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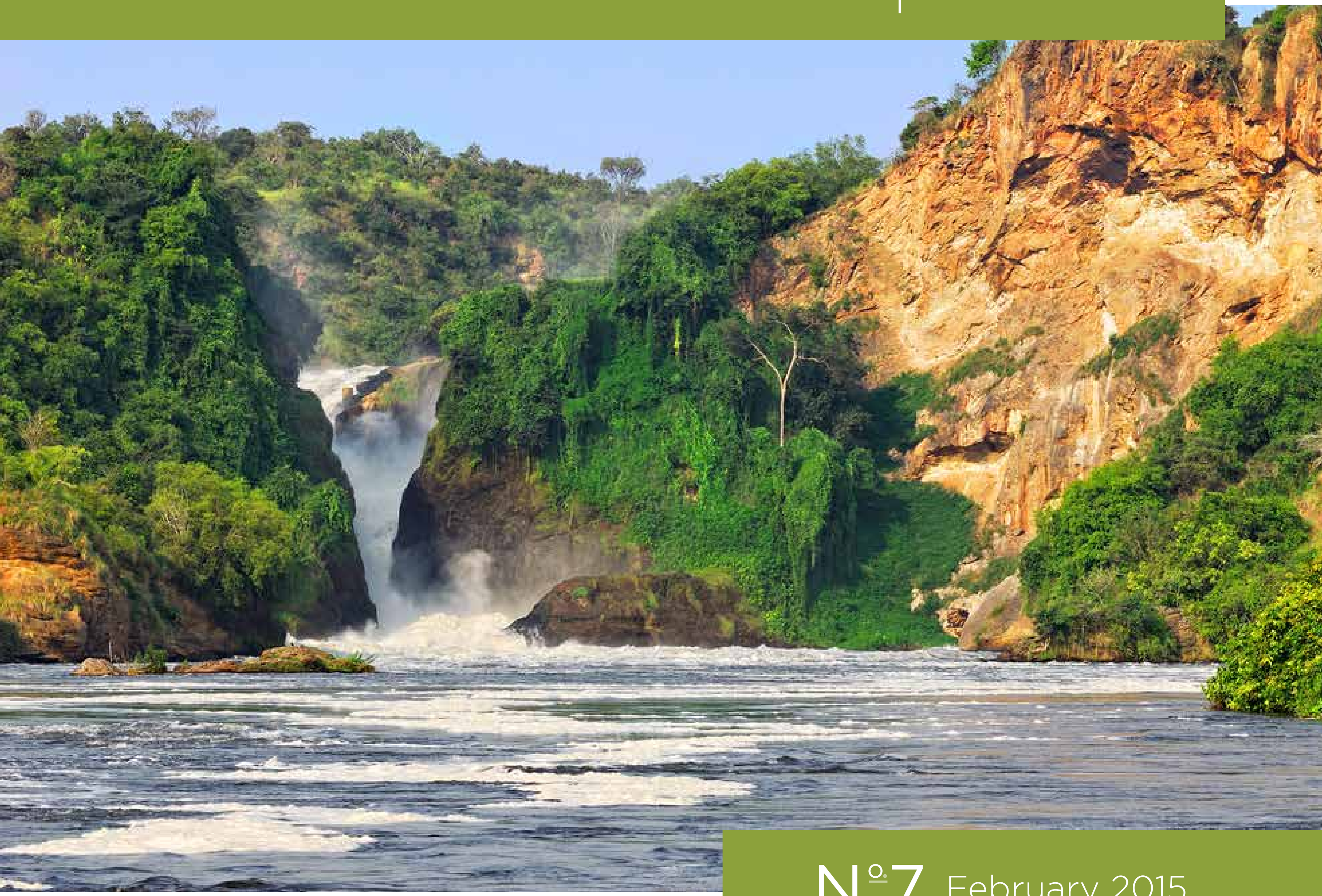
DISCUSSION PAPER



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A Cost Effectiveness Approach to Routing of Linear Infrastructure in Environmentally Sensitive Areas: A Case of Crude Oil Pipeline in the Albertine Rift in Uganda

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Photo: Oleg Znamenskiy

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1. Introduction

The government of Uganda has plans to construct a pipeline to deliver crude oil from its central processing facilities in Buliisa District, to a refinery to be located in Kabale parish in Hoima District. The proposed route, which passes through the biologically rich Albertine Rift, poses a significant risk of destroying, fragmenting, and altering vital habitats for important and endangered species, thereby damaging valuable ecosystem services which may negatively impact people and wildlife. These sorts of "external" costs are typically not paid for by developers, and are therefore frequently underestimated or ignored in project decisions. This study demonstrates a methodology to evaluate potential alternative routes for the pipeline, seeking to balance conservation impact considerations with financial costs.

2. Approach

The study included three major steps. First, we identified areas of conservation priority based on 41 important conservation features such as: elephants, lions, wetlands, and grasslands. We also set conservation targets ranging from 13% to 100% of the remaining distribution of each feature.[1] A conservation-planning tool called Marxan was then used to identify areas that achieved conservation targets at minimum socio-economic costs. Socio-economic costs were based on proximity to settlements, roads, and towns, and presence-absence of protected areas. The output of this process (figure 1) provided a basis for identifying avoidance areas (areas with high environmental cost) and assessing potential impacts of pipeline options.

The second step was to identify potential routes for the pipeline using a Least Cost Path (LCP) analysis. As the name suggests, this type of analysis finds the LCP between two points, where cost is measured based on a set of factors combined into a map of "path resistance." The higher the cost, the higher the resistance value for each cell on the map. We generated and compared LCPs under two scenarios. The first scenario was based only on financial factors, therefore called the Financial LCP. This scenario includes costs related to the length of the pipeline, crossing of major barriers in the landscape, and passing through populated areas such as settlements, urban centres, and the existing road network. The second scenario added the conservation area priorities from step one to the path resistance map. This scenario is called the Financial LCP with Environmental Considerations. The resistance layers and optimal pipeline routes under each scenario are shown in Figure 2.

The third step was to identify the direct impacts of each pipeline route on specific conservation features and in reducing options for achieving conservation targets. Impacts of the two pipelines on suitable habitats for species were quantified both within the direct path (Right Of Way – ROW) of the pipeline and within three buffers of varying width around the ROW. Impacts were estimated based on the understanding that pipeline construction will reduce the quality and size of species habitat through removal of vegetation directly under the pipeline ROW, create species migration barriers [edge effects] and disturbance of vegetation composition and structure that would affect the quality of habitat in adjacent areas.

[1] Conservation targets for the analysis were based on expert opinion for minimum viable population for threatened and endangered species and ecosystems and feedback of participants in a scenario planning workshop

3. Results

Priority conservation areas were identified. Figure 1 shows, in red, the most cost-effective areas to achieve conservation objectives and/or areas where few other remaining options for achieving conservation objectives exist.

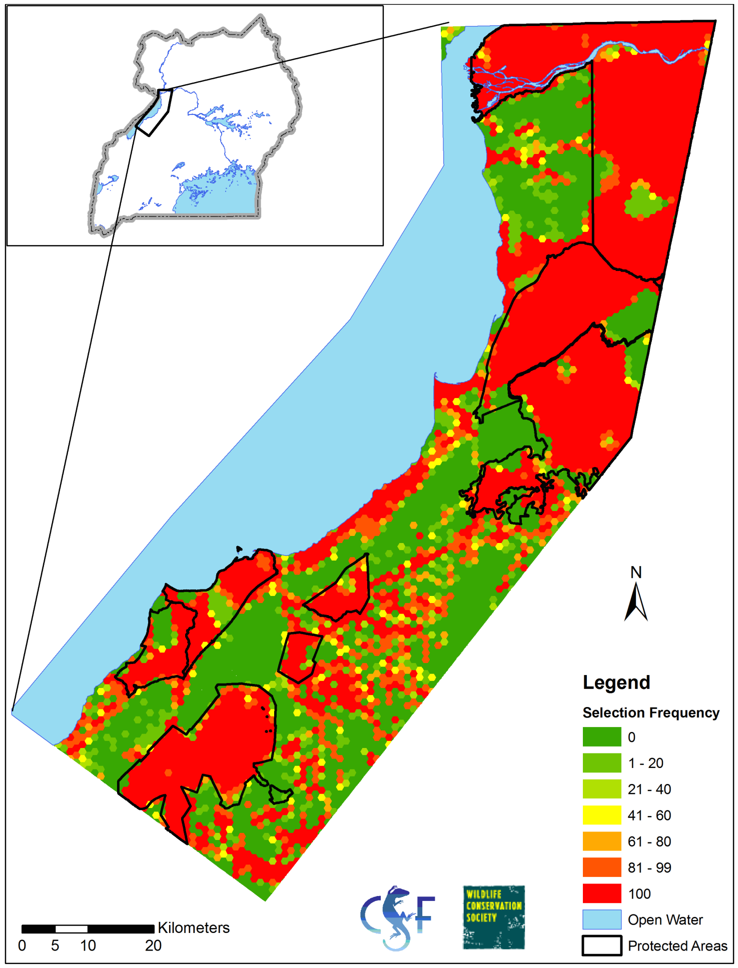

Figure 1. Map of conservation priorities.

The LCP routes were identified using the Financial Resistance Layer and the Financial with Environmental Considerations Resistance Layer. The optimal route identified in the Financial with Environmental Consideration scenario resulted in a 54% increase in relative financial costs compared to the pipeline route which only considered financial costs. This is the case, despite a shorter overall length of the pipeline (117km compared to 137km for the Financial LCP). This is partly due to the Financial LCP predominantly following the existing road network (Plate 2) as it would be financially cheaper to construct a pipeline adjacent to an existing road. The Environmental Considerations LCP, on the other hand, deviated from the road to avoid areas of very high environmental and biological significance (Plate 4).

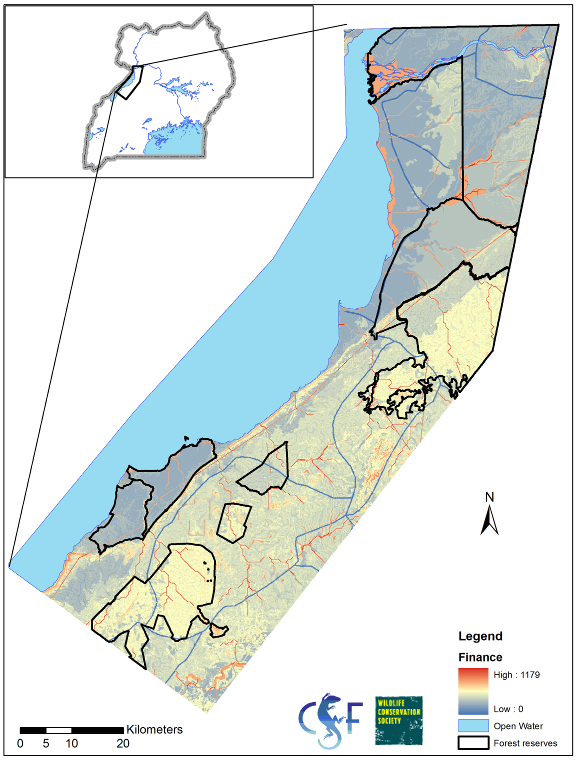

Plate 1: Resistance Layer Financial LCP

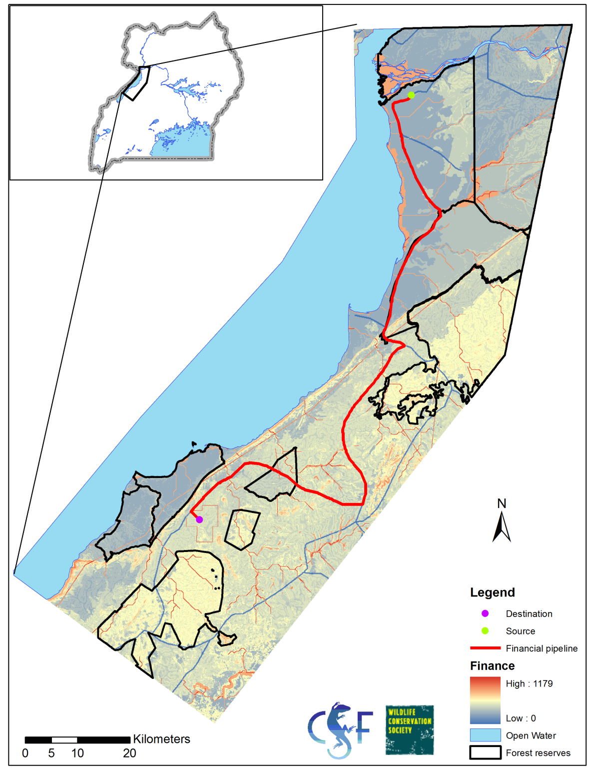

Plate 2: Financial LCP

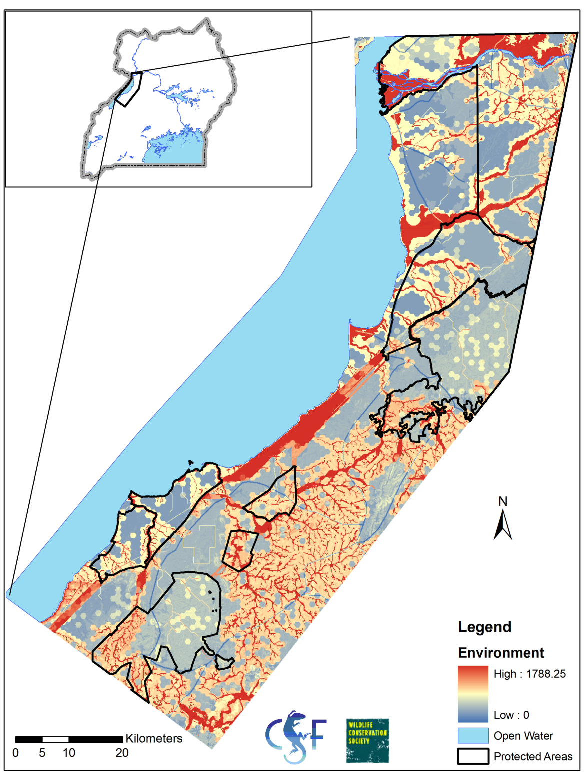

Plate 3: Resistance Layer Financial LCP with Environmental Considerations

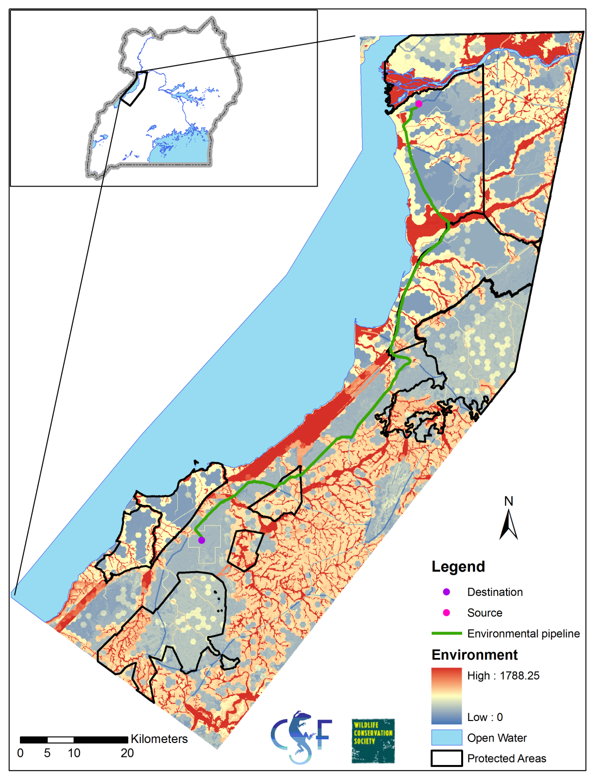

Plate 4: Financial LCP with Environmental Considerations

Figure 2: Scenario 1 and 2 Resistance Layers (plate 1 and 3) and Least Cost Path routes (plates 2 and 4) that were identified using a least cost path analysis.

In terms of direct environmental impact, the Financial LCP resulted in larger habitat loss for mammal and bird species of conservation concern. The relative impact of either pipeline route on individual ecosystem types is highly dependent on how far impacts are expected to spread around the pipeline as a result of attracting people to the area, improving access to resources, and infrastructure development-induced risks to wildlife through noise, vibration and pollution resulting in road kills, altered space-use, and home range patterns (Table 2). Due to the size of the landscape, even relatively small percentage differences represent fairly large areas.

Areas of particular notable difference among scenarios are highlighted in Table 2. Among the most preoccupying impacts of the Financial LCP, considering an impact area of 10km around the pipeline, are: loss of nearly 1/3rd of mangabey habitat, 100% of hyena habitat, and 60% of the landscape's grasslands.

Table 2: Impacts: proportion of feature in pipeline Right of Way (ROW) and buffers around the ROW, as a percentage of existing total area of feature in the landscape

Conservation Feature	**Impact (% area) within ROW**		**Impact (% area) in <1km of ROW**		**Impact (% area) in <10km of ROW**	
	Scenario 1 Fin. LCP	**Scenario 2 Fin. w/env. LCP**	**Scenario 1 Fin. LCP**	**Scenario 2 Fin. w/env. LCP**	**Scenario 1 Fin. LCP**	**Scenario 2 Fin. w/env. LCP**
Hippopotamus	4.81	4.57	13.01	12.78	60.95	60.8
Giraffe	4.74	4.5	13.15	12.86	64.45	64.01
Elephant	4.02	3.81	11.37	10.92	50.39	50.32
Crowned Crane	2.39	1.89	7.29	6.85	34.37	34.25
Mangabey	2.01	1.34	2.01	1.34	32.21	1.34
Nahan's Francolin	1.62	1.29	4.78	4.57	38.53	34.75
White Backed Vulture	1.26	0.85	3.72	3.87	34.89	33.5
Lion	1.22	1.22	2.55	2.55	13.05	13.05
Leopard	1.03	0.64	2.66	2.55	13.09	13.09
Shoebill	0.65	0.43	1.89	1.49	35.89	34.67
Chimpanzee	0.50	0.17	1.73	1.28	27.17	27.01
Hyena	0.00	0.00	0.00	0.00	100.00	0.00
Grasslands	5.65	4.22	13.98	11.31	60.02	47.05
Woodlands	3.87	3.35	10.6	10.18	52.98	49.69
Tropical High Forest	2.71	2.43	7.46	6.85	51.76	49.75
Bushlands	0.43	0.06	3.45	1.73	79.4	74.95
Wetlands	1.21	0.58	4.21	2.14	42.28	35.61
Tropical High Forest (Degraded)	6.09	5.91	18.48	17.55	63.64	62.46

With regard to the ability to achieve conservation targets, the Financial LCP was predicted to significantly limit the spatial distribution of future conservation areas. As such, there was an increase in area of places identified as the most suitable choices for meeting conservation targets (with no other option – as shown in Table 3). This is attributed to change in magnitude and intensity of socio-economic factors or the fact that conservation targets could not be achieved in any other area. Some conservation targets, however, could not be achieved under either scenario of pipeline construction routes. For instance, stakeholders suggested that 100% of the wetlands should be conserved in the landscape. While the Environmental LCP reduced impact on wetlands by up to three times that of the Financial LCP, important impacts still exist (0.5-1.0% as compared to 0.5-3.0%). Table 3 shows the area under each conservation priority category (as prioritised by Marxan planning tool) needed to achieve targets across scenarios assuming that pipelines only have an impact within the ROW.

Table 3: Land area in square kilometres per conservation priority category after running Marxan analysis; (a) with no pipeline (baseline), (b) when scenario 1 pipeline route was separately considered and (c) when scenario 2 pipeline route was separately considered in the analysis

Conservation priority categories as determined using Marxan	**Area selected for conservation (Km^2)**		
	(a) Baseline (no project scenario)	**(b) Scenario 1 Fin. LCP**	**(c) Scenario 2 Fin. w/Env. LCP**
Very high with no other options	2,123.9	2,142.1	2,131.4
Very high with few options	357.6	359.1	355
High	106.1	98.7	112
Medium	85.5	74.3	69.5
Low	71	70.7	80.4
Very low	338.8	317.5	330.3
Not selected	1,390.8	1,411.3	1,395.1

Finally, the relative cost of achieving conservation targets (based on a multi-attribute cost metric composed of proximity to settlements, roads, towns, and presence-absence of protected areas) was highest under Scenario 1: Financial LCP. In relative terms, using the no project scenario as baseline, achieving conservation targets was 0.8% more expensive under the Financial LCP; whereas, achieving the same under the Financial LCP with environmental considerations would only cost 0.5% more.

Given the limitations of the information used, it is not possible at this stage to compare in monetary terms the financial costs of building the pipelines against the costs of achieving conservation targets under the different scenarios.

4. Conclusion and recommendations

Contemporary environment and development policies require all projects likely to have significant impacts on biodiversity to apply the mitigation hierarchy to their development. This comprises of a sequential application of a set actions by project proponents to; first, avoid impacts (e.g. modify route), second, minimize or mitigate impacts (e.g. bury pipeline at animal crossing points), third, restore degraded/damaged sites (e.g. after building pipeline), and fourth, offset residual impacts (BBOP, 2012).

The analyses described here focused on presenting clear methodologies to reduce impact in a cost effective manner and therefore apply the first step in the mitigation hierarchy – avoidance. Findings suggest that there is indeed significant scope for reducing environmental impact of linear infrastructure, including pipelines, by systematically including information on conservation values when analysing potential routes. The environmental pipeline route has higher financial costs of construction but has likely lower costs of implementing the mitigation hierarchy. Given information gaps, these costs were not estimated in comparable units; therefore we cannot conclude which route minimizes total costs, assuming the mitigation hierarchy is followed.

In order to select the economically optimal pipeline route, the next step would be to systematically include important socio-economic variables and fine-tune financial and environmental costs of pipeline construction across the landscape. After this, a measurement of restoration might be applied and offsets considered for any remaining residual impacts, and achieve the goal of no net loss/net positive gain.

We recommend several specific refinements for follow up analysis. These include:

- Use higher resolution analysis; here, we used 90 meter resolution, which we see as sub-optimal; nevertheless it is worth mentioning that we do not know how feasible it would be to build a finer resolution dataset, and only through running the analysis with this finer resolution data would it be possible to know how sensitive results are to using finer resolution.
- Carry out more detailed *micro-routing* that allows for detailed examination of environmental impacts to select the path of least impact. Micro-routing can be done even after commencement of construction to avoid disturbing community settlements or areas of high biological or cultural value (Johnston and Kozloff, 2005);
- Add consideration of subterranean features such as seismic activity, as well as more detailed consideration of hydrological features such as river crossings. Whereas burying the pipeline reduces visual disturbance, movement barriers and risks of sabotage, doing so at river crossings could increase ecological risk during construction and can complicate detection and repair of possible leaks (Johnston and Kozloff, 2005);
- Add considerations of species habitat fragmentation effects;
- Move towards a full monetary valuation of alternatives, including construction and opportunity costs. We used relative values as proxies based on expert knowledge. Whereas such proxies simplify the analysis, monetary data should always be used where possible (Naidoo et al., 2006).
- Fine-tune environmental costs by determining how far around the pipeline route impacts are expected to spread.

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