint Factor	N [ppl]	N in Footprint [ppl]	Annual Chance of N Fatalities
Road	Night	100	2.00E-04	0.50	0.5	0.06	0.50	1	0.50	3.00E-06
		200	1.00E-04	0.50	0.5	0.12	0.50	1	0.50	3.00E-06
		300	6.00E-05	0.50	0.5	0.18	0.50	2	1.00	2.70E-06
	Day	100	2.00E-04	0.50	0.5	0.06	0.50	2	1.00	3.00E-06
		200	1.00E-04	0.50	0.5	0.12	0.50	4	2.00	3.00E-06
		300	6.00E-05	0.50	0.5	0.18	0.50	6	3.00	2.70E-06

N in Footprint [ppl]	Annual Chance of N Fatalities	Annual Chance of N or more Fatalities
1	1.17E-05	1.74E-05
2	3.00E-06	5.70E-06
3	2.70E-06	2.70E-06

OCR Outdor Collective Risk factor
Dinamic Factor Amount of time as % of 60 sec in the footprint

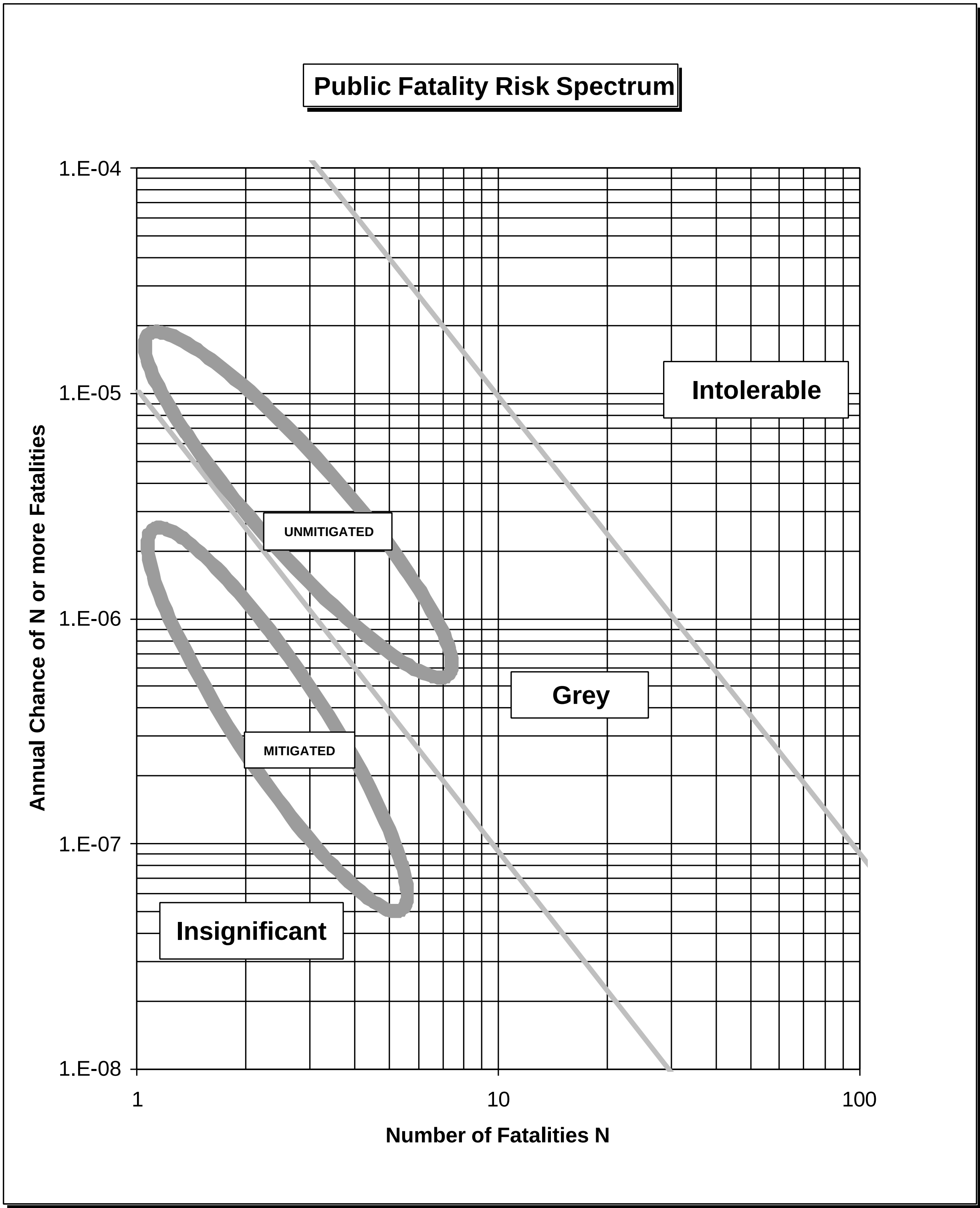


Figure D.3.14 – Collective Risk for CS1 Unmitigated

Table D.1.5W
Case Study 1 - Roadway Effects on Pipeline Failure Rate - Worst Case

CS1W ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris, Rockfall	2	25	1	km	1.00E-03	1.00E-03	2.00E-05
		Culvert Maintenance	2	25	10	item	1.00E-03	1.00E-02	2.00E-04
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-02	1.00E-01	8.00E-05
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Major Signs	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Ditch Grading - Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-03	2.00E-03	1.60E-06
		Major Section Repair, Excavation of Embankment	100	25	0.5	km	1.00E-02	5.00E-03	2.00E-06
		New Culvert X	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Culvert II	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility II	50	25	1	item	1.00E-01	1.00E-01	8.00E-05
		New Minor Sign	1	25	2	item	1.00E-02	2.00E-02	8.00E-04
		New Major Sign	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Ditch	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Guard Rail	5	25	5	km	5.00E-01	2.50E+00	2.00E-02
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**2.77E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							2.77E-03
		Unknown Total							**2.77E-03**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing - Debris, Rockfall	2	25	1	km	1.00E-03	1.00E-03	2.00E-05
		Culvert Maintenance	2	25	10	item	1.00E-03	1.00E-02	2.00E-04
		Ditch Grading - Localized	1	25	1	km	1.00E-02	1.00E-02	4.00E-04
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-02	1.00E-01	8.00E-05
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Major Signs	1	25	5	item	1.00E-02	5.00E-02	2.00E-03
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Ditch Grading - Continous	10	25	25	km	5.00E-01	1.25E+01	5.00E-02
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-03	2.00E-03	1.60E-06
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		New Culvert X	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Culvert II	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		New Utility II	50	25	1	item	1.00E-02	1.00E-02	8.00E-06
		New Minor Sign	1	25	2	item	1.00E-02	2.00E-02	8.00E-04
		New Major Sign	1	25	1	item	1.00E-02	1.00E-02	4.00E-04

Table D.1.5W
Case Study 1 - Roadway Effects on Pipeline Failure Rate - Worst Case

CS1W ROAD TYPE G									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Ditch	10	25	5	km	1.00E-01	5.00E-01	2.00E-03
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**5.98E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							5.99E-03
		Unknown Total							**5.99E-03**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-03	5.00E-03	1.00E-04
		Rock Scaling	5	25	2	km	1.00E-04	2.00E-04	1.60E-06
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New Power Line	10	25	5	km	1.00E-02	5.00E-02	2.00E-04
		New Driveway	1	25	1	item	1.00E-02	1.00E-02	4.00E-04
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**7.06E-04**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	20	25	0.5	km	1.00E-05	5.00E-06	1.00E-08
		Flood	100	25	0.5	km	1.00E-05	5.00E-06	2.00E-09
		Earth Movement Total							**2.33E-05**
	Unknown	Other							7.30E-05
		Unknown Total							**7.30E-05**

Table D.1.10W
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS1W ROAD TYPE G							
	Pipeline 08(06)"							
Base Leak	73.0%	**1.14E-02**	73.0%	**2.42E-02**	73.0%	**7.40E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**4.50E-03**	27.0%	**9.45E-03**	27.0%	**3.44E-04**	27.0%	**2.32E-04**
Leak	73.0%	1.14E-02	73.0%	2.42E-02	73.0%	7.40E-04	73.0%	4.51E-04
Hole	20.0%	3.33E-03	20.0%	7.00E-03	20.0%	2.55E-04	20.0%	1.72E-04
Rupture	4.6%	7.67E-04	4.6%	1.61E-03	4.6%	5.87E-05	4.6%	3.95E-05
D Rupture	2.4%	4.00E-04	2.4%	8.40E-04	2.4%	3.06E-05	2.4%	2.06E-05

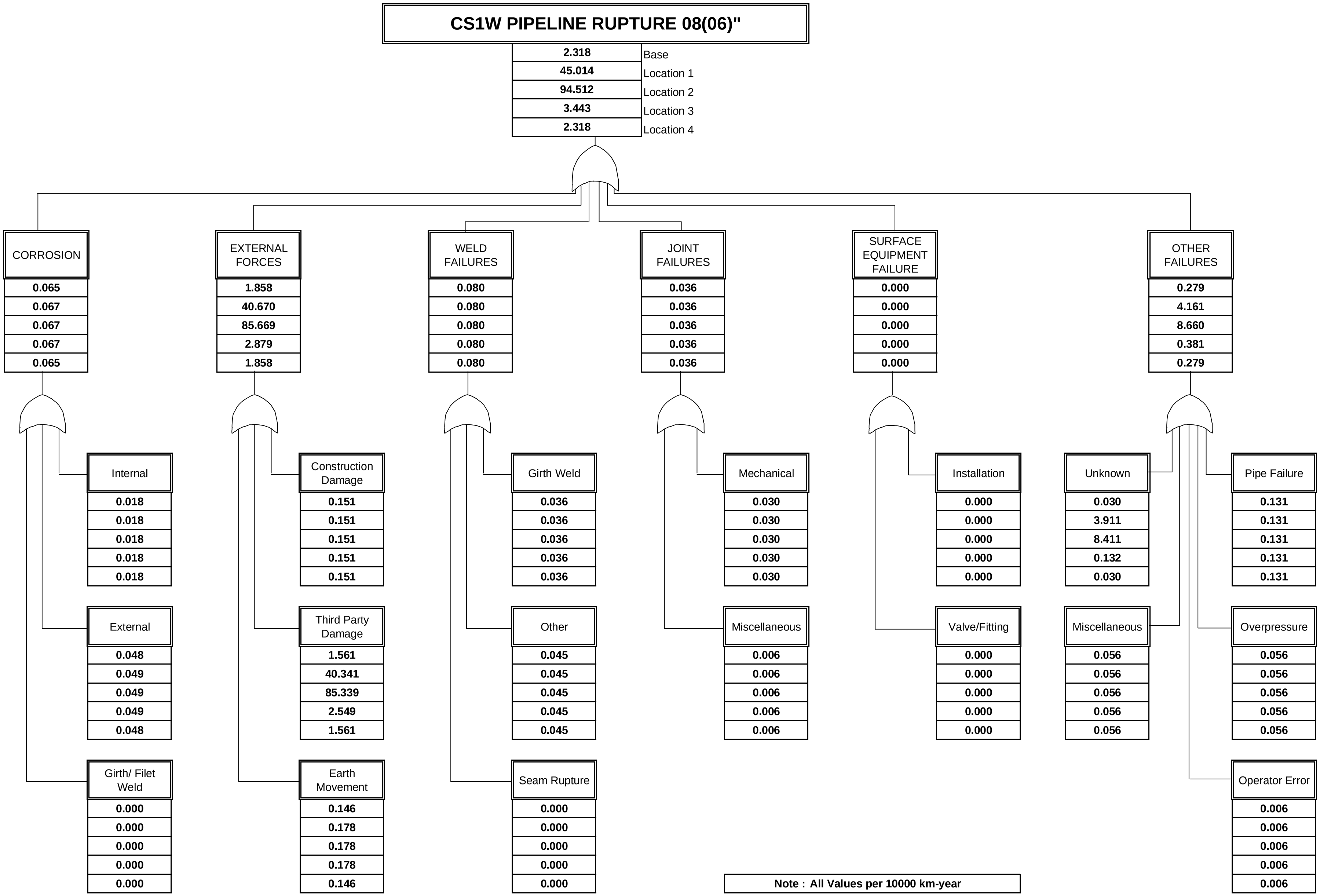


Figure D.1.1W Pipeline Rupture Rate Variation Fault Tree by Location 08(06)" - Worst Case

Table D.3.3W
Individual Risk Calculation - Worst Case

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS1U-Location 2																
GAS RELEASE	Leak	2.42E-02						-	-	-	-	-	-	-	-	-
	Hole	7.00E-03						-	-	-	-	-	-	-	-	-
	Rupture	1.61E-03						-	-	-	-	-	-	-	-	-
	D Rupture	8.40E-04						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.162	3.92E-03	0.1	6	0.25	1.18E-06	6.50E-07	-	-	-	-	-	-	-
	Hole		0.336	2.35E-03	0.1	102	0.25	1.20E-05	1.20E-05	1.19E-05	1.16E-05	1.05E-05	-	-	-	-
	Rupture		0.397	6.39E-04	0.1	146	0.25	4.67E-06	4.66E-06	4.65E-06	4.60E-06	4.38E-06	-	-	-	-
	D Rupture		0.397	3.33E-04	0.1	198	0.25	3.30E-06	3.30E-06	3.30E-06	3.28E-06	3.19E-06	2.16E-06	-	-	-
FLASH FIRE - Transverse	Leak		0.102	2.47E-03	0.5	12	0.25	7.41E-06	6.73E-06	4.09E-06	-	-	-	-	-	-
	Hole		0.094	6.58E-04	0.5	236	0.25	3.88E-05	3.88E-05	3.88E-05	3.86E-05	3.79E-05	3.00E-05	2.06E-05	-	-
	Rupture		0.083	1.34E-04	0.5	274	0.25	9.15E-06	9.15E-06	9.15E-06	9.12E-06	9.00E-06	7.66E-06	6.26E-06	3.75E-06	-
	D Rupture		0.083	6.97E-05	0.5	322	0.25	5.61E-06	5.61E-06	5.61E-06	5.60E-06	5.54E-06	4.97E-06	4.40E-06	3.54E-06	2.04E-06
FLASH FIRE - Parallel	Leak		0.102	2.47E-03	0.5	2	0.25	1.23E-06	-	-	-	-	-	-	-	-
	Hole		0.094	6.58E-04	0.5	47	0.25	7.73E-06	7.69E-06	7.55E-06	6.55E-06	-	-	-	-	-
	Rupture		0.083	1.34E-04	0.5	60	0.25	2.00E-06	2.00E-06	1.98E-06	1.82E-06	1.11E-06	-	-	-	-
	D Rupture		0.083	6.97E-05	0.5	104	0.25	1.81E-06	1.81E-06	1.80E-06	1.76E-06	1.59E-06	-	-	-	-
EXPLOSION	Leak		0.011	2.66E-04	0.1	2	1.00	1.06E-07	-	-	-	-	-	-	-	-
	Hole		0.040	2.80E-04	0.1	51	1.00	2.86E-06	2.84E-06	2.80E-06	2.49E-06	5.63E-07	-	-	-	-
	Rupture		0.036	5.80E-05	0.1	98	1.00	1.14E-06	1.13E-06	1.13E-06	1.10E-06	9.77E-07	-	-	-	-
	D Rupture		0.036	3.02E-05	0.1	65	1.00	3.93E-07	3.92E-07	3.88E-07	3.63E-07	2.51E-07	-	-	-	-
DISPERSION	Leak		0.838	2.03E-02	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.664	4.65E-03	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.603	9.71E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.603	5.07E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	9.94E-05	9.68E-05	9.32E-05	8.69E-05	7.50E-05	4.48E-05	3.13E-05	7.28E-06	2.04E-06
			1	Daily Commuter Loc 2			0.0020	1.98E-07	1.93E-07	1.86E-07	1.73E-07	1.49E-07	8.91E-08	6.23E-08	1.45E-08	4.06E-09
			2	Weekly Commuter Loc 2			0.0005	5.19E-08	5.05E-08	4.86E-08	4.54E-08	3.92E-08	2.34E-08	1.63E-08	3.80E-09	1.06E-09
			3	Worker Loc 2			0.0075	7.46E-07	7.27E-07	7.00E-07	6.53E-07	5.63E-07	3.36E-07	2.35E-07	5.47E-08	1.53E-08
			4	Resident Loc 2			0.0877	8.72E-06	8.49E-06	8.17E-06	7.62E-06	6.58E-06	3.92E-06	2.74E-06	6.39E-07	1.79E-07
			5	Ditcher Operator			0.2862	2.85E-05	2.77E-05	2.67E-05	2.49E-05	2.15E-05	1.28E-05	8.95E-06	2.08E-06	5.84E-07
TAC-VP06-MA-CS1U-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.151	6.81E-05	0.1	6	0.25	2.04E-08	1.13E-08	-	-	-	-	-	-	-
	Hole		0.169	2.90E-05	0.1	102	0.25	1.48E-07	1.48E-07	1.47E-07	1.43E-07	1.29E-07	-	-	-	-
	Rupture		0.175	6.91E-06	0.1	146	0.25	5.05E-08	5.04E-08	5.03E-08	4.97E-08	4.74E-08	-	-	-	-
	D Rupture		0.175	3.61E-06	0.1	198	0.25	3.57E-08	3.57E-08	3.57E-08	3.54E-08	3.45E-08	2.33E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	236	0.25	1.22E-07	1.22E-07	1.21E-07	1.21E-07	1.19E-07	9.39E-08	6.45E-08	-	-
	Rupture		0.012	4.74E-07	0.5	274	0.25	3.25E-08	3.25E-08	3.24E-08	3.23E-08	3.19E-08	2.72E-08	2.22E-08	1.33E-08	-
	D Rupture		0.012	2.47E-07	0.5	322	0.25	1.99E-08	1.99E-08	1.99E-08	1.98E-08	1.97E-08	1.76E-08	1.56E-08	1.25E-08	7.23E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.012	2.06E-06	0.5	47	0.25	2.42E-08	2.41E-08	2.37E-08	2.05E-08	-	-	-	-	-
	Rupture		0.012	4.74E-07	0.5	60	0.25	7.11E-09	7.08E-09	7.01E-09	6.46E-09	3.93E-09	-	-	-	-
	D Rupture		0.012	2.47E-07	0.5	104	0.25	6.43E-09	6.42E-09	6.40E-09	6.24E-09	5.64E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.005	8.59E-07	0.1	51	1.00	8.76E-09	8.72E-09	8.59E-09	7.63E-09	1.73E-09	-	-	-	-
	Rupture		0.005	1.97E-07	0.1	98	1.00	3.87E-09	3.87E-09	3.85E-09	3.74E-09	3.33E-09	-	-	-	-
	D Rupture		0.005	1.03E-07	0.1	65	1.00	1.34E-09	1.34E-09	1.32E-09	1.24E-09	8.56E-10	-	-	-	-
DISPERSION	Leak		0.849	3.83E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.831	1.43E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.825	3.26E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.825	1.70E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.03E-07	4.88E-07	4.68E-07	4.48E-07	3.97E-07	1.62E-07	1.02E-07	2.58E-08	7.23E-09
			4	Resident Loc 4			0.0877	4.41E-08	4.28E-08	4.11E-08	3.92E-08	3.48E-08	1.42E-08	8.97E-09	2.27E-09	6.34E-10

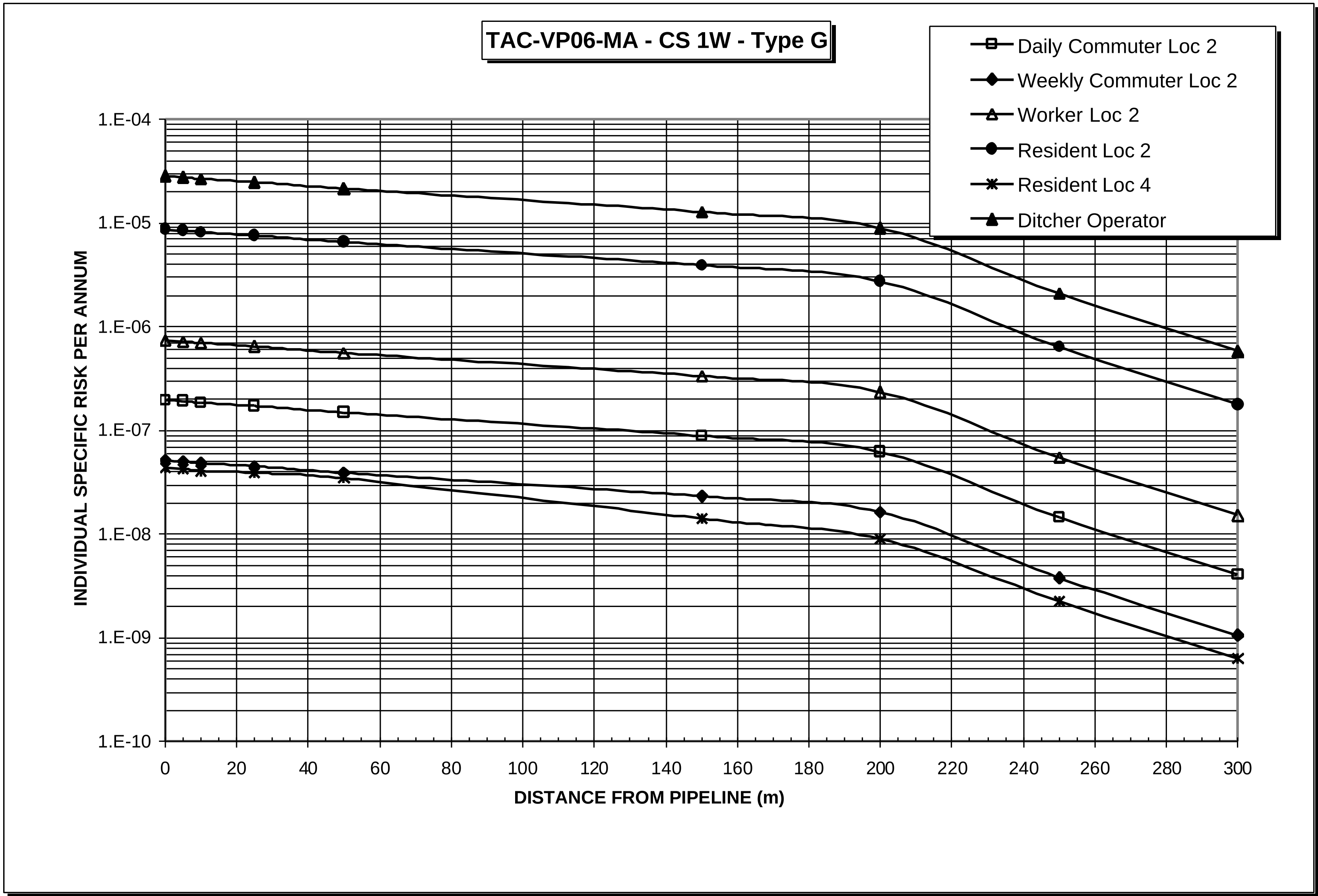


Figure D.3.3W – Transects CS1 VP06 Loc 2(4) – Worst Case

Table D.3.13W
Automobile Occupant IRI Calculation CS1W- Worst Case

Scenario	FLASH FIRE				JET FIRE				EXPLOSION			
Release type	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**
Releases [per km-year]	2.42E-02	7.00E-03	1.61E-03	8.40E-04	2.42E-02	7.00E-03	1.61E-03	8.40E-04	2.42E-02	7.00E-03	1.61E-03	8.40E-04
Interactive Length [km]	10											
Releases [per year]	2.42E-01	7.00E-02	1.61E-02	8.40E-03	2.42E-01	7.00E-02	1.61E-02	8.40E-03	2.42E-01	7.00E-02	1.61E-02	8.40E-03
ROO	0.172	0.480	0.590	0.590	0.108	0.134	0.124	0.124	0.012	0.058	0.053	0.053
Probability [per year]	4.16E-02	3.36E-02	9.50E-03	4.95E-03	2.62E-02	9.41E-03	1.99E-03	1.04E-03	2.91E-03	4.03E-03	8.55E-04	4.46E-04
Probability of Fatality	0.50				0.10				0.10			
Sheild Factor	0.10				0.10				0.10			
P-Footprint Factor	0.12				0.25				0.80			
Individual Risk Intensity	2.50E-04	2.02E-04	5.70E-05	2.97E-05	6.56E-05	2.35E-05	4.99E-06	2.60E-06	2.33E-05	3.22E-05	6.84E-06	3.57E-06
Hazard Distance [m]	9.0	204.0	294.0	327.0	4.0	8.0	210.0	290.0	0.0	82.0	169.0	208.0

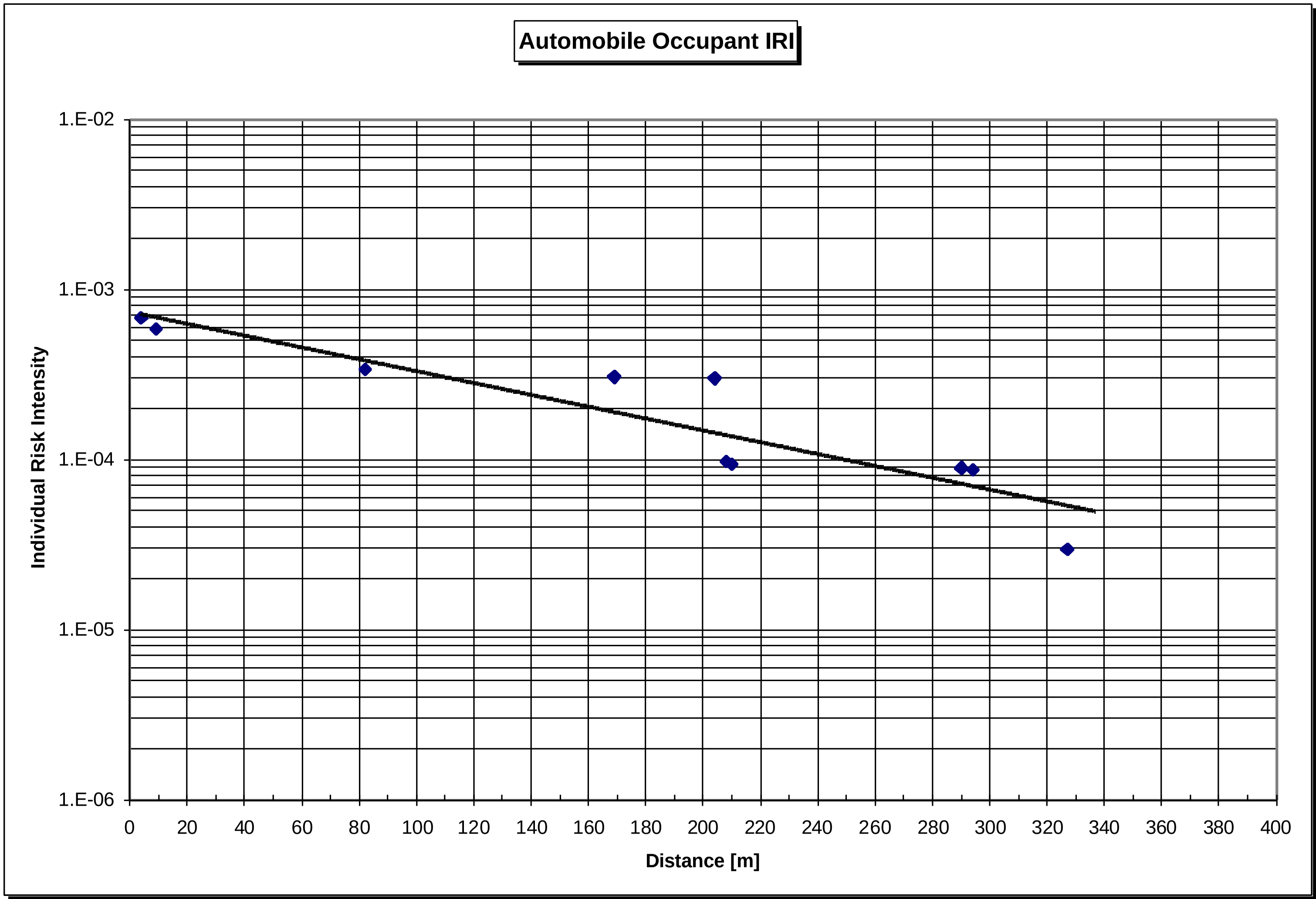


Figure D.3.13W – Automobile Occupant IRI CS1W – Worst Case

Table D.3.14W
Calculated Probabilities of Fatalities for CS1W -Worst Case

Location	Time	Distance [m]	IRI	OCR Factor	Directional Factor	Dynamic Factor	N Footprint Factor	N [ppl]	N in Footprint [ppl]	Annual Chance of N Fatalities
Road	Night	100	3.00E-04	0.50	0.5	0.06	0.50	1	0.50	4.50E-06
		200	2.00E-04	0.50	0.5	0.12	0.50	1	0.50	6.00E-06
		300	6.00E-05	0.50	0.5	0.18	0.50	2	1.00	2.70E-06
	Day	100	2.00E-04	0.50	0.5	0.06	0.50	2	1.00	3.00E-06
		200	1.00E-04	0.50	0.5	0.12	0.50	4	2.00	3.00E-06
		300	6.00E-05	0.50	0.5	0.18	0.50	6	3.00	2.70E-06

N in Footprint [ppl]	Annual Chance of N Fatalities	Annual Chance of N or more Fatalities
1	1.62E-05	2.19E-05
2	3.00E-06	5.70E-06
3	2.70E-06	2.70E-06

OCR	Outdor Collective Risk factor
Dinamic Factor	Amount of time as % of 60 sec in the footprint

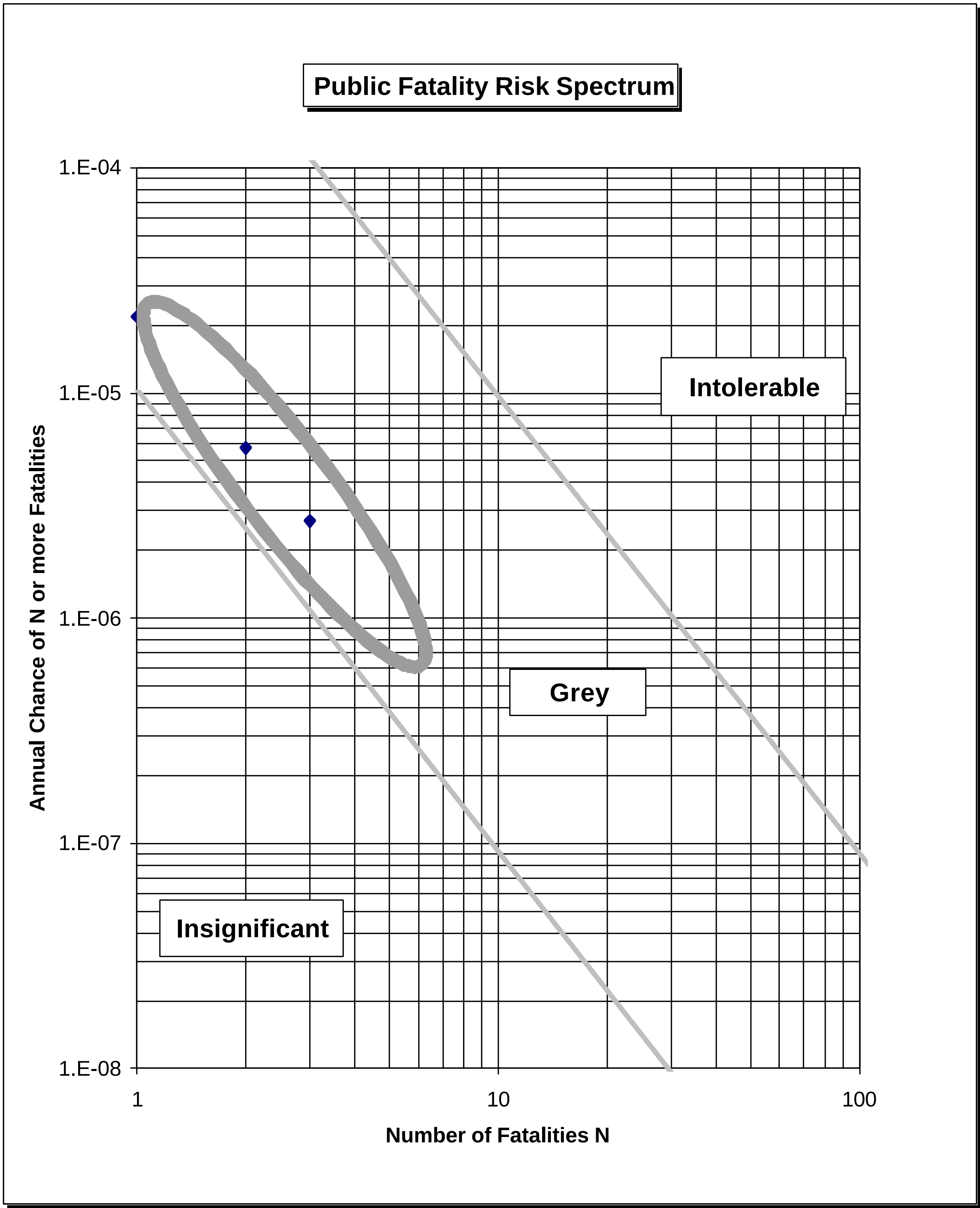


Figure D.3.14W – Collective Risk for CS1W – Worst Case

APPENDIX E

Case Study #2

Table E.1.1F
P/L 08(06)" Leak Failure Rates

AEUB LEAK CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08(06) DISTRIBUTION (%)	PL HP08(06) FAILURE RATE [per km-yr]
CORROSION	**52.4**	**4.21E-04**	**61.7**	**20.1**	**35.7**	**1.61E-04**
Internal	25.6	2.06E-04	75.0	6.4	11.4	5.14E-05
External	26.3	2.11E-04	50.0	13.2	23.4	1.06E-04
Girth/Filet Weld	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
EXTERNAL FORCES	**15.1**	**1.21E-04**	**43.1**	**8.6**	**15.3**	**6.90E-05**
Construction Damage	5.1	4.10E-05	70.7	1.5	2.7	1.20E-05
Third Party Damage	8.8	7.07E-05	25.0	6.6	11.8	5.30E-05
Earth Movement	1.2	9.64E-06	58.5	0.5	0.9	4.00E-06
WELD FAILURES	**10.6**	**8.51E-05**	**0.0**	**10.6**	**18.9**	**8.51E-05**
Girth Weld	6.2	4.98E-05	0.0	6.2	11.0	4.98E-05
Other	2.8	2.25E-05	0.0	2.8	5.0	2.25E-05
Seam Rupture	1.6	1.28E-05	0.0	1.6	2.8	1.28E-05
JOINT FAILURES	**5.6**	**4.50E-05**	**0.0**	**5.6**	**10.0**	**4.50E-05**
Mechanical	5.0	4.02E-05	0.0	5.0	8.9	4.02E-05
Miscellaneous	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
SURFACE EQUIPMENT FAILURE	**5.0**	**4.02E-05**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	4.02E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	4.5	3.61E-05	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**11.3**	**9.07E-05**	**0.0**	**11.3**	**20.1**	**9.07E-05**
Pipe Failure	5.3	4.26E-05	0.0	5.3	9.4	4.26E-05
Overpressure	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
Operator Error	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
Miscellaneous	2.0	1.61E-05	0.0	2.0	3.6	1.61E-05
Unknown	2.9	2.33E-05	0.0	2.9	5.2	2.33E-05
TOTALS	**100.0**	**8.03E-04**	**43.9**	**56.1**	**100.0**	**4.51E-04**

Table E.1.2F
P/L 08(06)" Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08 DISTRIBUTION (%)	PL HP08(06) FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**2.8**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	0.8	1.78E-06
External	3.2	9.50E-06	50.0	1.6	2.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**21.9**	**62.6**	**80.1**	**1.86E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	6.5	1.51E-05
Third Party Damage	70.1	2.08E-04	25.0	52.6	67.3	1.56E-04
Earth Movement	4.9	1.46E-05	0.0	4.9	6.3	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**3.5**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	1.5	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	1.9	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**1.5**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**12.0**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	5.6	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**21.9**	**78.1**	**100.0**	**2.32E-04**

Table E.1.5F
Case Study 2F - Roadway Effects on Pipeline Failure Rate

CS2F ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	50	25	2	km	1.00E-04	2.00E-04	1.60E-07
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	10	25	2	km	1.00E-05	2.00E-05	8.00E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**7.81E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	50	25	0.5	km	1.00E-05	5.00E-06	4.00E-09
		Flood	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		Earth Movement Total							**2.34E-05**
	Unknown	Other							1.02E-05
		Unknown Total							**1.02E-05**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	50	25	2	km	1.00E-04	2.00E-04	1.60E-07
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	10	25	2	km	1.00E-05	2.00E-05	8.00E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07

Table E.1.5F
Case Study 2F - Roadway Effects on Pipeline Failure Rate

CS2F ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**5.79E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	50	25	0.5	km	1.00E-05	5.00E-06	4.00E-09
		Flood	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		Earth Movement Total							**2.34E-05**
	Unknown	Other							8.23E-06
		Unknown Total							**8.23E-06**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	50	25	2	km	1.00E-04	2.00E-04	1.60E-07
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	10	25	2	km	1.00E-05	2.00E-05	8.00E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
		Third Party DamageTotal							**7.87E-06**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	50	25	0.5	km	1.00E-05	5.00E-06	4.00E-09
		Flood	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		Earth Movement Total							**2.34E-05**
	Unknown	Other							3.23E-06
		Unknown Total							**3.23E-06**

Table E.1.6F
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

CS2F ROAD TYPE E Pipeline 08(06)								
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.90E-05	2.48E-04	118.7
		Leak	5.30E-05	Leak	36	2.81E-05	8.11E-05	153.0
		Rupture	1.56E-04	Rupture	14	1.09E-05	1.67E-04	107.0
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.41E-06	1.24E-05	310.2
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	5.12E-06	3.14E-05	119.5
		Leak	2.33E-05	Leak	36	3.69E-06	2.70E-05	115.8
		Rupture	2.97E-06	Rupture	14	1.43E-06	4.40E-06	148.3
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	2.89E-05	2.38E-04	113.8
		Leak	5.30E-05	Leak	36	2.08E-05	7.39E-05	139.3
		Rupture	1.56E-04	Rupture	14	8.10E-06	1.64E-04	105.2
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.41E-06	1.24E-05	310.2
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	4.11E-06	3.04E-05	115.7
		Leak	2.33E-05	Leak	36	2.96E-06	2.62E-05	112.7
		Rupture	2.97E-06	Rupture	14	1.15E-06	4.12E-06	138.8
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.94E-06	2.13E-04	101.9
		Leak	5.30E-05	Leak	36	2.83E-06	5.59E-05	105.3
		Rupture	1.56E-04	Rupture	14	1.10E-06	1.57E-04	100.7
	Earth Movement	NLC	1.86E-05	NLC	50	1.17E-05	3.02E-05	162.9
		Leak	4.00E-06	Leak	36	8.41E-06	1.24E-05	310.2
		Rupture	1.46E-05	Rupture	14	3.27E-06	1.78E-05	122.5
	Unknown	NLC	2.63E-05	NLC	50	1.61E-06	2.79E-05	106.1
		Leak	2.33E-05	Leak	36	1.16E-06	2.44E-05	105.0
		Rupture	2.97E-06	Rupture	14	4.52E-07	3.42E-06	115.2

Table E.1.8F Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2F ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**1.06E-04**	**9.83E-05**	**8.03E-05**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	8.11E-05	7.39E-05	5.59E-05	5.30E-05
Earth Movement	4.00E-06	1.24E-05	1.24E-05	1.24E-05	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**9.44E-05**	**9.37E-05**	**9.19E-05**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	2.70E-05	2.62E-05	2.44E-05	2.33E-05
TOTALS	**4.51E-04**	**4.91E-04**	**4.83E-04**	**4.64E-04**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2F ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**2.00E-04**	**1.97E-04**	**1.90E-04**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.67E-04	1.64E-04	1.57E-04	1.56E-04
Earth Movement	1.46E-05	1.78E-05	1.78E-05	1.78E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**2.94E-05**	**2.91E-05**	**2.84E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	4.40E-06	4.12E-06	3.42E-06	2.97E-06
TOTALS	**2.32E-04**	**2.48E-04**	**2.45E-04**	**2.37E-04**	**2.32E-04**

Table E.1.10F
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS2F ROAD TYPE E							
	Pipeline 08(06)"							
Base Leak	73.0%	**4.91E-04**	73.0%	**4.83E-04**	73.0%	**4.64E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**2.48E-04**	27.0%	**2.45E-04**	27.0%	**2.37E-04**	27.0%	**2.32E-04**
Leak	73.0%	4.91E-04	73.0%	4.83E-04	73.0%	4.64E-04	73.0%	4.51E-04
Hole	20.0%	1.83E-04	20.0%	1.81E-04	20.0%	1.75E-04	20.0%	1.72E-04
Rupture	4.6%	4.22E-05	4.6%	4.17E-05	4.6%	4.03E-05	4.6%	3.95E-05
D Rupture	2.4%	2.20E-05	2.4%	2.17E-05	2.4%	2.10E-05	2.4%	2.06E-05

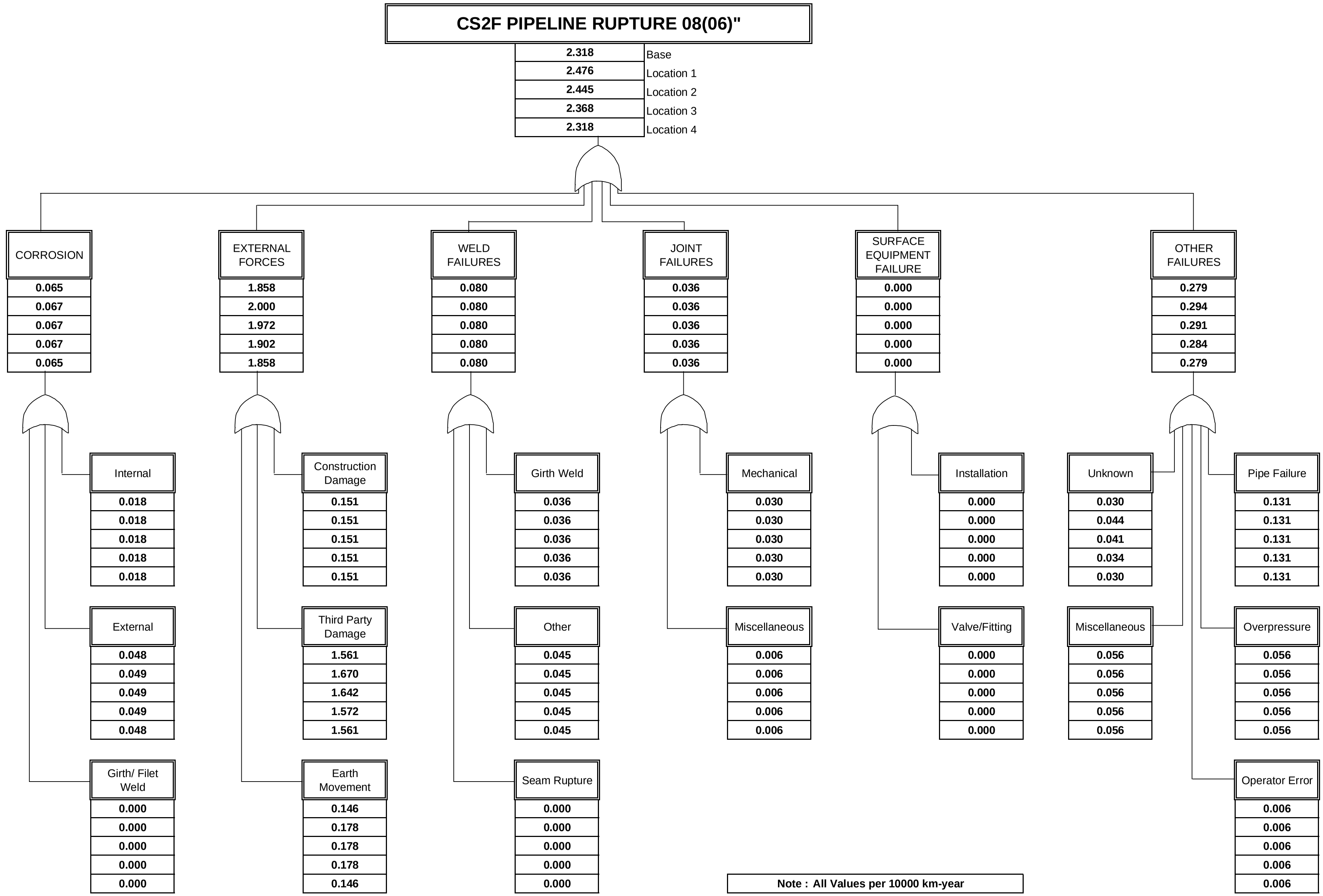


Figure E.1.1F Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

Table E.1.1M
P/L 08(06)" Leak Failure Rates

AEUB LEAK CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08(06) DISTRIBUTION (%)	PL HP08(06) FAILURE RATE [per km-yr]
CORROSION	**52.4**	**4.21E-04**	**61.7**	**20.1**	**35.7**	**1.61E-04**
Internal	25.6	2.06E-04	75.0	6.4	11.4	5.14E-05
External	26.3	2.11E-04	50.0	13.2	23.4	1.06E-04
Girth/Filet Weld	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
EXTERNAL FORCES	**15.1**	**1.21E-04**	**43.1**	**8.6**	**15.3**	**6.90E-05**
Construction Damage	5.1	4.10E-05	70.7	1.5	2.7	1.20E-05
Third Party Damage	8.8	7.07E-05	25.0	6.6	11.8	5.30E-05
Earth Movement	1.2	9.64E-06	58.5	0.5	0.9	4.00E-06
WELD FAILURES	**10.6**	**8.51E-05**	**0.0**	**10.6**	**18.9**	**8.51E-05**
Girth Weld	6.2	4.98E-05	0.0	6.2	11.0	4.98E-05
Other	2.8	2.25E-05	0.0	2.8	5.0	2.25E-05
Seam Rupture	1.6	1.28E-05	0.0	1.6	2.8	1.28E-05
JOINT FAILURES	**5.6**	**4.50E-05**	**0.0**	**5.6**	**10.0**	**4.50E-05**
Mechanical	5.0	4.02E-05	0.0	5.0	8.9	4.02E-05
Miscellaneous	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
SURFACE EQUIPMENT FAILURE	**5.0**	**4.02E-05**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	4.02E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	4.5	3.61E-05	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**11.3**	**9.07E-05**	**0.0**	**11.3**	**20.1**	**9.07E-05**
Pipe Failure	5.3	4.26E-05	0.0	5.3	9.4	4.26E-05
Overpressure	0.6	4.82E-06	0.0	0.6	1.1	4.82E-06
Operator Error	0.5	4.02E-06	0.0	0.5	0.9	4.02E-06
Miscellaneous	2.0	1.61E-05	0.0	2.0	3.6	1.61E-05
Unknown	2.9	2.33E-05	0.0	2.9	5.2	2.33E-05
TOTALS	**100.0**	**8.03E-04**	**43.9**	**56.1**	**100.0**	**4.51E-04**

Table E.1.2M
P/L 08(06)" Rupture Failure Rates

AEUB RUPTURE CAUSE CLASSIFICATION	HISTORICAL DISTRIBUTION (%)	HISTORICAL FAILURE RATE [per km-yr]	REDUCTION (%)	FRACTION OF HISTORICAL VALUE (%)	PL HP08(06) DISTRIBUTION (%)	PL HP08(06) FAILURE RATE [per km-yr]
CORROSION	**5.6**	**1.66E-05**	**60.7**	**2.2**	**2.8**	**6.53E-06**
Internal	2.4	7.13E-06	75.0	0.6	0.8	1.78E-06
External	3.2	9.50E-06	50.0	1.6	2.0	4.75E-06
Girth/Filet Weld	0.0	0.00E+00	-	-	0.0	0.00E+00
EXTERNAL FORCES	**80.1**	**2.38E-04**	**21.9**	**62.6**	**80.1**	**1.86E-04**
Construction Damage	5.1	1.51E-05	0.0	5.1	6.5	1.51E-05
Third Party Damage	70.1	2.08E-04	25.0	52.6	67.3	1.56E-04
Earth Movement	4.9	1.46E-05	0.0	4.9	6.3	1.46E-05
WELD FAILURES	**2.7**	**8.02E-06**	**0.0**	**2.7**	**3.5**	**8.02E-06**
Girth Weld	1.2	3.56E-06	0.0	1.2	1.5	3.56E-06
Other	1.5	4.46E-06	0.0	1.5	1.9	4.46E-06
Seam Rupture	0.0	0.00E+00	-	-	0.0	0.00E+00
JOINT FAILURES	**1.2**	**3.56E-06**	**0.0**	**1.2**	**1.5**	**3.56E-06**
Mechanical	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
Miscellaneous	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
SURFACE EQUIPMENT FAILURE	**1.0**	**2.97E-06**	**100.0**	**0.0**	**0.0**	**0.00E+00**
Installation	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
Valve/Fitting	0.5	1.49E-06	100.0	0.0	0.0	0.00E+00
OTHER FAILURES	**9.4**	**2.79E-05**	**0.0**	**9.4**	**12.0**	**2.79E-05**
Pipe Failure	4.4	1.31E-05	0.0	4.4	5.6	1.31E-05
Overpressure	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Operator Error	0.2	5.94E-07	0.0	0.2	0.3	5.94E-07
Miscellaneous	1.9	5.64E-06	0.0	1.9	2.4	5.64E-06
Unknown	1.0	2.97E-06	0.0	1.0	1.3	2.97E-06
TOTALS	**100.0**	**2.97E-04**	**21.9**	**78.1**	**100.0**	**2.32E-04**

Table E.1.5M
Case Study 2M - Roadway Effects on Pipeline Failure Rate

CS2M ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	1	25	1	km	1.00E-05	1.00E-05	4.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	1	25	2	km	1.00E-03	2.00E-03	8.00E-05
		Mud Slide Cleanup	5	25	2	km	1.00E-05	2.00E-05	1.60E-07
		Land slide Cleanup	5	25	2	km	1.00E-05	2.00E-05	1.60E-07
		Washout Repairs	5	25	2	km	1.00E-05	2.00E-05	1.60E-07
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail (Mitigated)	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**1.58E-04**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	5	25	0.5	km	1.00E-01	5.00E-02	4.00E-04
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		Earth Movement Total							**4.43E-04**
	Unknown	Other							6.03E-05
		Unknown Total							**6.03E-05**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous (Mitigated)	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	5	25	2	km	1.00E-03	2.00E-03	1.60E-05
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07

Table E.1.5M
Case Study 2M - Roadway Effects on Pipeline Failure Rate

CS2M ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
								Third Party DamageTotal	**7.36E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	5	25	0.5	km	1.00E-01	5.00E-02	4.00E-04
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
								Earth Movement Total	**4.43E-04**
	Unknown	Other							5.18E-05
								Unknown Total	**5.18E-05**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
								External Corrosion Total	**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	5	25	2	km	1.00E-03	2.00E-03	1.60E-05
		Mud Slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Land slide Cleanup	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
								Third Party DamageTotal	**2.36E-05**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	5	25	0.5	km	1.00E-01	5.00E-02	4.00E-04
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
								Earth Movement Total	**4.43E-04**
	Unknown	Other							4.68E-05
								Unknown Total	**4.68E-05**

Table E.1.6M
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

CS2M ROAD TYPE E Pipeline 08(06)								
Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	7.92E-05	2.88E-04	137.9
		Leak	5.30E-05	Leak	36	5.70E-05	1.10E-04	207.6
		Rupture	1.56E-04	Rupture	14	2.22E-05	1.78E-04	114.2
	Earth Movement	NLC	1.86E-05	NLC	50	2.22E-04	2.40E-04	1294.8
		Leak	4.00E-06	Leak	36	1.60E-04	1.64E-04	4090.0
		Rupture	1.46E-05	Rupture	14	6.21E-05	7.66E-05	526.5
	Unknown	NLC	2.63E-05	NLC	50	3.01E-05	5.64E-05	214.8
		Leak	2.33E-05	Leak	36	2.17E-05	4.50E-05	193.2
		Rupture	2.97E-06	Rupture	14	8.44E-06	1.14E-05	384.2
2	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	3.68E-05	2.46E-04	117.6
		Leak	5.30E-05	Leak	36	2.65E-05	7.95E-05	150.0
		Rupture	1.56E-04	Rupture	14	1.03E-05	1.66E-04	106.6
	Earth Movement	NLC	1.86E-05	NLC	50	2.22E-04	2.40E-04	1294.8
		Leak	4.00E-06	Leak	36	1.60E-04	1.64E-04	4090.0
		Rupture	1.46E-05	Rupture	14	6.21E-05	7.66E-05	526.5
	Unknown	NLC	2.63E-05	NLC	50	2.59E-05	5.22E-05	198.6
		Leak	2.33E-05	Leak	36	1.86E-05	4.19E-05	180.1
		Rupture	2.97E-06	Rupture	14	7.25E-06	1.02E-05	344.2
3	External Corrosion	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	1.18E-05	2.21E-04	105.7
		Leak	5.30E-05	Leak	36	8.51E-06	6.15E-05	116.1
		Rupture	1.56E-04	Rupture	14	3.31E-06	1.59E-04	102.1
	Earth Movement	NLC	1.86E-05	NLC	50	2.22E-04	2.40E-04	1294.8
		Leak	4.00E-06	Leak	36	1.60E-04	1.64E-04	4090.0
		Rupture	1.46E-05	Rupture	14	6.21E-05	7.66E-05	526.5
	Unknown	NLC	2.63E-05	NLC	50	2.34E-05	4.97E-05	189.1
		Leak	2.33E-05	Leak	36	1.68E-05	4.01E-05	172.4
		Rupture	2.97E-06	Rupture	14	6.55E-06	9.52E-06	320.6

Table E.1.8M Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2M ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**2.86E-04**	**2.55E-04**	**2.37E-04**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	1.10E-04	7.95E-05	6.15E-05	5.30E-05
Earth Movement	4.00E-06	1.64E-04	1.64E-04	1.64E-04	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**1.12E-04**	**1.09E-04**	**1.08E-04**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	4.50E-05	4.19E-05	4.01E-05	2.33E-05
TOTALS	**4.51E-04**	**6.90E-04**	**6.56E-04**	**6.36E-04**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2M ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**2.70E-04**	**2.58E-04**	**2.51E-04**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.78E-04	1.66E-04	1.59E-04	1.56E-04
Earth Movement	1.46E-05	7.66E-05	7.66E-05	7.66E-05	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**3.64E-05**	**3.52E-05**	**3.45E-05**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	1.14E-05	1.02E-05	9.52E-06	2.97E-06
TOTALS	**2.32E-04**	**3.25E-04**	**3.12E-04**	**3.04E-04**	**2.32E-04**

Table E.1.10M
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS2M ROAD TYPE E							
	Pipeline 08(06)"							
Base Leak	73.0%	**6.90E-04**	73.0%	**6.56E-04**	73.0%	**6.36E-04**	73.0%	**4.51E-04**
Base Rupture	27.0%	**3.25E-04**	27.0%	**3.12E-04**	27.0%	**3.04E-04**	27.0%	**2.32E-04**
Leak	73.0%	6.90E-04	73.0%	6.56E-04	73.0%	6.36E-04	73.0%	4.51E-04
Hole	20.0%	2.40E-04	20.0%	2.31E-04	20.0%	2.25E-04	20.0%	1.72E-04
Rupture	4.6%	5.53E-05	4.6%	5.31E-05	4.6%	5.18E-05	4.6%	3.95E-05
D Rupture	2.4%	2.89E-05	2.4%	2.77E-05	2.4%	2.70E-05	2.4%	2.06E-05

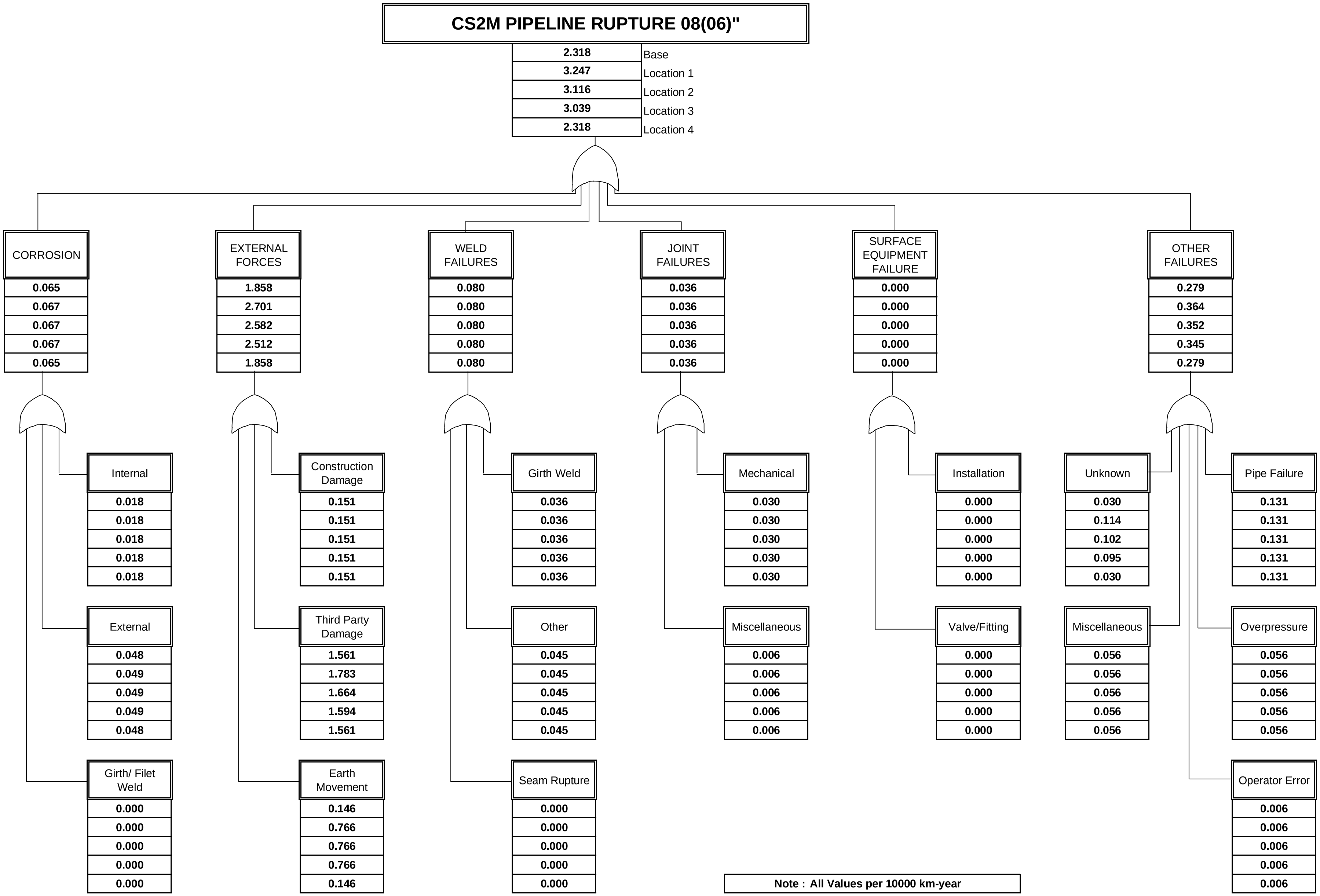


Figure E.1.1M Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

Table E.2.1 Ignition Probability Calculation

CS2 Ignition Probability Calculation								
Release Type	ADDT	Speed [km/h]	Cloud Length [m]	Cloud Probability	Ignition per Vehicle	Probability of Autoign.	Location Factor	Probability of Ignition
Type E - Location 1								
Leak	9000	80	10	0.95	0.50	0.15	1.00	**0.172**
Hole	9000	80	150	0.95	0.50	0.15	1.00	**0.484**
Rupture	9000	80	200	0.95	0.50	0.15	1.00	**0.595**
D Rupture	9000	80	200	0.95	0.50	0.15	1.00	**0.595**
Type E - Location 2								
Leak	9000	80	10	0.95	0.50	0.15	0.90	**0.170**
Hole	9000	80	150	0.95	0.50	0.15	0.90	**0.451**
Rupture	9000	80	200	0.95	0.50	0.15	0.90	**0.551**
D Rupture	9000	80	200	0.95	0.50	0.15	0.90	**0.551**
Type E - Location 3								
Leak	9000	80	10	0.95	0.50	0.15	0.80	**0.168**
Hole	9000	80	150	0.95	0.50	0.15	0.80	**0.417**
Rupture	9000	80	200	0.95	0.50	0.15	0.80	**0.506**
D Rupture	9000	80	200	0.95	0.50	0.15	0.80	**0.506**
Type E - Location 4								
Leak	9000	80	10	0.95	0.50	0.15	0.10	**0.152**
Hole	9000	80	150	0.95	0.50	0.15	0.10	**0.183**
Rupture	9000	80	200	0.95	0.50	0.15	0.10	**0.195**
D Rupture	9000	80	200	0.95	0.50	0.15	0.10	**0.195**

Table E.2.2 Event Tree Database

CS2 Event Tree Database - for All Scenarios											
Release Type	Ignition		Timing		Consequence			Ratio of Occurrence ROO			
	Yes	No	Imm.	Del.	F Fire	Expl.	Imm. J Fire	J Fire	F Fire	Expl.	Disp.
Type E - Location 1											
Leak	0.172	0.828	0.300	0.700	0.900	0.100	0.052	0.172	0.109	0.012	0.828
Hole	0.484	0.516	0.600	0.400	0.700	0.300	0.290	0.484	0.136	0.058	0.516
Rupture	0.595	0.405	0.700	0.300	0.700	0.300	0.417	0.595	0.125	0.054	0.405
D Rupture	0.595	0.405	0.700	0.300	0.700	0.300	0.417	0.595	0.125	0.054	0.405
Type E - Location 2											
Leak	0.170	0.830	0.300	0.700	0.900	0.100	0.051	0.170	0.107	0.012	0.830
Hole	0.451	0.549	0.600	0.400	0.700	0.300	0.270	0.451	0.126	0.054	0.549
Rupture	0.551	0.449	0.650	0.350	0.700	0.300	0.358	0.551	0.135	0.058	0.449
D Rupture	0.551	0.449	0.650	0.350	0.700	0.300	0.358	0.551	0.135	0.058	0.449
Type E - Location 3											
Leak	0.168	0.832	0.300	0.700	0.900	0.100	0.050	0.168	0.106	0.012	0.832
Hole	0.417	0.583	0.600	0.400	0.700	0.300	0.250	0.417	0.117	0.050	0.583
Rupture	0.506	0.494	0.600	0.400	0.700	0.300	0.304	0.506	0.142	0.061	0.494
D Rupture	0.506	0.494	0.600	0.400	0.700	0.300	0.304	0.506	0.142	0.061	0.494
Type E - Location 4											
Leak	0.152	0.848	0.900	0.100	0.900	0.100	0.137	0.152	0.014	0.002	0.848
Hole	0.183	0.817	0.900	0.100	0.700	0.300	0.165	0.183	0.013	0.006	0.817
Rupture	0.195	0.805	0.900	0.100	0.700	0.300	0.175	0.195	0.014	0.006	0.805
D Rupture	0.195	0.805	0.900	0.100	0.700	0.300	0.175	0.195	0.014	0.006	0.805

Table E.2.3
06" Pipeline Consequence Modelling Results

N	Scenario	Release Type	Release [min]	Max Release Rate [kg/s]	Meteorology		Max Isopleth Distance [m] Flash Fire, Thermal Radiation Flux [W/m2] 12500		25000		37500		Max Isopleth Distance [m] Jet Fire, Thermal Radiation Flux [W/m2] 12500		25000		37500		Max Isopleth Distance [m] Explosion Overpressure [Pa] 6895	20684	34474
					Class	%	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	Length	Width/2	L/W	L/W	L/W
1	TAC-VP06-L-MU	Leak .5 cm Dia	7772	0.2	A,B,C	15.9	17.5	3.5	17.5	2.0	17.5	1.8	7.5	2.5	6.8	1.0	6.5	1.0	0	0	0
2	TAC-VP06-L-MN				D	53.9	4.1	0.8	2.1	0.8	1.4	0.8	6.4	2.5	5.8	1.0	5.4	1.0	0	0	0
3	TAC-VP06-L-MS				E,F	30.2	28.9	7.0	28.8	5.0	28.7	5.0	8.3	2.5	7.6	1.0	7.3	1.0	37	12	7
4	TAC-VP06-L-MA				**Average**	**100**	**14**	**3**	**13**	**2**	**12**	**2**	**7**	**3**	**7**	**1**	**6**	**1**	**11**	**3**	**2**
5	TAC-VP06-H-MU	Hole 10 cm Dia	19.4	83.5	A,B,C	15.9	282	80	228	65	201	60	121	50	110	30	105	20	231	71	42
6	TAC-VP06-H-MN				D	53.9	271	44	270	26	270	24	109	50	98	30	93	20	142	44	26
7	TAC-VP06-H-MS				E,F	30.2	264	100	218	80	195	80	132	44	121	26	115	20	541	168	99
8	TAC-VP06-H-MA				**Average**	**100**	**271**	**67**	**248**	**49**	**236**	**47**	**118**	**48**	**107**	**29**	**102**	**20**	**277**	**86**	**51**
9	TAC-VP06-R-MU	Rupture 15 cm Dia			A,B,C	15.9	280	70	251	50	250	50	174	70	158	40	150	30	686	212	126
10	TAC-VP06-R-MN				D	53.9	352	70	305	40	298	30	157	70	141	50	134	30	686	212	126
11	TAC-VP06-R-MS				E,F	30.2	344	130	278	120	244	120	190	70	174	40	166	30	187	58	34
12	TAC-VP06-R-MA				**Average**	**100**	**338**	**88**	**288**	**66**	**274**	**60**	**170**	**70**	**154**	**45**	**146**	**30**	**535**	**165**	**98**
13	TAC-VP06-DR-MU	Double Rupture 21.2 cm Equ. Dia			A,B,C	15.9	417	140	348	120	313	120	237	100	215	60	205	50	509	158	93
14	TAC-VP06-DR-MN				D	53.9	491	120	387	100	340	80	213	100	192	60	181	50	380	118	70
15	TAC-VP06-DR-MS				E,F	30.2	424	160	338	140	294	140	259	90	237	60	226	40	217	67	40
16	TAC-VP06-DR-MA				**Average**	**100**	**459**	**135**	**366**	**115**	**322**	**104**	**231**	**97**	**209**	**60**	**198**	**47**	**351**	**109**	**65**

Table E.3.1
Derivation of Individual Specific Risk Factors

Nr	Road Type	Ni	Individual Type	E h/day	Nt trip/day	Nd days/week	Nw weeks/year	L km/trip	V km/h	LISRF	IF	OF	Sfi	Sfo	ISRF
1	CS 2 Type E	1	Daily Commuter	n/a	2	5	48	20	80	0.0137	0.95	0.05	0.1	1.0	0.0020
		2	Weekly Commuter	n/a	2	1	48	20	80	0.0027	0.90	0.10	0.1	1.0	0.0005
		3	Worker	8	n/a	5	2	n/a	n/a	0.0092	0.20	0.80	0.1	1.0	0.0075
		4	Resident	12	n/a	7	48	n/a	n/a	0.4615	0.90	0.10	0.1	1.0	0.0877
		5	Any Road User	20	n/a	7	52	n/a	n/a	0.8333	0.90	0.10	0.1	1.0	0.1583

Table E.3.2F
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS2F-Location 1																
GAS RELEASE	Leak	4.91E-04						-	-	-	-	-	-	-	-	-
	Hole	1.83E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.22E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.20E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.172	8.45E-05	0.1	6	0.25	2.53E-08	1.40E-08	-	-	-	-	-	-	-
	Hole		0.484	8.86E-05	0.1	102	0.25	4.52E-07	4.51E-07	4.50E-07	4.38E-07	3.94E-07	-	-	-	-
	Rupture		0.595	2.51E-05	0.1	146	0.25	1.83E-07	1.83E-07	1.83E-07	1.81E-07	1.72E-07	-	-	-	-
	D Rupture		0.595	1.31E-05	0.1	198	0.25	1.30E-07	1.30E-07	1.29E-07	1.29E-07	1.25E-07	8.46E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.109	5.35E-05	0.5	12	0.25	1.61E-07	1.46E-07	8.88E-08	-	-	-	-	-	-
	Hole		0.136	2.49E-05	0.5	236	0.25	1.47E-06	1.47E-06	1.47E-06	1.46E-06	1.44E-06	1.13E-06	7.80E-07	-	-
	Rupture		0.125	5.28E-06	0.5	274	0.25	3.61E-07	3.61E-07	3.61E-07	3.60E-07	3.55E-07	3.02E-07	2.47E-07	1.48E-07	-
	D Rupture		0.125	2.75E-06	0.5	322	0.25	2.21E-07	2.21E-07	2.21E-07	2.21E-07	2.19E-07	1.96E-07	1.73E-07	1.40E-07	8.04E-08
FLASH FIRE - Parallel	Leak		0.109	5.35E-05	0.5	2	0.25	2.68E-08	-	-	-	-	-	-	-	-
	Hole		0.136	2.49E-05	0.5	47	0.25	2.92E-07	2.91E-07	2.86E-07	2.48E-07	-	-	-	-	-
	Rupture		0.125	5.28E-06	0.5	60	0.25	7.91E-08	7.88E-08	7.80E-08	7.19E-08	4.37E-08	-	-	-	-
	D Rupture		0.125	2.75E-06	0.5	104	0.25	7.15E-08	7.14E-08	7.12E-08	6.94E-08	6.27E-08	-	-	-	-
EXPLOSION	Leak		0.012	5.89E-06	0.1	2	1.00	2.36E-09	-	-	-	-	-	-	-	-
	Hole		0.058	1.06E-05	0.1	51	1.00	1.08E-07	1.08E-07	1.06E-07	9.44E-08	2.13E-08	-	-	-	-
	Rupture		0.054	2.28E-06	0.1	98	1.00	4.47E-08	4.46E-08	4.44E-08	4.32E-08	3.84E-08	-	-	-	-
	D Rupture		0.054	1.19E-06	0.1	65	1.00	1.54E-08	1.54E-08	1.53E-08	1.43E-08	9.87E-09	-	-	-	-
DISPERSION	Leak		0.828	4.07E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.516	9.44E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.405	1.71E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.405	8.91E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.64E-06	3.58E-06	3.50E-06	3.33E-06	2.88E-06	1.72E-06	1.20E-06	2.87E-07	8.04E-08
			1	Daily Commuter Loc 1			0.0020	7.25E-09	7.14E-09	6.97E-09	6.63E-09	5.73E-09	3.42E-09	2.39E-09	5.72E-10	1.60E-10
			2	Weekly Commuter Loc 1			0.0005	1.90E-09	1.87E-09	1.83E-09	1.74E-09	1.50E-09	8.96E-10	6.26E-10	1.50E-10	4.20E-11
			3	Worker Loc1			0.0075	2.73E-08	2.69E-08	2.63E-08	2.50E-08	2.16E-08	1.29E-08	9.01E-09	2.16E-09	6.04E-10
			4	Resident Loc 1			0.0877	3.19E-07	3.14E-07	3.07E-07	2.92E-07	2.52E-07	1.51E-07	1.05E-07	2.52E-08	7.05E-09
TAC-VP06-MA-CS2F-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.85E-05	0.1	6	0.25	2.06E-08	1.14E-08	-	-	-	-	-	-	-
	Hole		0.183	3.14E-05	0.1	102	0.25	1.60E-07	1.60E-07	1.60E-07	1.55E-07	1.40E-07	-	-	-	-
	Rupture		0.195	7.70E-06	0.1	146	0.25	5.62E-08	5.62E-08	5.61E-08	5.54E-08	5.28E-08	-	-	-	-
	D Rupture		0.195	4.02E-06	0.1	198	0.25	3.98E-08	3.98E-08	3.97E-08	3.95E-08	3.85E-08	2.60E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	236	0.25	1.32E-07	1.32E-07	1.32E-07	1.31E-07	1.29E-07	1.02E-07	6.99E-08	-	-
	Rupture		0.014	5.53E-07	0.5	274	0.25	3.79E-08	3.79E-08	3.79E-08	3.77E-08	3.72E-08	3.17E-08	2.59E-08	1.55E-08	-
	D Rupture		0.014	2.89E-07	0.5	322	0.25	2.32E-08	2.32E-08	2.32E-08	2.32E-08	2.29E-08	2.06E-08	1.82E-08	1.46E-08	8.44E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	47	0.25	2.62E-08	2.61E-08	2.56E-08	2.22E-08	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	60	0.25	8.29E-09	8.27E-09	8.18E-09	7.54E-09	4.58E-09	-	-	-	-
	D Rupture		0.014	2.89E-07	0.5	104	0.25	7.50E-09	7.49E-09	7.47E-09	7.28E-09	6.58E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.006	1.03E-06	0.1	51	1.00	1.05E-08	1.05E-08	1.03E-08	9.16E-09	2.07E-09	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	98	1.00	4.64E-09	4.64E-09	4.62E-09	4.49E-09	3.99E-09	-	-	-	-
	D Rupture		0.006	1.24E-07	0.1	65	1.00	1.61E-09	1.60E-09	1.59E-09	1.48E-09	1.03E-09	-	-	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.40E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.805	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.805	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.51E-07	5.36E-07	5.16E-07	4.94E-07	4.38E-07	1.80E-07	1.14E-07	3.01E-08	8.44E-09
			4	Resident Loc 4			0.0877	4.83E-08	4.70E-08	4.53E-08	4.33E-08	3.84E-08	1.58E-08	1.00E-08	2.64E-09	7.40E-10

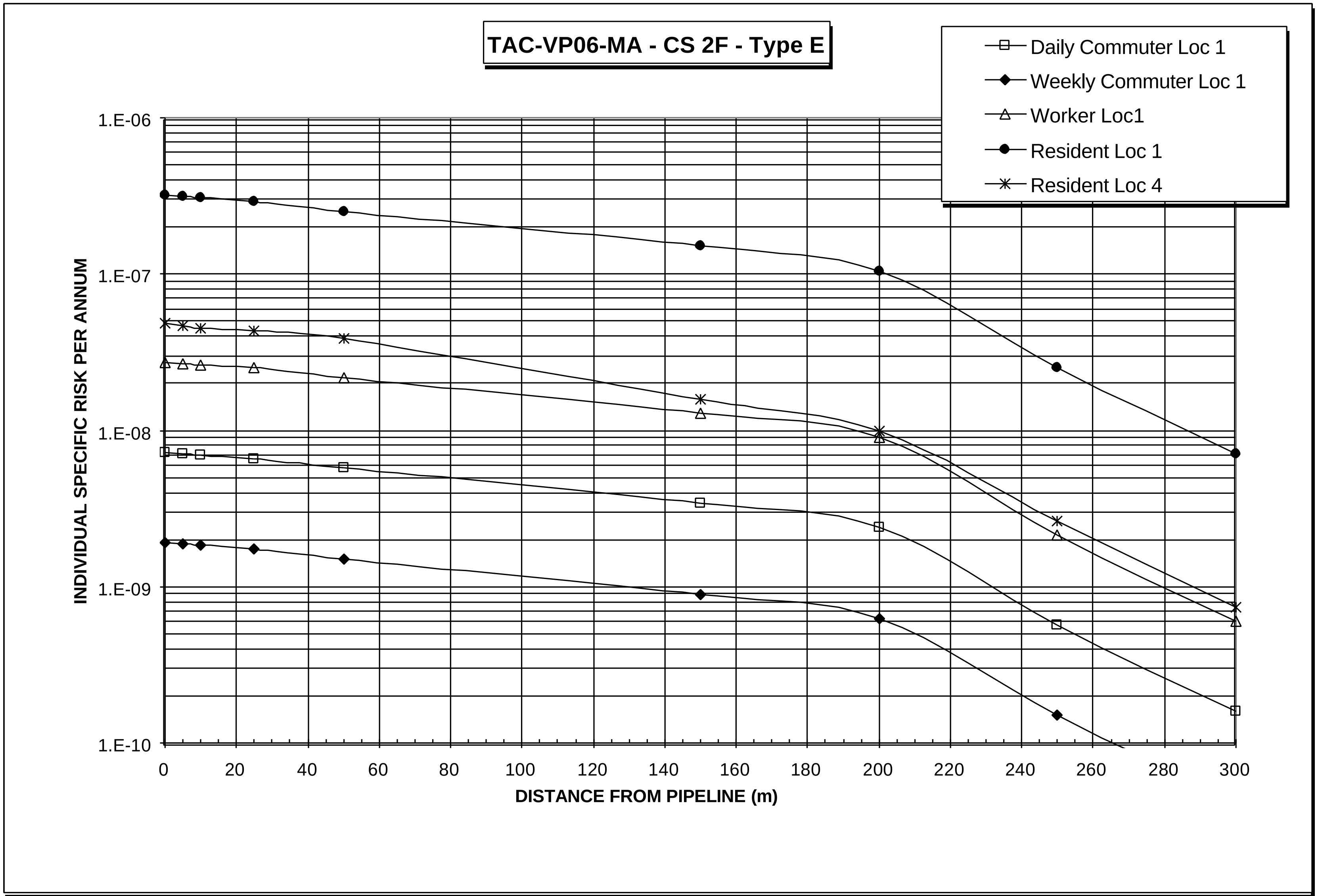


Figure E.3.2F – Transects CS2F VP06 Loc 1(4)

Table E.3.2M
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS2M-Location 1																
GAS RELEASE	Leak	6.90E-04						-	-	-	-	-	-	-	-	-
	Hole	2.40E-04						-	-	-	-	-	-	-	-	-
	Rupture	5.53E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.89E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		1.720	1.19E-03	0.1	6	0.25	3.56E-07	1.97E-07	-	-	-	-	-	-	-
	Hole		0.484	1.16E-04	0.1	102	0.25	5.92E-07	5.92E-07	5.90E-07	5.74E-07	5.16E-07	-	-	-	-
	Rupture		0.595	3.29E-05	0.1	146	0.25	2.40E-07	2.40E-07	2.40E-07	2.37E-07	2.26E-07	-	-	-	-
	D Rupture		0.595	1.72E-05	0.1	198	0.25	1.70E-07	1.70E-07	1.70E-07	1.69E-07	1.65E-07	1.11E-07	-	-	-
FLASH FIRE - Transverse	Leak		0.109	7.52E-05	0.5	12	0.25	2.26E-07	2.05E-07	1.25E-07	-	-	-	-	-	-
	Hole		0.136	3.26E-05	0.5	236	0.25	1.93E-06	1.93E-06	1.92E-06	1.91E-06	1.88E-06	1.49E-06	1.02E-06	-	-
	Rupture		0.125	6.91E-06	0.5	274	0.25	4.74E-07	4.73E-07	4.73E-07	4.72E-07	4.66E-07	3.96E-07	3.24E-07	1.94E-07	-
	D Rupture		0.125	3.61E-06	0.5	322	0.25	2.91E-07	2.91E-07	2.91E-07	2.90E-07	2.87E-07	2.57E-07	2.28E-07	1.83E-07	1.06E-07
FLASH FIRE - Parallel	Leak		0.109	7.52E-05	0.5	2	0.25	3.76E-08	-	-	-	-	-	-	-	-
	Hole		0.136	3.26E-05	0.5	47	0.25	3.84E-07	3.81E-07	3.75E-07	3.25E-07	-	-	-	-	-
	Rupture		0.125	6.91E-06	0.5	60	0.25	1.04E-07	1.03E-07	1.02E-07	9.43E-08	5.73E-08	-	-	-	-
	D Rupture		0.125	3.61E-06	0.5	104	0.25	9.39E-08	9.38E-08	9.35E-08	9.12E-08	8.24E-08	-	-	-	-
EXPLOSION	Leak		0.012	8.28E-06	0.1	2	1.00	3.31E-09	-	-	-	-	-	-	-	-
	Hole		0.058	1.39E-05	0.1	51	1.00	1.42E-07	1.41E-07	1.39E-07	1.24E-07	2.80E-08	-	-	-	-
	Rupture		0.054	2.99E-06	0.1	98	1.00	5.85E-08	5.85E-08	5.82E-08	5.66E-08	5.03E-08	-	-	-	-
	D Rupture		0.054	1.56E-06	0.1	65	1.00	2.03E-08	2.02E-08	2.00E-08	1.87E-08	1.30E-08	-	-	-	-
DISPERSION	Leak		0.828	5.71E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.516	1.24E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.405	2.24E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.405	1.17E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.12E-06	4.89E-06	4.60E-06	4.37E-06	3.77E-06	2.25E-06	1.57E-06	3.77E-07	1.06E-07
			1	Daily Commuter Loc 1			0.0020	1.02E-08	9.74E-09	9.16E-09	8.70E-09	7.51E-09	4.48E-09	3.13E-09	7.51E-10	2.10E-10
			2	Weekly Commuter Loc 1			0.0005	2.67E-09	2.55E-09	2.40E-09	2.28E-09	1.97E-09	1.18E-09	8.22E-10	1.97E-10	5.51E-11
			3	Worker Loc1			0.0075	3.84E-08	3.67E-08	3.45E-08	3.28E-08	2.83E-08	1.69E-08	1.18E-08	2.83E-09	7.93E-10
			4	Resident Loc 1			0.0877	4.49E-07	4.29E-07	4.03E-07	3.83E-07	3.31E-07	1.97E-07	1.38E-07	3.31E-08	9.26E-09
TAC-VP06-MA-CS2M-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.85E-05	0.1	6	0.25	2.06E-08	1.14E-08	-	-	-	-	-	-	-
	Hole		0.183	3.14E-05	0.1	102	0.25	1.60E-07	1.60E-07	1.60E-07	1.55E-07	1.40E-07	-	-	-	-
	Rupture		0.195	7.70E-06	0.1	146	0.25	5.62E-08	5.62E-08	5.61E-08	5.54E-08	5.28E-08	-	-	-	-
	D Rupture		0.195	4.02E-06	0.1	198	0.25	3.98E-08	3.98E-08	3.97E-08	3.95E-08	3.85E-08	2.60E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	236	0.25	1.32E-07	1.32E-07	1.32E-07	1.31E-07	1.29E-07	1.02E-07	6.99E-08	-	-
	Rupture		0.014	5.53E-07	0.5	274	0.25	3.79E-08	3.79E-08	3.79E-08	3.77E-08	3.72E-08	3.17E-08	2.59E-08	1.55E-08	-
	D Rupture		0.014	2.89E-07	0.5	322	0.25	2.32E-08	2.32E-08	2.32E-08	2.32E-08	2.29E-08	2.06E-08	1.82E-08	1.46E-08	8.44E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	47	0.25	2.62E-08	2.61E-08	2.56E-08	2.22E-08	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	60	0.25	8.29E-09	8.27E-09	8.18E-09	7.54E-09	4.58E-09	-	-	-	-
	D Rupture		0.014	2.89E-07	0.5	104	0.25	7.50E-09	7.49E-09	7.47E-09	7.28E-09	6.58E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.006	1.03E-06	0.1	51	1.00	1.05E-08	1.05E-08	1.03E-08	9.16E-09	2.07E-09	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	98	1.00	4.64E-09	4.64E-09	4.62E-09	4.49E-09	3.99E-09	-	-	-	-
	D Rupture		0.006	1.24E-07	0.1	65	1.00	1.61E-09	1.60E-09	1.59E-09	1.48E-09	1.03E-09	-	-	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.40E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.805	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.805	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.51E-07	5.36E-07	5.16E-07	4.94E-07	4.38E-07	1.80E-07	1.14E-07	3.01E-08	8.44E-09
			4	Resident Loc 4			0.0877	4.83E-08	4.70E-08	4.53E-08	4.33E-08	3.84E-08	1.58E-08	1.00E-08	2.64E-09	7.40E-10

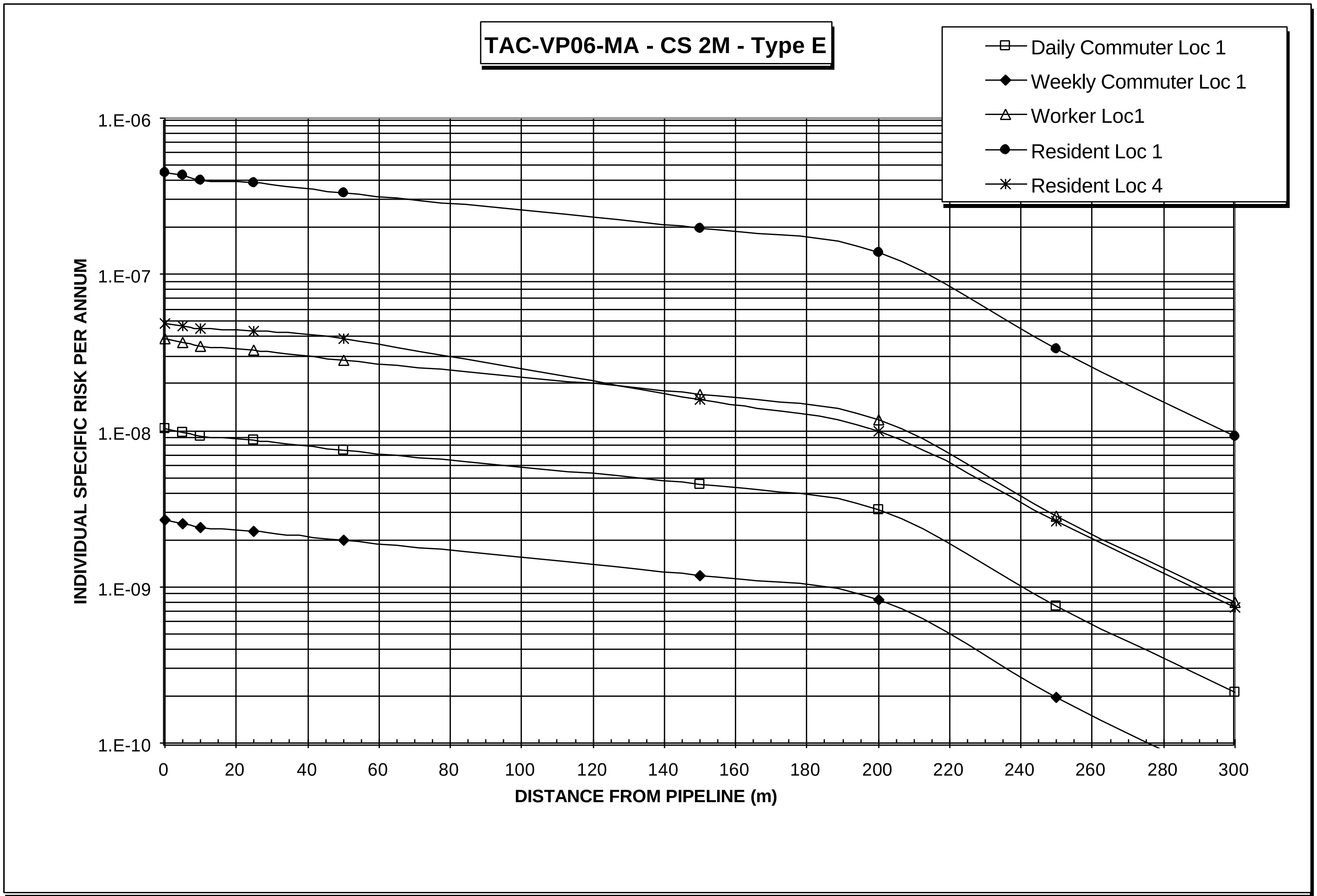


Figure E.3.2M – Transects CS2M VP06 Loc 1(4)

Table E.3.3F
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	$p_r \times P_s$ (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS2F-Location 2																
GAS RELEASE	Leak	4.83E-04						-	-	-	-	-	-	-	-	-
	Hole	1.81E-04						-	-	-	-	-	-	-	-	-
	Rupture	4.17E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.17E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.170	8.21E-05	0.1	6	0.25	2.46E-08	1.36E-08	-	-	-	-	-	-	-
	Hole		0.458	8.29E-05	0.1	102	0.25	4.23E-07	4.22E-07	4.21E-07	4.10E-07	3.69E-07	-	-	-	-
	Rupture		0.551	2.30E-05	0.1	146	0.25	1.68E-07	1.68E-07	1.67E-07	1.65E-07	1.58E-07	-	-	-	-
	D Rupture		0.551	1.20E-05	0.1	198	0.25	1.18E-07	1.18E-07	1.18E-07	1.17E-07	1.15E-07	7.73E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.107	5.17E-05	0.5	12	0.25	1.55E-07	1.41E-07	8.57E-08	-	-	-	-	-	-
	Hole		0.126	2.28E-05	0.5	236	0.25	1.35E-06	1.35E-06	1.34E-06	1.34E-06	1.32E-06	1.04E-06	7.14E-07	-	-
	Rupture		0.135	5.63E-06	0.5	274	0.25	3.86E-07	3.86E-07	3.85E-07	3.84E-07	3.79E-07	3.23E-07	2.64E-07	1.58E-07	-
	D Rupture		0.135	2.93E-06	0.5	322	0.25	2.36E-07	2.36E-07	2.36E-07	2.35E-07	2.33E-07	2.09E-07	1.85E-07	1.49E-07	8.57E-08
FLASH FIRE - Parallel	Leak		0.107	5.17E-05	0.5	2	0.25	2.58E-08	-	-	-	-	-	-	-	-
	Hole		0.126	2.28E-05	0.5	47	0.25	2.68E-07	2.66E-07	2.62E-07	2.27E-07	-	-	-	-	-
	Rupture		0.135	5.63E-06	0.5	60	0.25	8.44E-08	8.41E-08	8.33E-08	7.68E-08	4.67E-08	-	-	-	-
	D Rupture		0.135	2.93E-06	0.5	104	0.25	7.62E-08	7.61E-08	7.58E-08	7.39E-08	6.68E-08	-	-	-	-
EXPLOSION	Leak		0.012	5.80E-06	0.1	2	1.00	2.32E-09	-	-	-	-	-	-	-	-
	Hole		0.054	9.77E-06	0.1	51	1.00	9.97E-08	9.92E-08	9.78E-08	8.69E-08	1.96E-08	-	-	-	-
	Rupture		0.058	2.42E-06	0.1	98	1.00	4.74E-08	4.73E-08	4.72E-08	4.58E-08	4.08E-08	-	-	-	-
	D Rupture		0.058	1.26E-06	0.1	65	1.00	1.64E-08	1.63E-08	1.62E-08	1.51E-08	1.05E-08	-	-	-	-
DISPERSION	Leak		0.830	4.01E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.549	9.94E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.449	1.87E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.449	9.74E-06	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	3.48E-06	3.42E-06	3.34E-06	3.18E-06	2.75E-06	1.65E-06	1.16E-06	3.06E-07	8.57E-08
			1	Daily Commuter Loc 2			0.0020	6.92E-09	6.81E-09	6.65E-09	6.32E-09	5.48E-09	3.28E-09	2.32E-09	6.10E-10	1.71E-10
			2	Weekly Commuter Loc 2			0.0005	1.81E-09	1.78E-09	1.74E-09	1.66E-09	1.44E-09	8.60E-10	6.07E-10	1.60E-10	4.47E-11
			3	Worker Loc2			0.0075	2.61E-08	2.57E-08	2.51E-08	2.38E-08	2.07E-08	1.24E-08	8.73E-09	2.30E-09	6.43E-10
			4	Resident Loc 2			0.0877	3.05E-07	3.00E-07	2.93E-07	2.78E-07	2.41E-07	1.44E-07	1.02E-07	2.69E-08	7.51E-09
TAC-VP06-MA-CS2F-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.85E-05	0.1	6	0.25	2.06E-08	1.14E-08	-	-	-	-	-	-	-
	Hole		0.183	3.14E-05	0.1	102	0.25	1.60E-07	1.60E-07	1.60E-07	1.55E-07	1.40E-07	-	-	-	-
	Rupture		0.195	7.70E-06	0.1	146	0.25	5.62E-08	5.62E-08	5.61E-08	5.54E-08	5.28E-08	-	-	-	-
	D Rupture		0.195	4.02E-06	0.1	198	0.25	3.98E-08	3.98E-08	3.97E-08	3.95E-08	3.85E-08	2.60E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	236	0.25	1.32E-07	1.32E-07	1.32E-07	1.31E-07	1.29E-07	1.02E-07	6.99E-08	-	-
	Rupture		0.014	5.53E-07	0.5	274	0.25	3.79E-08	3.79E-08	3.79E-08	3.77E-08	3.72E-08	3.17E-08	2.59E-08	1.55E-08	-
	D Rupture		0.014	2.89E-07	0.5	322	0.25	2.32E-08	2.32E-08	2.32E-08	2.32E-08	2.29E-08	2.06E-08	1.82E-08	1.46E-08	8.44E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	47	0.25	2.62E-08	2.61E-08	2.56E-08	2.22E-08	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	60	0.25	8.29E-09	8.27E-09	8.18E-09	7.54E-09	4.58E-09	-	-	-	-
	D Rupture		0.014	2.89E-07	0.5	104	0.25	7.50E-09	7.49E-09	7.47E-09	7.28E-09	6.58E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.006	1.03E-06	0.1	51	1.00	1.05E-08	1.05E-08	1.03E-08	9.16E-09	2.07E-09	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	98	1.00	4.64E-09	4.64E-09	4.62E-09	4.49E-09	3.99E-09	-	-	-	-
	D Rupture		0.006	1.24E-07	0.1	65	1.00	1.61E-09	1.60E-09	1.59E-09	1.48E-09	1.03E-09	-	-	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.40E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.805	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.805	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.51E-07	5.36E-07	5.16E-07	4.94E-07	4.38E-07	1.80E-07	1.14E-07	3.01E-08	8.44E-09
			4	Resident Loc 4			0.0877	4.83E-08	4.70E-08	4.53E-08	4.33E-08	3.84E-08	1.58E-08	1.00E-08	2.64E-09	7.40E-10

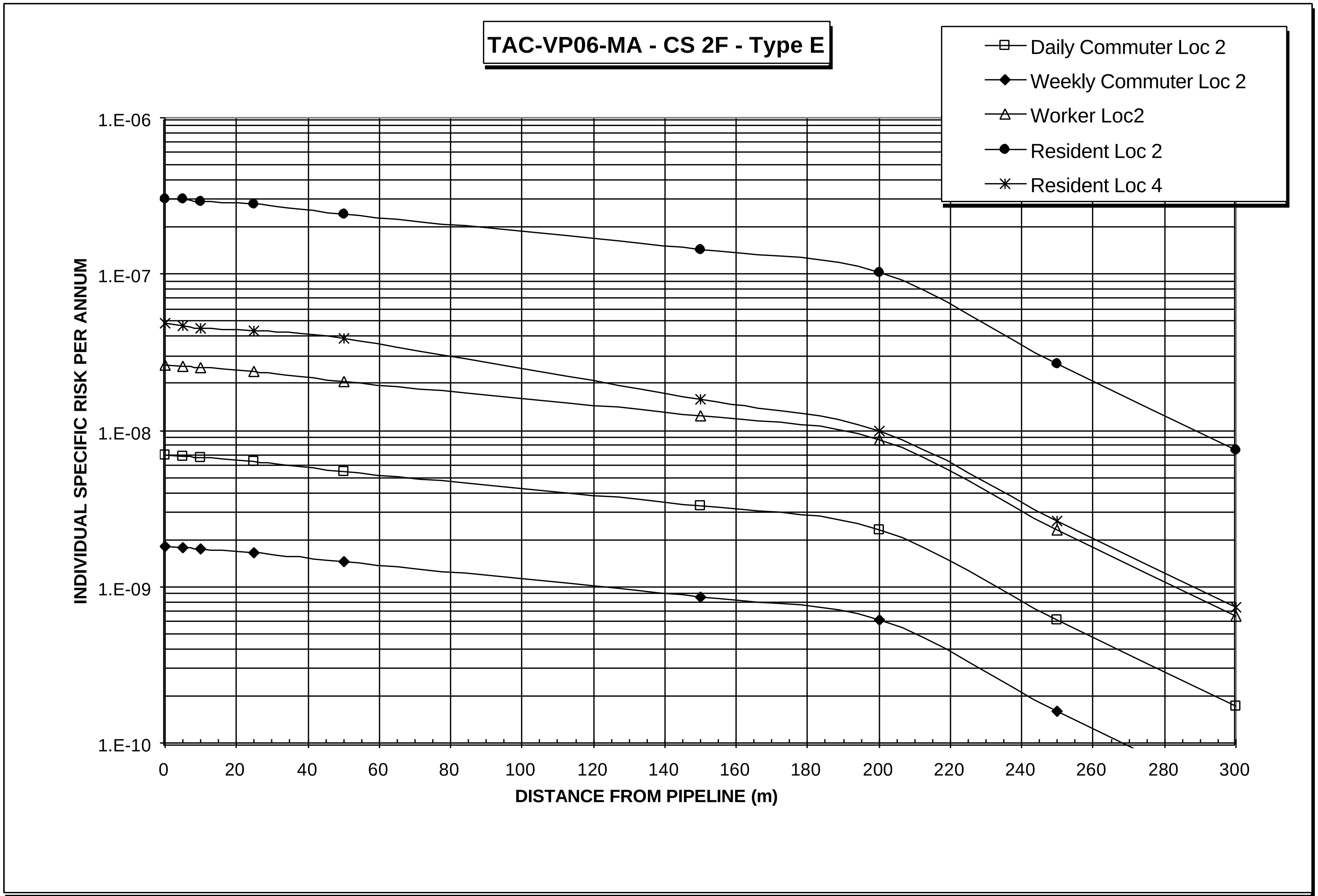


Figure E.3.3F – Transects CS2F VP06 Loc 2(4)

Table E.3.3M
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m) 0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS2M-Location 2																
GAS RELEASE	Leak	6.56E-04						-	-	-	-	-	-	-	-	-
	Hole	2.31E-04						-	-	-	-	-	-	-	-	-
	Rupture	5.31E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.77E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.170	1.12E-04	0.1	6	0.25	3.35E-08	1.85E-08	-	-	-	-	-	-	-
	Hole		0.458	1.06E-04	0.1	102	0.25	5.40E-07	5.39E-07	5.37E-07	5.23E-07	4.70E-07	-	-	-	-
	Rupture		0.551	2.93E-05	0.1	146	0.25	2.14E-07	2.13E-07	2.13E-07	2.10E-07	2.01E-07	-	-	-	-
	D Rupture		0.551	1.53E-05	0.1	198	0.25	1.51E-07	1.51E-07	1.51E-07	1.50E-07	1.46E-07	9.86E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.107	7.02E-05	0.5	12	0.25	2.11E-07	1.91E-07	1.16E-07	-	-	-	-	-	-
	Hole		0.126	2.91E-05	0.5	236	0.25	1.72E-06	1.72E-06	1.72E-06	1.71E-06	1.68E-06	1.33E-06	9.12E-07	-	-
	Rupture		0.135	7.17E-06	0.5	274	0.25	4.91E-07	4.91E-07	4.91E-07	4.89E-07	4.83E-07	4.11E-07	3.36E-07	2.01E-07	-
	D Rupture		0.135	3.74E-06	0.5	322	0.25	3.01E-07	3.01E-07	3.01E-07	3.00E-07	2.97E-07	2.66E-07	2.36E-07	1.90E-07	1.09E-07
FLASH FIRE - Parallel	Leak		0.107	7.02E-05	0.5	2	0.25	3.51E-08	-	-	-	-	-	-	-	-
	Hole		0.126	2.91E-05	0.5	47	0.25	3.42E-07	3.40E-07	3.34E-07	2.90E-07	-	-	-	-	-
	Rupture		0.135	7.17E-06	0.5	60	0.25	1.08E-07	1.07E-07	1.06E-07	9.77E-08	5.94E-08	-	-	-	-
	D Rupture		0.135	3.74E-06	0.5	104	0.25	9.72E-08	9.71E-08	9.68E-08	9.44E-08	8.53E-08	-	-	-	-
EXPLOSION	Leak		0.012	7.87E-06	0.1	2	1.00	3.15E-09	-	-	-	-	-	-	-	-
	Hole		0.054	1.25E-05	0.1	51	1.00	1.27E-07	1.27E-07	1.25E-07	1.11E-07	2.51E-08	-	-	-	-
	Rupture		0.058	3.08E-06	0.1	98	1.00	6.04E-08	6.03E-08	6.00E-08	5.84E-08	5.19E-08	-	-	-	-
	D Rupture		0.058	1.61E-06	0.1	65	1.00	2.09E-08	2.08E-08	2.06E-08	1.93E-08	1.33E-08	-	-	-	-
DISPERSION	Leak		0.830	5.44E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.549	1.27E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.449	2.38E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.449	1.24E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	4.45E-06	4.37E-06	4.27E-06	4.05E-06	3.51E-06	2.10E-06	1.48E-06	3.91E-07	1.09E-07
			1	Daily Commuter Loc 2			0.0020	8.87E-09	8.71E-09	8.50E-09	8.07E-09	6.99E-09	4.19E-09	2.95E-09	7.78E-10	2.18E-10
			2	Weekly Commuter Loc 2			0.0005	2.32E-09	2.28E-09	2.23E-09	2.11E-09	1.83E-09	1.10E-09	7.74E-10	2.04E-10	5.71E-11
			3	Worker Loc2			0.0075	3.34E-08	3.28E-08	3.20E-08	3.04E-08	2.64E-08	1.58E-08	1.11E-08	2.93E-09	8.21E-10
			4	Resident Loc 2			0.0877	3.90E-07	3.84E-07	3.74E-07	3.55E-07	3.08E-07	1.84E-07	1.30E-07	3.43E-08	9.59E-09
TAC-VP06-MA-CS2M-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.85E-05	0.1	6	0.25	2.06E-08	1.14E-08	-	-	-	-	-	-	-
	Hole		0.183	3.14E-05	0.1	102	0.25	1.60E-07	1.60E-07	1.60E-07	1.55E-07	1.40E-07	-	-	-	-
	Rupture		0.195	7.70E-06	0.1	146	0.25	5.62E-08	5.62E-08	5.61E-08	5.54E-08	5.28E-08	-	-	-	-
	D Rupture		0.195	4.02E-06	0.1	198	0.25	3.98E-08	3.98E-08	3.97E-08	3.95E-08	3.85E-08	2.60E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	236	0.25	1.32E-07	1.32E-07	1.32E-07	1.31E-07	1.29E-07	1.02E-07	6.99E-08	-	-
	Rupture		0.014	5.53E-07	0.5	274	0.25	3.79E-08	3.79E-08	3.79E-08	3.77E-08	3.72E-08	3.17E-08	2.59E-08	1.55E-08	-
	D Rupture		0.014	2.89E-07	0.5	322	0.25	2.32E-08	2.32E-08	2.32E-08	2.32E-08	2.29E-08	2.06E-08	1.82E-08	1.46E-08	8.44E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	47	0.25	2.62E-08	2.61E-08	2.56E-08	2.22E-08	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	60	0.25	8.29E-09	8.27E-09	8.18E-09	7.54E-09	4.58E-09	-	-	-	-
	D Rupture		0.014	2.89E-07	0.5	104	0.25	7.50E-09	7.49E-09	7.47E-09	7.28E-09	6.58E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.006	1.03E-06	0.1	51	1.00	1.05E-08	1.05E-08	1.03E-08	9.16E-09	2.07E-09	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	98	1.00	4.64E-09	4.64E-09	4.62E-09	4.49E-09	3.99E-09	-	-	-	-
	D Rupture		0.006	1.24E-07	0.1	65	1.00	1.61E-09	1.60E-09	1.59E-09	1.48E-09	1.03E-09	-	-	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.40E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.805	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.805	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.51E-07	5.36E-07	5.16E-07	4.94E-07	4.38E-07	1.80E-07	1.14E-07	3.01E-08	8.44E-09
			4	Resident Loc 4			0.0877	4.83E-08	4.70E-08	4.53E-08	4.33E-08	3.84E-08	1.58E-08	1.00E-08	2.64E-09	7.40E-10

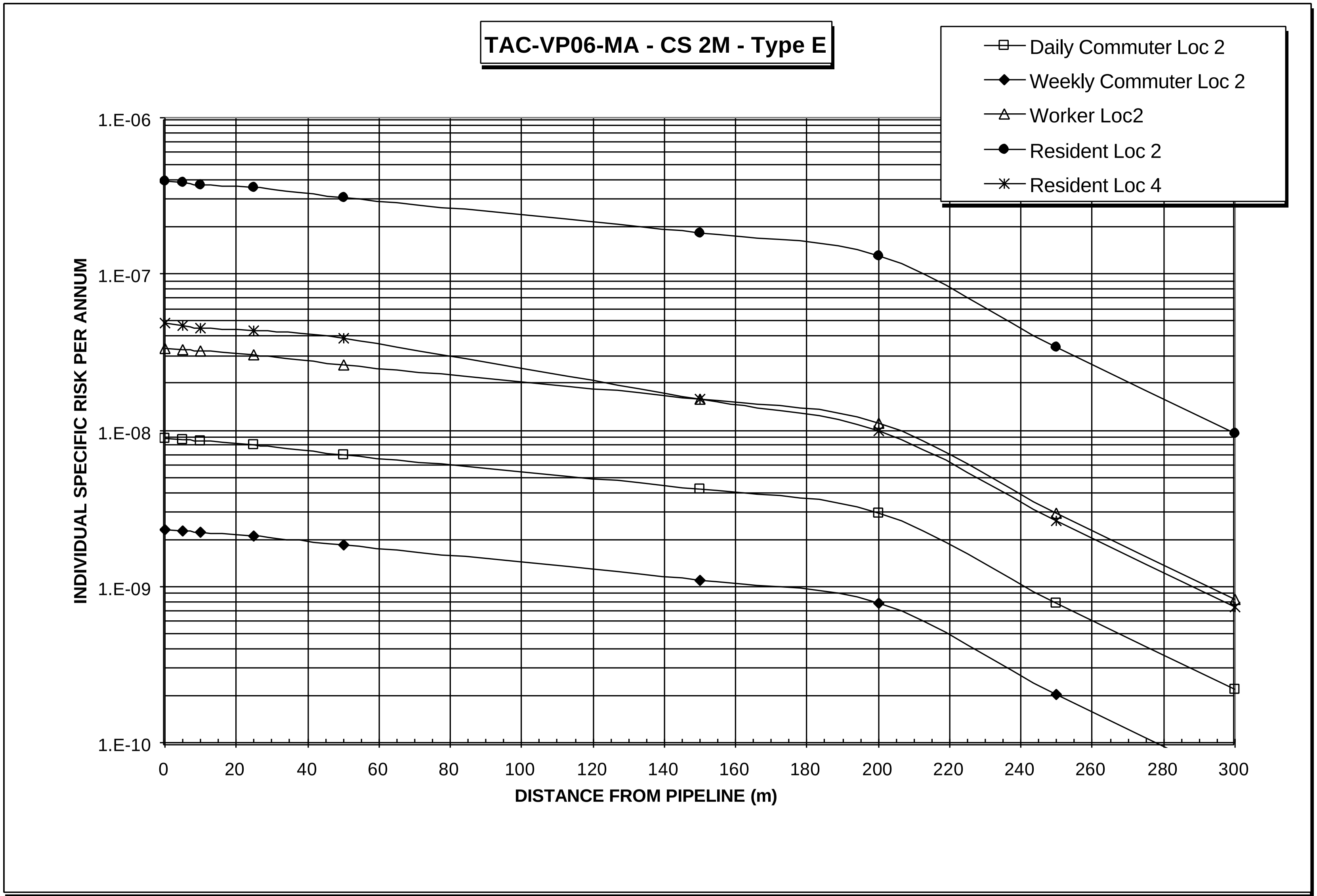


Figure E.3.3M – Transects CS2M VP06 Loc 2(4)

BERCHA GROUP

Table E.1.5MU
Case Study 2M - Roadway Effects on Pipeline Failure Rate

CS2MU ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
1	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	1	25	1	km	1.00E-05	1.00E-05	4.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous	5	25	25	km	1.00E-06	2.50E-05	2.00E-07
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	5	25	2	km	1.00E-05	2.00E-05	1.60E-07
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Guard Rail	5	25	5	km	1.00E-03	5.00E-03	4.00E-05
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
		Third Party DamageTotal							**8.01E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
		Earth Movement Total							**8.04E-03**
	Unknown	Other							8.81E-03
		Unknown Total							**8.81E-03**
2	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
		External Corrosion Total							**1.05E-06**
	Third Party Damage	Roadway Clearing-Debris,Rockfall	2	25	1	km	1.00E-05	1.00E-05	2.00E-07
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Ditch Grading-Localized	1	25	1	km	1.00E-04	1.00E-04	4.00E-06
		Supply, Remove, & Install Minor Culverts	50	25	10	item	1.00E-05	1.00E-04	8.00E-08
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts	1	25	10	item	1.00E-06	1.00E-05	4.00E-07
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Ditch Grading- Continous -w/grader	5	25	25	km	1.00E-04	2.50E-03	2.00E-05
		Snow Ploughing	0.1	25	25	km	1.00E-06	2.50E-05	1.00E-05
		Rock scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		Major Section Repair, Excavation of Embankment	10	25	0.5	km	1.00E-05	5.00E-06	2.00E-08
		New Culvert X	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Culvert II	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility X (e.g., FOC)	1	25	1	item	1.00E-04	1.00E-04	4.00E-06
		New Utility II	50	25	1	item	1.00E-04	1.00E-04	8.00E-08
		New Minor Sign	1	25	2	item	1.00E-05	2.00E-05	8.00E-07
		New Major Sign	1	25	1	item	1.00E-05	1.00E-05	4.00E-07

Table E.1.5MU
Case Study 2M - Roadway Effects on Pipeline Failure Rate

CS2MU ROAD TYPE E									
Loc	Classification	Hazard to P/L	Return Period [years]	P/L Length [km]	Hazard Quantity		P/L Damage Probability		Failure Rate Change [per km-year]
					Value	Unit	per Unit	Total	
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Ditch	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-03	2.00E-03	4.00E-06
								Third Party DamageTotal	**8.01E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
								Earth Movement Total	**8.04E-03**
	Unknown	Other							8.81E-03
								Unknown Total	**8.81E-03**
3	**External Corrosion**	Percolation	10	25	25	km	1.00E-05	2.50E-04	1.00E-06
		EMF	20	25	25	km	1.00E-06	2.50E-05	5.00E-08
								External Corrosion Total	**1.05E-06**
		Culvert Maintenance	2	25	10	item	1.00E-06	1.00E-05	2.00E-07
		Installation of Minor Signs (Single Post)	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Major Signs	1	25	5	item	1.00E-05	5.00E-05	2.00E-06
		Installation of Guide Posts							
		Installation of Extra or Repl. Power Poles	2	25	5	Item	1.00E-05	5.00E-05	1.00E-06
		Rock scaling	0.1	25	2	km	1.00E-01	2.00E-01	8.00E-02
		Mud Slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Land slide Cleanup	0.5	25	2	km	1.00E-05	2.00E-05	1.60E-06
		Washout Repairs	50	25	2	km	1.00E-05	2.00E-05	1.60E-08
		New power Line	10	25	5	km	1.00E-04	5.00E-04	2.00E-06
		New Driveway	1	25	1	item	1.00E-05	1.00E-05	4.00E-07
		Railway Crossing Accident Derailment	20	25	2	item	1.00E-04	2.00E-04	4.00E-07
								Third Party DamageTotal	**8.00E-02**
	Earth Movement	Vibration from Traffic	1	25	25	km	1.00E-05	2.50E-04	1.00E-05
		Frost Heave	3	25	10	km	1.00E-04	1.00E-03	1.33E-05
		Landslide	0.25	25	0.5	km	1.00E-01	5.00E-02	8.00E-03
		Flood	10	25	0.5	km	1.00E-02	5.00E-03	2.00E-05
								Earth Movement Total	**8.04E-03**
	Unknown	Other							8.81E-03
								Unknown Total	**8.81E-03**

Table E.1.6MU
Roadway Effects on Pipeline Failure Rate
P/L 08(06)

CS2MU ROAD TYPE E Pipeline 08(06)

Loc	Classification	Base Failure Rate [per km-year]		Failure Rate Change [per km-year]			Total Failure Rate [per km/year]	
		Type	Value	Type	%	Value	Value	% Base
1	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.00E-02	4.02E-02	19246.8
		Leak	5.30E-05	Leak	36	2.88E-02	2.89E-02	54469.2
		Rupture	1.56E-04	Rupture	14	1.12E-02	1.14E-02	7282.2
	Earth Movement	NLC	1.86E-05	NLC	50	4.02E-03	4.04E-03	21776.6
		Leak	4.00E-06	Leak	36	2.90E-03	2.90E-03	72490.0
		Rupture	1.46E-05	Rupture	14	1.13E-03	1.14E-03	7837.7
	Unknown	NLC	2.63E-05	NLC	50	4.41E-03	4.43E-03	16881.4
		Leak	2.33E-05	Leak	36	3.17E-03	3.20E-03	13723.6
		Rupture	2.97E-06	Rupture	14	1.23E-03	1.24E-03	41640.7
2	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.00E-02	4.02E-02	19241.9
		Leak	5.30E-05	Leak	36	2.88E-02	2.89E-02	54455.3
		Rupture	1.56E-04	Rupture	14	1.12E-02	1.14E-02	7280.3
	Earth Movement	NLC	1.86E-05	NLC	50	4.02E-03	4.04E-03	21776.6
		Leak	4.00E-06	Leak	36	2.90E-03	2.90E-03	72490.0
		Rupture	1.46E-05	Rupture	14	1.13E-03	1.14E-03	7837.7
	Unknown	NLC	2.63E-05	NLC	50	4.41E-03	4.43E-03	16877.5
		Leak	2.33E-05	Leak	36	3.17E-03	3.20E-03	13720.4
		Rupture	2.97E-06	Rupture	14	1.23E-03	1.24E-03	41631.1
3	**External Corrosion**	NLC	1.10E-04	NLC	50	5.25E-07	1.11E-04	100.5
		Leak	1.06E-04	Leak	36	3.78E-07	1.06E-04	100.4
		Rupture	4.75E-06	Rupture	14	1.47E-07	4.90E-06	103.1
	Third Party Damage	NLC	2.09E-04	NLC	50	4.00E-02	4.02E-02	19229.9
		Leak	5.30E-05	Leak	36	2.88E-02	2.89E-02	54421.3
		Rupture	1.56E-04	Rupture	14	1.12E-02	1.14E-02	7275.9
	Earth Movement	NLC	1.86E-05	NLC	50	4.02E-03	4.04E-03	21776.6
		Leak	4.00E-06	Leak	36	2.90E-03	2.90E-03	72490.0
		Rupture	1.46E-05	Rupture	14	1.13E-03	1.14E-03	7837.7
	Unknown	NLC	2.63E-05	NLC	50	4.40E-03	4.43E-03	16867.9
		Leak	2.33E-05	Leak	36	3.17E-03	3.19E-03	13712.7
		Rupture	2.97E-06	Rupture	14	1.23E-03	1.24E-03	41607.5

Table E.1.8MU
Failure Rate Calculation Leak and Rupture 08(06)

LEAK CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2MU ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**	**1.61E-04**
Internal	5.14E-05	5.14E-05	5.14E-05	5.14E-05	5.14E-05
External	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Girth/Filet Weld	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
EXTERNAL FORCES	**6.90E-05**	**3.18E-02**	**3.18E-02**	**3.18E-02**	**6.90E-05**
Construction Damage	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
Third Party Damage	5.30E-05	2.89E-02	2.89E-02	2.89E-02	5.30E-05
Earth Movement	4.00E-06	2.90E-03	2.90E-03	2.90E-03	4.00E-06
WELD FAILURES	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**	**8.51E-05**
Girth Weld	4.98E-05	4.98E-05	4.98E-05	4.98E-05	4.98E-05
Other	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05
Seam Rupture	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
JOINT FAILURES	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**	**4.50E-05**
Mechanical	4.02E-05	4.02E-05	4.02E-05	4.02E-05	4.02E-05
Miscellaneous	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**9.07E-05**	**3.26E-03**	**3.26E-03**	**3.26E-03**	**9.07E-05**
Pipe Failure	4.26E-05	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Overpressure	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06
Operator Error	4.02E-06	4.02E-06	4.02E-06	4.02E-06	4.02E-06
Miscellaneous	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
Unknown	2.33E-05	3.20E-03	3.20E-03	3.19E-03	2.33E-05
TOTALS	**4.51E-04**	**3.53E-02**	**3.53E-02**	**3.53E-02**	**4.51E-04**

RUPTURE CAUSE CLASSIFICATION	PL 08(06) FAILURE RATE [per km-yr]	CS2MU ROAD TYPE E Failure Rate [per km-yr]			
		Loc 1	Loc 2	Loc 3	Loc 4
CORROSION	**6.53E-06**	**6.68E-06**	**6.68E-06**	**6.68E-06**	**6.53E-06**
Internal	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
External	4.75E-06	4.90E-06	4.90E-06	4.90E-06	4.75E-06
Girth/Filet Weld	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXTERNAL FORCES	**1.86E-04**	**1.25E-02**	**1.25E-02**	**1.25E-02**	**1.86E-04**
Construction Damage	1.51E-05	1.51E-05	1.51E-05	1.51E-05	1.51E-05
Third Party Damage	1.56E-04	1.14E-02	1.14E-02	1.14E-02	1.56E-04
Earth Movement	1.46E-05	1.14E-03	1.14E-03	1.14E-03	1.46E-05
WELD FAILURES	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**	**8.02E-06**
Girth Weld	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06
Other	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Seam Rupture	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
JOINT FAILURES	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**	**3.56E-06**
Mechanical	2.97E-06	2.97E-06	2.97E-06	2.97E-06	2.97E-06
Miscellaneous	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
SURFACE EQUIPMENT FA	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**0.00E+00**
Installation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Valve/Fitting	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER FAILURES	**2.79E-05**	**1.26E-03**	**1.26E-03**	**1.26E-03**	**2.79E-05**
Pipe Failure	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Overpressure	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Operator Error	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Miscellaneous	5.64E-06	5.64E-06	5.64E-06	5.64E-06	5.64E-06
Unknown	2.97E-06	1.24E-03	1.24E-03	1.24E-03	2.97E-06
TOTALS	**2.32E-04**	**1.38E-02**	**1.38E-02**	**1.38E-02**	**2.32E-04**

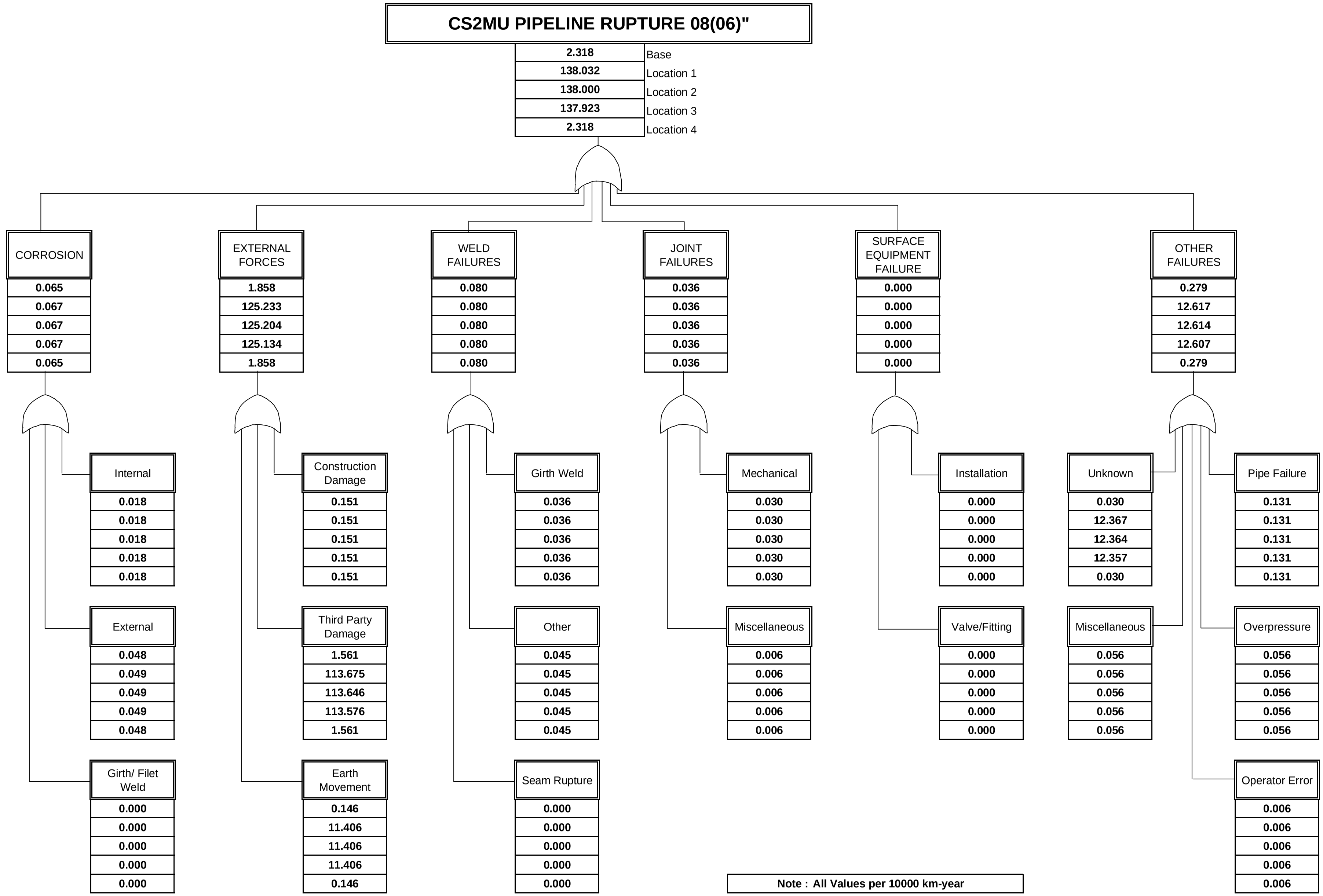


Figure E.1.1MU Pipeline Rupture Rate Variation Fault Tree by Location 08(06)"

Table E.1.10MU
Failure Rate Distribution by Aperture Size

	Location 1		Location 2		Location 3		Location 4	
	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]	Distrib.	Failure Rate [/km-year]	Distrib.	Failure Rate [km-year]
	CS2MU ROAD TYPE E							
	Pipeline 08(06)"							
Base Leak	73.0%	**3.53E-02**	73.0%	**3.53E-02**	73.0%	**3.53E-02**	73.0%	**4.51E-04**
Base Rupture	27.0%	**1.38E-02**	27.0%	**1.38E-02**	27.0%	**1.38E-02**	27.0%	**2.32E-04**
Leak	73.0%	3.53E-02	73.0%	3.53E-02	73.0%	3.53E-02	73.0%	4.51E-04
Hole	20.0%	1.02E-02	20.0%	1.02E-02	20.0%	1.02E-02	20.0%	1.72E-04
Rupture	4.6%	2.35E-03	4.6%	2.35E-03	4.6%	2.35E-03	4.6%	3.95E-05
D Rupture	2.4%	1.23E-03	2.4%	1.23E-03	2.4%	1.23E-03	2.4%	2.06E-05

Table E.3.2MU
Individual Risk Calculation

SCENARIO	RELEASE TYPE	p_r (/km - yr)	P_s	p_r x P_s (/km - yr)	p_f	H (m)	Directional Probability	INDIVIDUAL ANNUAL RISK AT DISTANCE "x" (m)								
								0	5	10	25	50	150	200	250	300
TAC-VP06-MA-CS2MU-Location 1																
GAS RELEASE	Leak	3.53E-02						-	-	-	-	-	-	-	-	-
	Hole	1.02E-02						-	-	-	-	-	-	-	-	-
	Rupture	2.35E-03						-	-	-	-	-	-	-	-	-
	D Rupture	1.23E-03						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		1.720	6.07E-02	0.1	6	0.25	1.82E-05	1.01E-05	-	-	-	-	-	-	-
	Hole		0.484	4.94E-03	0.1	102	0.25	2.52E-05	2.51E-05	2.51E-05	2.44E-05	2.19E-05	-	-	-	-
	Rupture		0.595	1.40E-03	0.1	146	0.25	1.02E-05	1.02E-05	1.02E-05	1.01E-05	9.59E-06	-	-	-	-
	D Rupture		0.595	7.32E-04	0.1	198	0.25	7.25E-06	7.24E-06	7.24E-06	7.19E-06	7.01E-06	4.73E-06	-	-	-
FLASH FIRE - Transverse	Leak		0.109	3.85E-03	0.5	12	0.25	1.15E-05	1.05E-05	6.38E-06	-	-	-	-	-	-
	Hole		0.136	1.39E-03	0.5	236	0.25	8.18E-05	8.18E-05	8.18E-05	8.14E-05	8.00E-05	6.32E-05	4.34E-05	-	-
	Rupture		0.125	2.94E-04	0.5	274	0.25	2.01E-05	2.01E-05	2.01E-05	2.00E-05	1.98E-05	1.68E-05	1.38E-05	8.24E-06	-
	D Rupture		0.125	1.54E-04	0.5	322	0.25	1.24E-05	1.24E-05	1.24E-05	1.23E-05	1.22E-05	1.10E-05	9.70E-06	7.80E-06	4.50E-06
FLASH FIRE - Parallel	Leak		0.109	3.85E-03	0.5	2	0.25	1.92E-06	-	-	-	-	-	-	-	-
	Hole		0.136	1.39E-03	0.5	47	0.25	1.63E-05	1.62E-05	1.59E-05	1.38E-05	-	-	-	-	-
	Rupture		0.125	2.94E-04	0.5	60	0.25	4.41E-06	4.39E-06	4.34E-06	4.01E-06	2.44E-06	-	-	-	-
	D Rupture		0.125	1.54E-04	0.5	104	0.25	4.00E-06	3.99E-06	3.98E-06	3.88E-06	3.51E-06	-	-	-	-
EXPLOSION	Leak		0.012	4.24E-04	0.1	2	1.00	1.69E-07	-	-	-	-	-	-	-	-
	Hole		0.058	5.92E-04	0.1	51	1.00	6.03E-06	6.01E-06	5.92E-06	5.26E-06	1.19E-06	-	-	-	-
	Rupture		0.054	1.27E-04	0.1	98	1.00	2.49E-06	2.48E-06	2.47E-06	2.40E-06	2.14E-06	-	-	-	-
	D Rupture		0.054	6.64E-05	0.1	65	1.00	8.63E-07	8.61E-07	8.53E-07	7.97E-07	5.52E-07	-	-	-	-
DISPERSION	Leak		0.828	2.92E-02	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.516	5.26E-03	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.405	9.52E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.405	4.98E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	2.23E-04	2.11E-04	1.97E-04	1.86E-04	1.60E-04	9.57E-05	6.69E-05	1.60E-05	4.50E-06
			1	Daily Commuter Loc 1			0.0020	4.44E-07	4.21E-07	3.92E-07	3.70E-07	3.19E-07	1.91E-07	1.33E-07	3.19E-08	8.96E-09
			2	Weekly Commuter Loc 1			0.0005	1.16E-07	1.10E-07	1.03E-07	9.69E-08	8.37E-08	5.00E-08	3.49E-08	8.37E-09	2.35E-09
			3	Worker Loc1			0.0075	1.67E-06	1.59E-06	1.48E-06	1.39E-06	1.20E-06	7.19E-07	5.02E-07	1.20E-07	3.38E-08
			4	Resident Loc 1			0.0877	1.95E-05	1.85E-05	1.72E-05	1.63E-05	1.41E-05	8.39E-06	5.87E-06	1.41E-06	3.94E-07
TAC-VP06-MA-CS2MU-Location 4																
GAS RELEASE	Leak	4.51E-04						-	-	-	-	-	-	-	-	-
	Hole	1.72E-04						-	-	-	-	-	-	-	-	-
	Rupture	3.95E-05						-	-	-	-	-	-	-	-	-
	D Rupture	2.06E-05						-	-	-	-	-	-	-	-	-
JET FIRE	Leak		0.152	6.85E-05	0.1	6	0.25	2.06E-08	1.14E-08	-	-	-	-	-	-	-
	Hole		0.183	3.14E-05	0.1	102	0.25	1.60E-07	1.60E-07	1.60E-07	1.55E-07	1.40E-07	-	-	-	-
	Rupture		0.195	7.70E-06	0.1	146	0.25	5.62E-08	5.62E-08	5.61E-08	5.54E-08	5.28E-08	-	-	-	-
	D Rupture		0.195	4.02E-06	0.1	198	0.25	3.98E-08	3.98E-08	3.97E-08	3.95E-08	3.85E-08	2.60E-08	-	-	-
FLASH FIRE - Transverse	Leak		0.014	6.31E-06	0.5	12	0.25	1.89E-08	1.72E-08	1.05E-08	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	236	0.25	1.32E-07	1.32E-07	1.32E-07	1.31E-07	1.29E-07	1.02E-07	6.99E-08	-	-
	Rupture		0.014	5.53E-07	0.5	274	0.25	3.79E-08	3.79E-08	3.79E-08	3.77E-08	3.72E-08	3.17E-08	2.59E-08	1.55E-08	-
	D Rupture		0.014	2.89E-07	0.5	322	0.25	2.32E-08	2.32E-08	2.32E-08	2.32E-08	2.29E-08	2.06E-08	1.82E-08	1.46E-08	8.44E-09
FLASH FIRE - Parallel	Leak		0.014	6.31E-06	0.5	2	0.25	3.16E-09	-	-	-	-	-	-	-	-
	Hole		0.013	2.23E-06	0.5	47	0.25	2.62E-08	2.61E-08	2.56E-08	2.22E-08	-	-	-	-	-
	Rupture		0.014	5.53E-07	0.5	60	0.25	8.29E-09	8.27E-09	8.18E-09	7.54E-09	4.58E-09	-	-	-	-
	D Rupture		0.014	2.89E-07	0.5	104	0.25	7.50E-09	7.49E-09	7.47E-09	7.28E-09	6.58E-09	-	-	-	-
EXPLOSION	Leak		0.002	9.02E-07	0.1	2	1.00	3.61E-10	-	-	-	-	-	-	-	-
	Hole		0.006	1.03E-06	0.1	51	1.00	1.05E-08	1.05E-08	1.03E-08	9.16E-09	2.07E-09	-	-	-	-
	Rupture		0.006	2.37E-07	0.1	98	1.00	4.64E-09	4.64E-09	4.62E-09	4.49E-09	3.99E-09	-	-	-	-
	D Rupture		0.006	1.24E-07	0.1	65	1.00	1.61E-09	1.60E-09	1.59E-09	1.48E-09	1.03E-09	-	-	-	-
DISPERSION	Leak		0.848	3.82E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Hole		0.817	1.40E-04	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	Rupture		0.805	3.18E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
	D Rupture		0.805	1.66E-05	0.0	0	0.25	-	-	-	-	-	-	-	-	-
							ISFR	5.51E-07	5.36E-07	5.16E-07	4.94E-07	4.38E-07	1.80E-07	1.14E-07	3.01E-08	8.44E-09
			4	Resident Loc 4			0.0877	4.83E-08	4.70E-08	4.53E-08	4.33E-08	3.84E-08	1.58E-08	1.00E-08	2.64E-09	7.40E-10

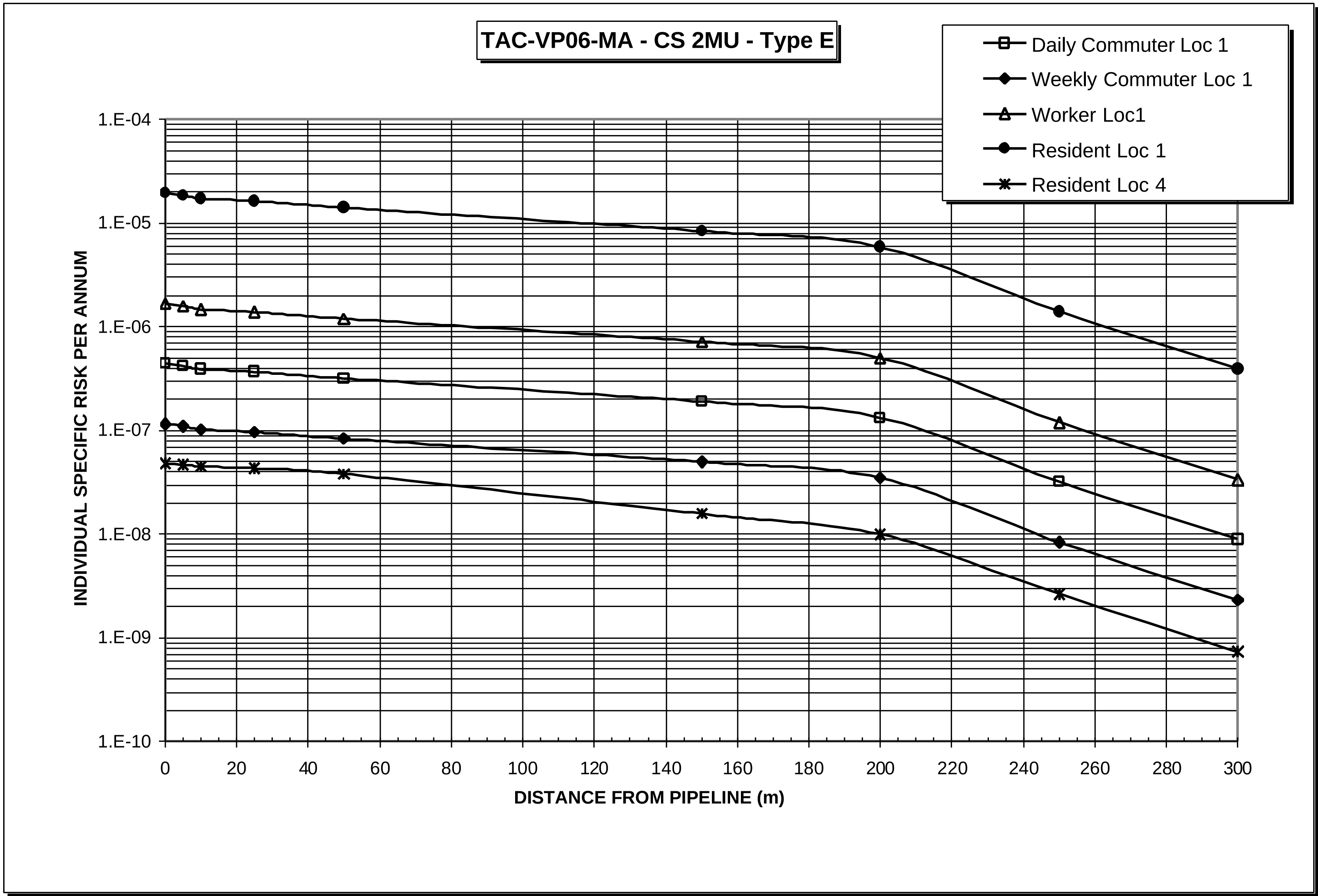


Figure E.3.2MU – Transects CS2MU VP06 Loc 1(4)

Table E.3.12
Collective Risk Exposure Numbers CS2

Nr	Road Type	ADDT	Hazard	V	Spacing		Number of cars		Number of People	
		cars/day max	m	km/h min	Day m	Night m	Day	Night	Day	Night
1	CS2 Type E	9000	300	80	107	427	2.81	0.70	6	2

Table E.3.13
Automobile Occupant IRI Calculation CS2

Scenario	FLASH FIRE				JET FIRE				EXPLOSION			
Release type	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**	**Leak**	**Hole**	**Rupture**	**D. Rup.**
Releases [per km-year]	3.53E-02	1.02E-02	2.35E-03	1.23E-03	3.53E-02	1.02E-02	2.35E-03	1.23E-03	3.53E-02	1.02E-02	2.35E-03	1.23E-03
Interactive Length [km]	10											
Releases [per year]	3.53E-01	1.02E-01	2.35E-02	1.23E-02	3.53E-01	1.02E-01	2.35E-02	1.23E-02	3.53E-01	1.02E-01	2.35E-02	1.23E-02
ROO	0.172	0.480	0.590	0.590	0.108	0.134	0.124	0.124	0.012	0.058	0.053	0.053
Probability [per year]	6.07E-02	4.89E-02	1.39E-02	7.25E-03	3.82E-02	1.37E-02	2.91E-03	1.52E-03	4.25E-03	5.87E-03	1.25E-03	6.53E-04
Probability of Fatality	0.50				0.10				0.10			
Sheild Factor	0.10				0.10				0.10			
P-Footprint Factor	0.12				0.25				0.80			
Individual Risk Intensity	3.64E-04	2.94E-04	8.32E-05	4.35E-05	9.56E-05	3.43E-05	7.28E-06	3.81E-06	3.40E-05	4.70E-05	9.98E-06	5.22E-06
Hazard Distance [m]	9.0	204.0	294.0	327.0	4.0	8.0	210.0	290.0	0.0	82.0	169.0	208.0

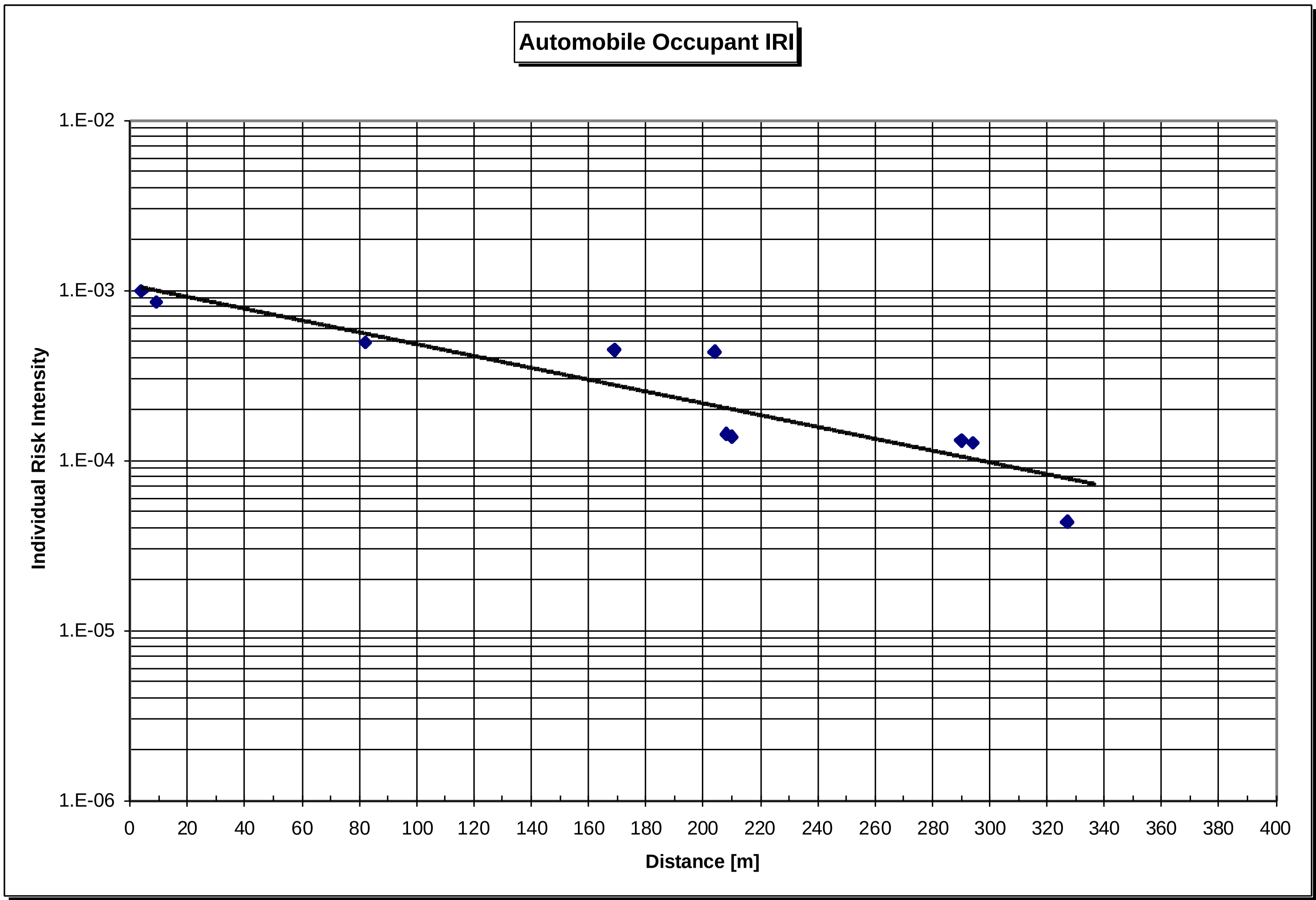


Figure E.3.13 – CS2 Automobile Occupant IRI

Table E.3.14
Calculated Probabilities of Fatalities for CS2

Location	Time	Distance [m]	IRI	OCR Factor	Directional Factor	Dynamic Factor	N Footprint Factor	N [ppl]	N in Footprint [ppl]	Annual Chance of N Fatalities
Road	Night	100	5.00E-04	0.50	0.5	0.06	0.50	1	0.50	7.50E-06
		200	2.00E-04	0.50	0.5	0.12	0.50	1	0.50	6.00E-06
		300	1.00E-04	0.50	0.5	0.18	0.50	2	1.00	4.50E-06
	Day	100	5.00E-04	0.50	0.5	0.06	0.50	2	1.00	7.50E-06
		200	2.00E-04	0.50	0.5	0.12	0.50	4	2.00	6.00E-06
		300	1.00E-04	0.50	0.5	0.18	0.50	6	3.00	4.50E-06

N in Footprint [ppl]	Annual Chance of N Fatalities	Annual Chance of N or more Fatalities
1	2.55E-05	3.60E-05
2	6.00E-06	1.05E-05
3	4.50E-06	4.50E-06

OCR	Outdor Collective Risk factor
Dinamic Factor	Amount of time as % of 60 sec in the footprint

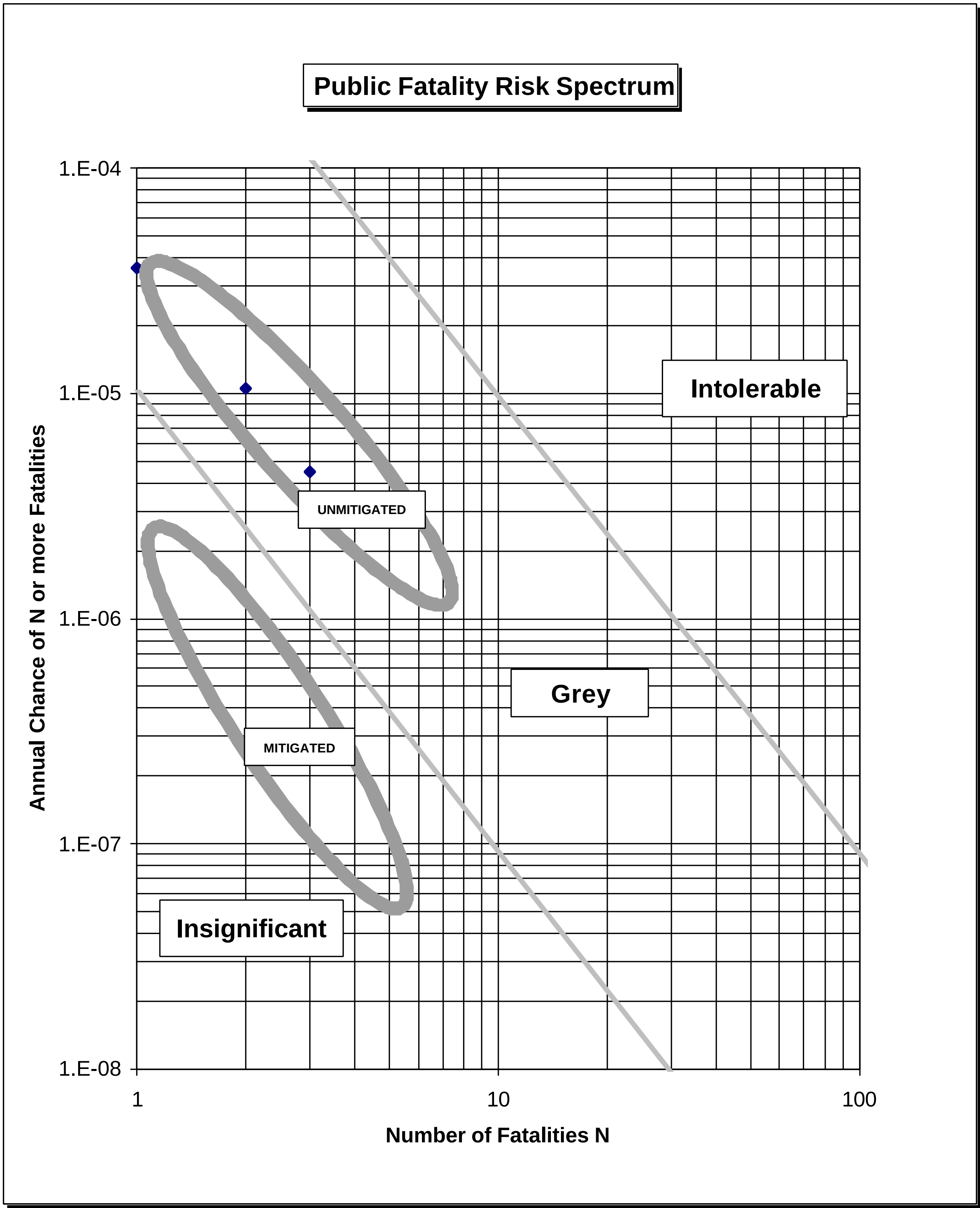


Figure E.3.14 – Collective Risk for CS2 Umitigated

APPENDIX F

Regulatory Information

Table F.1
Pipeline Location Risk Mitigation Measures

Classification	Hazard to P/L	ROAD TYPE	P/L LOC	MITIGATION MEASURES
External Corrosion				
	Percolation	ALL	ALL	1-Ensure adequate protective coating for expected soil ph/moisture conditions
				2-Ensure adequate drainage control
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	EMF	ALL	ALL	1-Ensure adequate Cathodic protection system and check regularly
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
	Salt efffects	ALL	ALL	1-Ensure adequate protective coating for expected salt concentrations
				2-Ensure adequate drainage control to minimize road salt drainage to p/l
				3-conduct regular inspection pigging to detect incipient corrosion and permit repairs
Third Party Damage				
	Roadway Clearing-Debris,Rockfall	ALL	ALL	1-Identify pipeline locations from p/l markers if grading to max .3m ok
				2-Use care with excavators or loaders CPEP within 30m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Culvert Maintenance	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Supply, Remove, & Install Minor Culverts	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Minor Signs (Single Post)	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Major Signs	ALL	1,2	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Installation of Guide Posts	ALL	ALL	1-Locate p/l and use CPEP
				2-Ensure guide post holes do not exceed .5m depth if within 3m
	Installation of Extra or Repl. Power Poles	ALL	ALL	1-Locate p/l and use CPEP
				2-Locate p/l in location 3
	Ditch Grading- Continous, Grader	ALL	2	1-Locate p/l and use CPEP
				2-Conduct depth of cover survey prior to commencement of grading of ditches
	Ditch Grading- Continous, Excavator	ALL	2	1-Ditch grading with excavator not permitted if p/l installed less than 2m below ditch invert
				2-Install p/l in alternate location
				3-Develop safe ditch grading procedure and p/l installation method
	Snow Ploughing	1	ALL	1-Locate p/l (from markers) and use care if over p/l
	Rock scaling	1	ALL	1-Avoid locating p/l in frequent (<20yr) rock fall locations
				2-Use nets/deflectors to deflect rockfalls from p/l locations
				3-Protect p/l with grade surface protectors -slabs, plates adequate to absorb rock fall impacts
				4-Design and install p/l for maximum rock fall impact resistance
	Mud Slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP
	Land slide Cleanup	5	ALL	1-Identify pipeline locations from p/l markers
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Washout Repairs	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m
	Major Section Repair, Excavation of Embankment	5	ALL	1-Locate p/l and use CPEP
				2-Use care with excavators or loaders within 3m of p/l
				3-Minimize heavy equipment operations over p/l
				4-If excavating below original grade locate p/l and use CPEP within 2m

Table F.1
Pipeline Location Risk Mitigation Measures

				5-Conduct full scale p/l resistance/integrity tests for expected dynamic compaction methods
				6. P/l should be located at as depth where it is safe fromheavy equipment/vibratory compaction
	New Culvert X	1	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Culvert II	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Utility X (e.g., FOC)	ALL	ALL	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
	New Utility II	ALL	1,2	1-Locate p/l
				2-Use CPEP within 2m of p/l
	New Minor Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New Major Sign	ALL	1,2	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
	New power Line	ALL	ALL	1-Locate p/l and use CPEP
	New Ditch	ALL	1	1-Locate p/l and use CPEP
				2-Use CPEP within 2m of p/l
				3-Install p/l in loc 3
			2	1-No new ditch over 1.2m cover p/l location
				2-Relocate p/l to alternate location
	New Guard Rail (Unmitigated)	ALL	ALL	1-Locate p/l and use CPEP
				2-Plan ahead and install p/l in location 3 or 4 where guardrail work expected
	New Guard Rail (Mitigated)	ALL	1,2	1-Locate p/l and use CPEP
	New Driveway	ALL	ALL	1-Locate p/l
				1-Locate p/l and use CPEP
				3-Plan ahead-Install new access grade at time of p/l installation
	Railway Crossing Accident Derailment	ALL	ALL	1-Install p/l as far as possible from railroad, preferred >20m to avoid derailed train impact
				2-Implement derailment ERP, including immediate p/l shutin and blowdown
Earth Movement				
	Vibration from Traffic	1	ALL	1-Ensure adequate protective coating and pipe beddin design/installation
				2-Conduct regular inspection pigging to detect incipient damageand permit repairs
	Frost Heave	3	ALL	1-Ensure adequate protective coating and pipe bedding design/installation
				2-Drainage control to avoid water/ice buildup in vicinity of p/l
	Landslide	5	ALL	1-Locate outside landslide zone
				2-If in landslide zone design and install p/l for maximum landslide survival
				3-Shut in and blowdown if landslide warning red alert
	Flood	10	ALL	1-Locate outside flood zone
				2-If on flood plain design/install to maintain integrity in max flood
				3-Shut in and blowdown if flood buildup predicted and underway

Note re CPEP: If excavation more than 0.3m deep planned:
1. Within 30m of p/l contact p/l operator and locate and mark p/l
2. Within 5m of p/l daylight p/l by hand excavation
3. Witin 0.6m of p/l surface hand excavate
4. Hand excavation includes low pressure air of water jet of vacuum (Hydrovac)

Table F.2
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
	ROAD ACTIVITIES			
	NORMAL ROAD OPERATION			
		ALL	ALL	None
	ROAD MAINTENANCE			
	Routine Maintenance	ALL	ALL	None
	Road Surface Maintenance	ALL	ALL	None
	Roadside Maintenance	ALL	ALL	None
	Roadside Repairs and Installations			
	Supply, Remove, & Install Culverts-x	ALL	1.2	1-Use of culvert liner inside existing colvert would require no additional mitigation
		ALL	1,2	2-If culvert replaced, locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within .6m of p'l, use CPEP
		ALL	1,2	3-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	4-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
	Supply, Remove, & Install Culverts-ll	ALL	1,2	1-Use of culvert liner inside existing colvert would require no additional mitigation
		ALL	1,2	2-If culvert replaced, locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within .6m of p'l;use CPEP
		ALL	1,2	3-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	4-Avoid p/l in loc 2 if culvert replacement anticipated
	Installation of Minor Signs (single post)	ALL	1	1-Locate p/l min 2m from minor sign location (ie 6.5 m from edge of road); adopt CPEP
	Installation of Major Signs	ALL	1	1-Locate p/l min 2m beyond outside post of major sign; adopt CPEP
	Installation of Guard Rail	ALL	1	1-Locate p/l min 2m beyond guardrail post outside face; adopt CPEP
		ALL	1	2-Increase p/l cover to be min .5 m below bottom of post and conduct cover survey (daylight) before drilling and use auger depth governor when drilling
				3. Use CPEP
	Ditch Grading - continuous-backhoe	ALL	2	1-Avoid ditch location 1 for p/l where ditch grading anticipated
		ALL	2	2-Locate top of p/l in loc 2 min 2m below ditch invert and conduct cover survey before grading
	Installation of Extra or Replacement Power Poles	ALL	ALL	1-Locate p/l min 5m from existing power line , use CPEP
	Winter Operations			
	Snow Ploughing	ALL	1,2	None
	Mountain Operations			
	Rock scaling	ALL	ALL	1-Avoid locating p/l in continuous rock fall locations
				2-Design and install pipeline to withstand maximum rock drop impact
	ROAD CONSTRUCTION			
	Road Surface			Mitigation depends on extent of 3R/4R programme

Table F.2
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
	Major Section Repair/resurfacing	ALL	1,2	1-Locate p/l in location 3
	Add Climbing/Passing Lane	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	Add Turn Lane	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	Widen Road	ALL	1,2	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	Pave Shoulder	ALL	1	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	New Exit/Entry	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	New Overpass	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	New Underpass	ALL	ALL	1-Relocate p/l 2. Construct road over p/l using special constr supervised by p/l oper.
	Blasting for wider road surface	ALL	ALL	1-Use blast mats and take p/l out of service during blasting operations
	ROW (Off Surface)			
	New Culvert X	ALL	1,2	1-Locate new culvert invert .5m minimum from top (or bottom) of p/l and use CPEP
		ALL	1,2	2-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	3-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
	New Culvert II	ALL	1,2	1-Locate new culvert invert .5m minimum from top (or bottom) of p/l and hand or hydrovac excavate within 2m of p'l
		ALL	1,2	2-Plan ahead -locate p/l in loc 1 or 2 at least .5 to 1m below expected replacement culvert invert
		ALL	1,2	3-Avoid p/l in loc 1 or 2 if culvert replacement anticipated
	New Utility X (e.g., FOC)	ALL	1,2	1-Plan ahead-install x utility conduits during p/l construction
				2-Install p/l with sufficient depth to clear future utility by .5m vertical and use CPEP
	New Utility II	ALL	1,2	1-Install new utility in common trench during p/l construction;use CPEP
	New Minor Sign	ALL	1,2	1-Locate p/l min 2m from minor sign location (ie 6.5 m from edge of road);use CPEP
	New Major sign	ALL	1,2	1-Locate p/l min 2m beyond outside post of major sign;use CPEP
	New O/H Sign Bridge	ALL	1,2	1-Locate footings min 2m from p/l;use CPEP
	New power Line	ALL	1,2	1-Locate new power line min 2m from p/l;use CPEP
	New Ditch	ALL	1,2	1-Avoid ditch location 1 for p/l where new ditch anticipated
	New guard rail	ALL	1	1-Locate p/l min .6m beyond guardrail post outside face;use CPEP
		ALL	1	2-Increase p/l cover to be min .5 m below bottom of post and conduct daylighting cover survey before drilling survey and use auger depth governor when drilling
	New Driveway/Access road	ALL	1,2	1-Plan ahead-locate p/l for min 1.2 m clearance below max excavation depth
				2-Reinforce p/l backfill and bedding to accept localized paving
				3-Design driveway/ access to give 2m clearance from grade to top of p/l
	PIPELINE ACTIVITIES			
	NORMAL PIPELINE OPERATION			
	Pipeline remotely operated	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
	Pipeline failure	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
	Suspected pipeline damage	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
	PIPELINE MAINTENANCE			
	Pipeline repair (major)	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
	Pipeline Exposure for Coating/Pipe Inspection	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
	Pipeline Repair (minor) - Exposure	ALL	ALL	1-Follow Temporary Traffic Control Guidelines

Table F.2
Pipeline Location and Pipeline Activity Operational and Economic Impact Mitigation Measures

ITEM	ACTIVITY	ROAD TYPE	P/L LOCN.	MITIGATION MEASURE
F	**PIPELINE CONSTRUCTION**			
F.13	New pipeline construction	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.1	Looping	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.2	Tap away from road	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.3	Tap across road	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
		ALL	ALL	2-Use boring rather than open trench
F.4	New valve	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.5	Valve replacement	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.6	P/l section Replacement	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.7	Lateral away from road	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.8	Lateral under road	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
				2-Use boring rather than open trench
F.9	New cathodic Protection	ALL		1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.10	Instrument Installation	ALL	ALL	1-Plan construction to avoid Road encroachment, may need workspace off ROW
F.11	Blasting for new trench	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
F.12	Hydrotesting	ALL	ALL	1-Follow Temporary Traffic Control Guidelines
G	**LONG TERM**			
G.1	ROW Usability			1-Install any parallel utilities in common trench at time of p/l construction
G.2	Road system structural Integrity			1-Assure optimal backfill/compaction procedure in p/l trench
				2-conduct geotechnical investigation prior to p/l installation to avoid integrity problems