

**Memo**

To	Jamie Quesnel and Michel Groleau, Agnico Eagle Mines Limited
From	ERM Consultants Canada Ltd.
Date	9 October 2020
Reference	0530275-0010
Subject	Literature review of caribou, waterlines, and roads Revision 2

1. INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) is interested in exploring the use of a waterline from the Meliadine site to the ocean to discharge saline groundwater. This memo is Revision 2. It provides background on waterlines in the Arctic, mitigation for waterlines, and the response of caribou to these linear features. It has been updated to address information requests on the August 2020 FEIS Addendum (Agnico Eagle 2020) and Golder (2020) is attached to provide additional literature review primarily related to woodland caribou response to pipelines in Alberta (Attachment A).

Agnico Eagle's Meliadine Gold Mine is located approximately 24 kilometres northwest of Rankin Inlet in the Kivalliq region of Nunavut, Canada. The mine began commercial production in May 2019 and has an estimated 14-year mine life.

Caribou (*Rangifer tarandus*) have spiritual, cultural and socioeconomic significance to the Inuit and protecting them is important to Agnico Eagle, Inuit and other stakeholders. Barren-ground caribou are also a biological keystone species as they play a significant role in maintaining the structure and function of the ecosystem in the area (Thompson, 2005). The Qamanirjuaq Caribou herd migrate from below treeline to the Kivalliq region in the north for calving in the spring (Thompson, 2005). The herd then migrates back south in the fall.

The objectives of this memo are to: 1) review what types of waterlines are used at other Arctic mines, 2) describe the mitigation measures used to help ungulates cross waterlines in the Canadian Arctic and oil pipelines elsewhere, and 3) review the literature on caribou crossing these structures.

2. SUMMARY OF WATERLINES AT OTHER CANADIAN ARCTIC MINES

The use of waterlines to transport water is widely used in the mining industry. Waterlines in the Arctic range from 20 to 120 cm in diameter and can consist of multiple lines in a single area.

2.1 Ekati Jay Project

The Ekati project located in the Northwest Territories has several 50 to 60 cm HDPE waterlines used to discharge tailings from the mill to the Tailings Impoundment Area. The waterlines are located on a bench beside on-site roads. In some locations, there are 2-3 waterlines adjacent to each other on the roadside bench.

During the recent Ekati Jay Project Environmental Impact Assessment (EIA) review, Ekati proposed an additional three waterlines ranging from 66 to 92 cm diameter alongside a 2.8 km section of road to prevent the waterlines acting as barriers to wildlife, Ekati included mitigation measures in the EIA application, including the examples below:

- The HDPE waterlines were placed on a 7.5 m wide bench constructed adjacent to and below the level of the road. The bench was constructed so that the top of the pipes did not exceed the height of the road to avoid visual and physical barriers to crossing.
- Crossing ramps were constructed by covering the waterlines with 20 cm or less of crushed rock for ease of walking in areas where the infrastructure crossed through caribou habitat.
- Crossing ramps had gradual slopes angled at 1:5 (rise:run).
- Snowbanks were maintained at a low height during the winter to minimize visual barriers.
- Power lines were located on the opposite side of the road from the waterline.
- The waterline was not buried at the following locations:
 - where joints and valves were installed,
 - where safety berms were built on the road, or
 - where caribou habitat was not present.

To maximize the length of waterline that was buried and designed to function as a caribou crossing, the waterline was designed to reduce joints and valves in areas of caribou habitat. A regular waterline monitoring schedule and wildlife effects monitoring plan was implemented to evaluate the effectiveness of these mitigations.

2.2 Hope Bay (Doris North) Project

The Hope Bay Project uses a waterline to discharge water from Tail Lake to Roberts Bay and from the Doris mill to the Tailings Impoundment Area. This waterline is 25 cm in diameter, and is placed on the side of active project roads. This waterline is relatively short and oriented in parallel to the direction of migration of Island (Dolphin and Union) caribou. The waterline from Tail Lake to the ocean was approved by the NIRB following a Project Certificate amendment application in 2016. As part of management of linear features, Inuit Elders with experience in the Project area chose the location of where crossing structures were installed across Project roads.

3. LITERATURE REVIEW OF WATERLINE DESIGN MEASURES

Arctic waterline systems inherently have a unique set of environmental challenges due to ground movements associated with frost heave and thaw settlement (DeGeer and Nessim 2008). Steel pipes for oil transport have been elevated above ground to combat these ground movements; however, the Wells Pipeline and Trans-Alaska Pipeline proved to be examples of successful buried systems, which is now the preferred method for larger diameter steel oil pipes from an environmental perspective (DeGeer and Nessim 2008). In contrast, small diameter lines with

lighter contents are more susceptible to wind induced vibrations, which could compromise the pipe when elevated aboveground (Shannon and Wilson Inc. 2013).

Linear infrastructure, such as pipes, have been designed to permit wildlife movement. There is no specific guidance for waterline design in Nunavut or Northwest Territories to manage wildlife movement and, from a wildlife perspective, the best analogues are recommendations and guidelines intended for oil and gas pipelines.

An above-ground pipeline wildlife crossing directive was released by the Alberta government in 2014 for the oil and gas industry that details specific design requirements to help mitigate any barrier effect on wildlife (Alberta 2017). The recommendations were made specifically for woodland caribou, living in a forested environment, so the design requirements may not all apply to a tundra environment. The recommendations include the following information:

- Detailed maps and cross-sections in the design phase outlining mitigation measures such as: ground clearance, crossing ramps, and adjacent infrastructure.
- For large-diameter pipes, under crossings should account for 65% of crossing opportunities and is the preferred method of mitigation. The pipes should be elevated at a minimum height of 180 cm above ground.
- Over pipe crossings should be a minimum of 8 m wide at the surface with a 1:6 slope, or following existing topography. The crossings should never exceed a slope of 1:3.
- There should be three crossing opportunities per 1,000 m (or 6% of total length) of above-ground pipes outside of caribou range, and four crossing opportunities per 1,000 m (or 8% of total length) within caribou range.
- Minimum distance between crossing structures is 100 m and maximum distance is 500 m.
- Pipes that are less than 250 m from project infrastructure do not require crossing structures.

Another example of mitigation measures are from a stand-alone pipeline project (ASAP 2015). A 90 cm diameter natural gas pipeline from Prudhoe Bay to Anchorage, Alaska was buried and the following mitigation measures were considered:

- The route for this pipeline was designed to avoid sensitive habitat and terrain features such as waterbodies, steep terrain or other infrastructure wherever possible.
- Construction was scheduled outside of sensitive timing windows for fish and wildlife.
- Existing roads and infrastructure were used whenever possible and the pipeline right of way was limited to minimize the overall project footprint.
- Restricted road access was put in place to help control hunting and motorized recreational vehicle access.
- Berms that were developed for pipeline infrastructure were constructed on the windward side of the road to avoid snow drifting.

Since 2000, elevated oil pipelines in Alaska must be constructed at least 150 m away from roads and be elevated a minimum of 2.1 m above ground (Prichard et al. 2020).

4. CARIBOU LITERATURE REVIEW

Barren-ground caribou are a highly valued species across Canada and Alaska. The management of this species is a complex issue as there are multiple factors that can influence population including predation, human activity, and climate change (Gunn et al., 2011). Barren-ground caribou are migratory, and their migration may result in caribou encountering linear features associated with industrial development, notably pipelines and roads. Nicholson et al. (2016) observed considerable variation among years in migratory pathways of the Central Arctic Herd in Alaska. They reported that migratory routes are often located where snow is shallow or hard and where rivers are frozen; while the migration has a defined destination, the routes can vary by year.

As resource extraction expands in the Arctic region, there is a corresponding increase in studies assessing the impacts on wildlife populations. The effects of linear developments on caribou migration and habitat have been studied since the 1960s and include; roads, traffic, seismic lines, snow berms, power lines and pipes carrying water, natural gas and oil. These linear developments have individual effects but have also been shown to have combined effects on caribou behaviour and migration.

Based on research results, mitigation techniques have been implemented to minimize the impact these developments have on wildlife and wildlife habitat. The two principal mitigations specifically for pipelines have been: 1) ramps so that caribou can cross over pipes (used with HDPE waterlines and steel oil pipes), and 2) elevating steel oil pipes so caribou can cross under pipes.

This section focuses on research that describes how human activity and linear developments, specifically waterline, oil pipeline and road infrastructure, can influence caribou behavioural or physiological responses and how mitigation measures can assist caribou crossing linear developments.

4.1 Oil Pipelines

The effects of oil pipelines on barren-ground caribou behaviour in Alaska have been studied since the 1970s. A simulated 175 cm diameter pipeline design in Prudhoe Bay, Alaska was used to study how caribou would respond to different pipeline orientations (Child 1973). The pipeline structure had sections that were elevated from 1.2 to 2.1 m; buried under crossing ramps 60 m long at a slope of 1:5; and sitting on the ground. Although caribou generally avoided the structure by reversing direction or travelling to the terminals, the crossing structures and ramps were found to be the best method to facilitate caribou crossing. Owing to the success of the crossing structures, Child (1973) recommended that ramps be constructed as frequently as possible along the pipeline.

Smith and Cameron (1985) reported similar results; they observed that caribou were more likely to cross over a 50 cm pipe where it was buried than under the same pipe where it was elevated ≥ 1.5 m above the ground. In their 2006 review of pipeline crossing by caribou, Lawhead et al. (2006) confirmed that crossing ramps were repeatedly recommended as the most effective pipeline crossing structure.

Child (1973) and Curotolo and Murphy (1987) reported that individual caribou or bulls were more likely to have crossing success than larger groups or cows with young calves. They also saw an increase of crossing later in the season and during periods of higher insect harassment. This could be due to an increase in motivation for crossing under these conditions.

In contrast, a study by Carruthers and Jakimchuk (1987) reported that the barren-land Nelchina caribou herd in Alaska did not have a preference to pipeline placement and would cross wherever they encountered the structure. The pipeline in this study was a 122 cm diameter pipe that had elevated sections to at least 1.8 m above ground, buried pipe sections, and crossing ramps throughout caribou habitat. Overall, there did not seem to be preference in pipe orientation when each method was properly constructed to allow crossing. Similarly, Cronin et al. (1998) reported that properly elevated pipe structures to ≥ 1.5 m did not affect caribou crossing, and that the ungulates would actually seek shade and relief from insect harassment under these structures in the summer. Overall, the study done by Cronin et al. (1998) reported that acceptable mitigation measures to facilitate caribou movement across large-diameter (> 61 cm) pipes include; elevated pipes, gravel ramps, buried pipes and separation of large elevated pipes from busy roads.

Several studies suggest minimum height for crossing under an elevated pipe to be 1.5 m above ground during snow-free periods (Curatolo and Murphy 1986, Carruthers and Jakimchuk 1987, Cronin et al. 1998, Lawhead et al., 2006). To account for drifting snow, pipeline heights greater than 2.1 m are more likely to be used by caribou (Lawhead et al. 2006). Local snowfall levels need be accounted for when determining the appropriate height of elevated pipelines

In a review of literature considering the effects of low-elevation pipelines (elevated to 1 m or less) on caribou and reindeer, Lawhead et al. (2006) indicated that:

“...that caribou crossing success is blocked or significantly reduced when the clearance beneath elevated pipelines is 1 m or less. The information available on the effects of simulated and actual pipelines located on or near the ground leaves little doubt that low-elevation pipelines pose serious impediments or complete barriers to caribou movements; therefore, they should not be considered for use in caribou range.”
(Lawhead et al. 2006, p. 7).

4.2 Crossing Linear Features

Linear features may be perceived as a barrier based on visual obstruction; caribou avoided or changed direction when encountering berms large enough to act as visual barriers (1.5 m; Hanson, 1981 and Wolfe et al., 2000). The study by Hanson (1981) reported that caribou avoided berms that exceeded heights of 1.5 m on calving grounds. Rescan (2011) reported that the height of a feature was the main factor for crossing success; with snow berms > 50 cm having reduced crossings by caribou compared to lower snow berms. Dyer et al. (2002) reported that roads deflected caribou more often in the winter, which could be due to an increase in traffic or snow berm height.

Caribou crossed elevated pipelines and roads with similar frequencies, but that crossing frequency declined by 70% when an elevated pipeline paralleled a road with high levels of traffic (Curatolo and Murphy 1986). Murphy and Curatolo (1987) reported that caribou crossed under elevated (minimum 1.5 m above ground level) pipes near inactive or lightly trafficked roads as often as control sites with no road infrastructure; elevated pipelines adjacent to roads with traffic (approximately 15 vehicles per hour) were crossed successfully less than half as frequently.

In terms of magnitude of the effect of traffic level, Panzacchi et al. (2013) studied migratory reindeer in Norway and showed a 5 day delay in migration when reindeer encountered a road with an average of approximately 500 vehicles per day (21 vehicles per hour). Wilson et al. (2016) studied road crossing behaviour near the Red Dog mine in Alaska. In the study, they

examined movement rates of individual caribou at a road with an average of 4 vehicles per hour. They reported two responses to caribou encountering roads: “normal crossers” that proceeded virtually uninterrupted in their migration; and “slow crossers” that remained on the upstream side of the road by an average of 32 days, and following crossing travelled at 1.5 faster times that of normal crossing animals. In contrast, caribou groups encountering an elevated pipeline on the Alaskan tundra spent about 1 minute longer than animals travelling through areas without pipelines and Noel et al. (2006) concluded that elevated pipelines (≥ 1.5 m high) did not delay crossing.

Roads can have a direct impact on caribou habitat by increasing mortality from wildlife-vehicle collisions, hunting, and predation though the increase in predation risk associated with roads may be more significant for woodland caribou than barren-ground caribou residing in tundra landscapes (Dyer et al., 2002).

Avoidance of roads has been reported for both barren-ground (Cameron et al. 1992, Nellemann and Cameron 1996, Haskell et al. 2006) and boreal caribou (Dyer et al. 2001, 2002, Beauchesne et al. 2014). However, avoidance of habitat near the road does not necessarily indicate the road is a barrier to movement. While roads may result in caribou choosing to avoid habitat within some distance of influence, road crossing will occur when the road lies within a migratory pathway.

Beyond the physical structure, traffic volume is the most important factor affecting caribou response to roads (Curatolo and Murphy 1986, Murphy and Curatolo 1987, Wolfe et al. 2000, Lawhead et al. 2006). When roads and elevated pipelines are constructed adjacent to each other, traffic volume on roads also determines much of the combined barrier effect (Curatolo and Murphy 1986, Murphy and Curatolo 1987, Lawhead et al. 2006). Well-maintained roads that experience low volumes of traffic and low snow berms do not typically act as physical barriers to caribou movement (Wolfe et al., 2000).

4.3 Seasonal Behaviour and Habituation

After 40 years of exposure to oil pipelines and infrastructure, caribou in the Central Arctic Herd in Alaska still reduce their use of areas within 5 km of development during calving period and within 2 km during the post-calving period, with reduced effects later in summer (Johnson et al. 2020). The authors suggest that this is part of a body of evidence that barren-ground caribou in the Arctic are unlikely to habituate to industrial development (Johnson et al. 2020). Beauchesne et al. (2014) also reported a limited adaptability to development for woodland caribou in Quebec, with the impact of roads on behaviour more pronounced during calving, summer, and the rut. The pronounced seasonal avoidance of roads during the calving season was also reported for Alberta (Dyer et al. 2001).

4.4 Crossing Structures

Construction of gravel ramps across ground-level pipelines or burying pipelines has been recommended by many researchers (e.g., Child 1973, Smith and Cameron 1985, Curatolo and Murphy 1986). In their 2006 review of pipeline crossing by caribou, Lawhead et al. (2006) confirmed crossing ramps as the most effective pipeline crossing structure.

5. SUMMARY

Caribou from the Qamanirjuaq herd use the tundra generally to the south and west of the Meliadine Project location. During the post-calving and early summer periods, generally in July, some caribou from this herd move east and use the area surrounding the Meliadine Project all-weather access road, sometimes crossing the road in the process.

Overall, the scientific literature indicates:

- Small diameter plastic (HDPE) waterlines should be placed on the ground, because they can oscillate in the wind if raised above ground level.
- Caribou will cross structures such as snow berms on the ground when they are less than 20 inches (50 cm) high without any specific mitigation.
- Avoid installing elevated pipes immediately adjacent to roads with high traffic rates.
- Much of the research conducted on pipes has been on larger diameter pipes used in oil and gas production. Standard mitigation measures for pipelines placed on the ground are to install crossing structures for caribou to cross, such as ramps. Alternatively, larger diameter steel pipes may be elevated a minimum of 1.5 to 2.1 m above ground level, allowing added height for regional winter snow accumulation.

Mitigation measures to consider for a waterline on the tundra in caribou habitat include:

- Inuit elders and land users should be consulted on the locations of caribou movement corridors and high-value habitats.
- Use small diameter pipes, so caribou can cross without the need for crossing structures.
- Install the waterline outside of sensitive times of year.
- Lay the waterline on a bench build into the side of the existing all-weather access road (instead of laying the waterline on top of the road) so that the pipe does not become a visual barrier for caribou.
- Install crossing structures at known caribou movement corridors and high-value habitats and/or regularly at a pre-determined interval distance if the locations of corridors or high-value habitats are not known.
- Crossing structures should be composed of finer-grain material, with a size and shape to be determined based on-site characteristics and road geometry and height. The locations of crossing structures should be informed by the surrounding landscape features that may block or funnel caribou access. Alternatively, cover the waterline.

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TECHNICAL MEMORANDUM

DATE October 13, 2020

Project No. 20351262-795-TM-Rev0

TO
Agnico Eagle Mines Limited

CC

FROM Golder Associates Ltd.

GENERAL LITERATURE REVIEW – CARIBOU AND ABOVE GROUND PIPELINES

Below provides a brief summary of relevant literature between barren ground caribou and large diameter pipe (i.e., Trans-Alaska Pipeline) and woodland caribou, and other ungulates, interacting with above-ground pipelines (AGP) in Alberta.

Barren Ground Caribou

Curatolo and Murphy (1986) found that barren-ground caribou were affected by above-ground pipelines when the pipelines ran parallel to an active road. The authors also found that buried pipe, in the absence of road traffic, seemed to be the most effective mitigation. Smith and Cameron (1985) found that above-ground pipelines created a semi-permeable physical barrier to migrating caribou, with some animals crossing under elevated sections (46% and 26% of groups of 917 and 655 animals), some animals crossing buried sections (13% and 37% respectively) and some animals failing to cross or becoming separated from the herd and not being accounted for. However, Carruthers and Jakimchuk (1987) found that the TransAlaska pipeline had no effect on the traditional migration route of the Nelchina Herd when properly mitigated and properly constructed. Specific mitigation consisted of burying refrigerated sections of the pipeline at traditional migration passes and incorporating special crossing structures. Cronin et al. (1994) found that above-ground pipelines that were elevated to a minimum ground clearance of 1.5 m to the bottom of the pipe was highly effective for facilitating the movements of caribou with heights greater than 1.5 m being preferred. Linear corridors with both pipelines and adjacent roads (usually within 25 to 50 m) with moderate to heavy traffic levels were found to impede caribou movement (Cronin et al. 1994). Cronin et al. (1994) found that ramp crossing structures were effective; however, it was not clear if they were used opportunistically or if the structures were sought out. No systematic tests of different ramp designs have been undertaken (Cronin et al. 1994). Cronin et al. (1994) concluded that the most effective mitigation is achieved with elevated pipelines (>1.5 m), ramps with long approaches, long sections of buried pipe and separation of roads from above-ground pipelines. Eide et al. (1986) found that barren-ground caribou selected to cross under sections of pipe greater than 2.4 m and avoided sections lower than 2.1 m.

In general, barren-ground caribou tend to select to cross buried sections of pipeline rather than under raised sections. Klein (1979) found that resident (i.e., non-migratory) populations of caribou and reindeer tend to habituate to obstructions and disturbances. It has also been suggested that there is a strong selection for barren ground caribou to move over buried section of pipe compared to elevated pipelines (McLoughlin N.D.). In general, it has been claimed that barren ground caribou showed strong selection for long sections of buried pipelines (Eide et al. 1986), however, it also appeared that this selection was strongest if the buried pipe was isolated from road traffic

(Smith and Cameron 1985). Simulated pipelines were used to understand preferred profile of gravel ramps over pipelines, and it was shown that low-profile gravel ramps with slopes <6:1 for crossing were successful (Child and Lent 1973).

Alberta Oil Sands In Situ Projects

In-situ Steam Assisted Gravity Drainage (SAGD) operations require the use of pipelines to carry steam to the well, which is then pumped into the ground to melt the bitumen. The liquefied bitumen is then pumped back to a central facility for processing and refining and eventual delivery to market. Thus, each SAGD well usually requires pipelines for steam, produced emulsion (i.e., oil and water), produced vapours and fuel gas. As the steam pipeline remains warm year-round, burying of this pipe is not feasible for long stretches, thus, gathering lines (i.e., pipelines) between wells are above-ground. Consequently, the network of above-ground pipelines and associated roads cause the greatest potential for negative interactions to wildlife for SAGD projects.

There is a wide variety of information available on the effects of development corridors on wildlife (see Jalkotzy et al. 1997 for a review); however, there is relatively little information available on wildlife interactions with above-ground pipelines, with the exception of studies in Alaska and monitoring reports in the Oil Sands Region.

An above-ground pipeline may affect large mammals simply by its presence as it forms an obstacle and reduces line of sight. Pipeline rights-of-way tend to have the same effect on wildlife that occurs with roads; however, with less significant consequences than roads (Jalkotzy et al. 1997) particularly in terms of direct mortality and sensory disturbance. In general, effects from above-ground pipelines primarily include barrier effects and habitat avoidance. Another possible effect could be a “corralling” effect by predators that may increase predation efficiency, however, there is little to no quantitative analysis on this issue. In situ projects result in rights-of-way with active roads and above-ground pipelines parallel to each other with typical rights-of-way being 50 m wide, and usually within a forested environment. The synergistic effects of roads and above-ground pipelines may exacerbate the barrier and avoidance effects. To further understand the potential barrier effects to wildlife movement given potential rapid expansion of in situ projects, Muhly et al. (2015) simulated current and future development effects on woodland caribou movement. They acquired turning angles and step lengths from caribou telemetry data and estimated the permeability of above-ground pipelines to caribou based on camera data. The authors wanted to understand the relationship between permeability, spacing between projects and the use of protected areas to maintain caribou movement and home ranges for regional planning purposes and to focus on potential mitigation. Muhly et al. (2015) found that pipeline permeability was the main factor affecting home range size and small increases in permeability resulted in a disproportionately greater benefit to caribou movement.

At one of the oldest in situ oil projects in Alberta in the Cold Lake area, average height of pipelines has been measured at 0.9 m (range 0.5 to 2.2 m) to the bottom of the pipe and pipelines often consisted of one to five, 34 to 50 cm diameter pipes for the CNRL Primrose and Wolf Lake Project (Golder 2000). Pipe widths averaged 1.8 m with a range from 0.3 to 6.0 m (Golder 2000).

The primary sources of data come from effects monitoring programs as part of regulatory compliance of in situ oil sands projects. To achieve compliance, operators have to follow a directive (Directive 2014, No.07) established by the Government of Alberta (GOA 2014). This directive is intended to:

- Provide wildlife with reasonable opportunities for movement across above ground pipelines;
- Establish a minimum number of crossings per segment of pipeline; and

- Set minimum design criteria for crossing opportunities.

Wildlife crossings typically used over above ground pipelines in Alberta consist of road crossings (i.e., culverts), culvert style over pipe crossings covered in soil and vegetation and larger wooden structures for pipe with higher elevations. As an example, woodland caribou crossing success for one of these projects was 100%, albeit with limited observations (Canadian Natural 2020). The main portions of this Project have been in production since the late 80's, including the development and implementation of wildlife crossings. Consequently, the Government of Alberta no longer requires monitoring of above ground pipelines as wildlife have continually been demonstrated to cross the pipe and barriers to movement have been mitigated.

Finally, Dunne and Quinn (2009) evaluated elevated pipeline clearances and pipeline crossing structures to understand the mitigation of barrier effects to Alberta's largest mammal, moose. Moose and deer, unfortunately this study did not occur in woodland caribou range, showed high use of crossing structures (i.e., 88% of approaches for moose and 83% of approaches for deer).

In summary, barrier effects to wildlife as a result of above ground pipelines can largely be mitigated provided that they can be buried or elevated to allow free passage of ungulates. For the purpose of the waterline application, 80 to 90% of the waterlines will be covered (i.e., buried) with fine-grained esker materials as an extension to the physical structure of the existing All-Weather Access Road (AWAR). Consequently, the waterlines are not anticipated to act as a movement barrier to caribou and other wildlife.

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