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# Canopy Bridges along a Rainforest Pipeline in Ecuador

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## Abstract
One of the most significant social-environmental and construction challenges for pipeline installation in primary tropical rainforest is preventing the secondary impact of deforestation and land-use conflicts. Occidental Petroleum in Ecuador and WALSH developed an innovative technique of constructing a pipeline right-of way (ROW) in the lowland rainforest of the Ecuadorian Amazon without a permanent road and leaving canopy bridges to facilitate migration of arboreal mammals.

## Introduction
The new petroleum reserves in Ecuador are located in high diversity and threatened rainforests. Road building by petroleum companies and other actors into protected areas and indigenous communities has indirectly caused deforestation and displacement of indigenous communities since the 1970s.

Occidental Petroleum in Ecuador made a decision to develop the Eden-Yuturi field in 1999, which is also located in primary tropical rainforest and an indigenous community, approximately 42 kilometers from the current front of human settlement and deforestation. Access control and protection of biodiversity were identified as the most significant management goals during the environmental impact assessment process. A small diameter 12-inch product line had been constructed by Arco in Ecuador in 1999 without road access, but the technique used in this project was not economically or technically feasible due to need for a larger pipeline requiring heavy machinery and a larger ROW working area (1).

A critical decision was made not to construct a permanent road based on the findings of the Environmental Impact Assessment. The planned access to the Eden-Yuturi production site was with helicopters and fluvial transport on the Napo River **(Fig. 1)**.

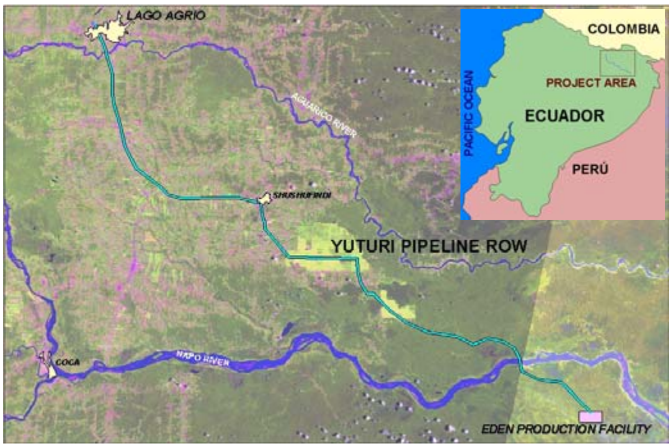


**Fig. 1: Location of Eden-Yuturi Field and pipeline in the Oriente region of Ecuador.**

The most significant social-environmental and construction challenge was how to build and operate a 24-inch diameter product line from the EPF (Eden Production Field) to the city of Lago Agrio in primary rainforest (including a nationally protected reserve), while minimizing impact to flora and fauna, preventing a front of deforestation and invasion of indigenous lands, and controlling costs. The front of deforestation in relation to project is shown clearly in **Fig. 2**.

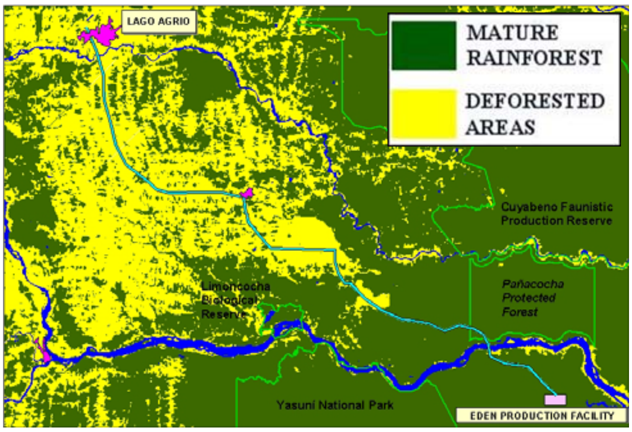


**Fig. 2: A land-use classification from field observations and Landsat imagery from 2001, prior to pipeline construction.**

## Environmental Management Plan
One particular concern of biologists was the barrier effect of breaking the canopy within the mature rainforest with forty-two kilometers of pipeline ROW. Most arboreal mammals in

the Ecuadorian Amazon rarely walk on the ground due to danger from predators. A linear break in the canopy, like a pipeline ROW, can cut-off migration routes and drastically reduce habitat of these important seed dispersers (3).

The following provisions were developed in the Environmental Management Plan (EMP) to address impacts associated with construction of the ROW:

- The ROW width was restricted to a 15 meter width to limit deforestation and impacts to fragile rainforest soils.
- Final routing was surveyed with biologists to avoid sensitive micro-habitats (e.g. morete wetlands) and endangered tree species (**Fig. 3**).
- Intermediate pumping stations were eliminated from the design.
- No shoe-flies (access roads) were constructed and all traffic was restricted to the ROW.
- No permanent road was installed.
- No wood from the primary rainforest outside the 15 meter wide ROW was harvested.
- The pipeline was buried with a SCADA leak detection system, eliminating the requirement of visual inspections from the air.
- Removal of temporary bridges after construction required.
- Biodiversity monitoring stations were installed to monitor impacts to flora and fauna.
- Indigenous community members were trained as environmental monitors.
- Tree canopy bridges were protected at 24 locations to facilitate migration of arboreal mammals (**Fig. 4**).
- Post-construction natural and artificial reforestation with goal of complete canopy connection.

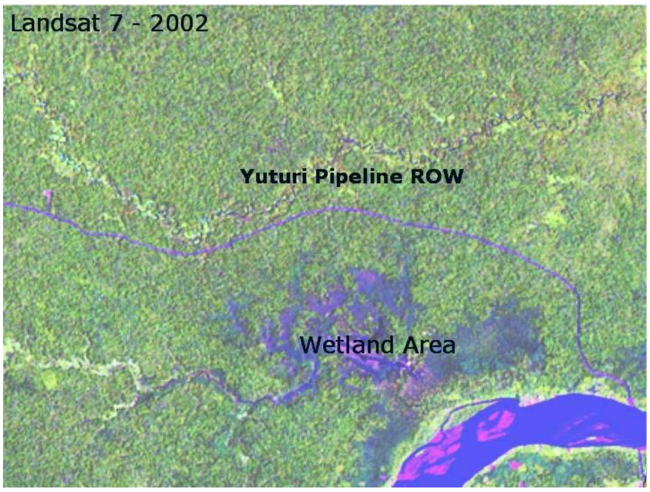


**Fig. 3 – Pipeline routing altered to avoid sensitive wetland ecosystem.**

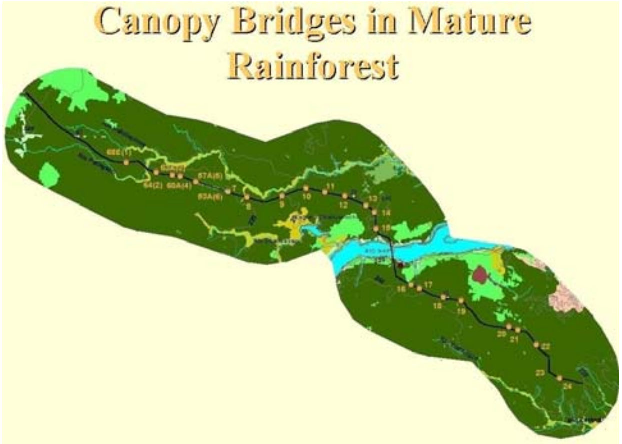


**Fig. 4 – Vegetation map of the pipeline within the mature rainforest with canopy bridges indicated.**

The pipeline was constructed in 2001 and 2002 under strict supervision from the Ecuadorian government and the affected indigenous communities. It is currently delivering crude oil to the OCP terminal near Lago Agrio, Ecuador.

## Post-Construction Results

- The monitoring of the construction phase and post-construction phase indicate a high degree of success in restricting deforestation to the 15 meter wide ROW. There is no evidence in satellite images or in the field of settlers or timber harvesters deforesting areas parallel to the pipeline corridor in the sensitive mature rainforest area.
- The environmental monitors from indigenous communities prevent the entry of illegal settlers and hunters.
- All temporary river bridges were removed and no vehicles have entered the ROW in the post-construction phase.
- The biodiversity monitoring along the axis of the ROW, at 200 meters, and 400 meters does not indicate significant long-term impacts to mammals, birds, amphibians/reptiles, fish, or macro-invertebrates.
- The ROW corridor is narrow and shaded most of day, so the soil stays moist. Consequently, natural reseading by trees along the corridor has resulted in new trees growing to two meters in nine months. Seedling planting has been less successful and proven unnecessary by the success of natural revegetation.

## Canopy Bridges

The canopy bridges are the most interesting success. They are simply 40-meter-long sections where the working ROW was narrowed to seven meters to preserve canopy connection (**Fig. 5**)

**Fig. 5 – The 15 meter wide ROW of the pipeline, which narrows to seven meters to form a canopy bridge.**

The canopy bridges were identified based on the following criteria of a biologist in cooperation with the survey team:

- Locations with good natural canopy connection.
- Sufficient spacing between trunks to allow for a seven meter wide ROW.
- Located along axis of theoretical ROW to avoid unnecessary bends in the pipeline.
- Even spacing between canopy bridges (approximately 1.8 kilometers, well within the distance a primate can travel in one to two days) (2).
- Evidence of arboreal mammal activity in the area.

These canopy bridge areas were marked for special management before ROW opening. Only trees less than 20 centimeter DBH (Diameter at Breast Height) were removed. A sandwich of geotextitle, riprap and soil was installed to protect the thin topsoil and roots from damage during transport of pipe along the ROW (**Fig. 6**).

**Fig. 6 – Geotextile and riprap installed to support the weight of the pipe carriers and protect tree roots in the thin rainforest soils.**

The construction company was skeptical the narrow ROW might cause traffic delays and difficultly in installation of pipe. Special procedures for traffic control, preservation of each canopy bridge forest, and tie-ins were developed and functioned well, without causing significant delays.

All 24 bridges were installed successfully and have survived all phases of construction and operation **(Fig. 6 and 7)**.

Fig. 7 – Canopy bridge in 2004 near the EPF.


**Fig. 8 – High-resolution IKONOS imagery (1 meter pixel) showing narrow pipeline ROW and canopy bridges near the EPF.**

Movement of arboreal mammals (primarily monkeys) has been observed at all 24 bridges (**Fig. 9**). Some canopy crossings occurred while construction activities were in process, confirming importance of aerial pathways. These species include: Golden-mantle tamarin (Saguinus tripartitus), Common woolly monkey (Lagothrix lagotrichia), Common squirrel monkey (Saimiri sciureus), Black-mantle tamarin (Saguinus nigricollis), Pygmy marmoset (Callithrix pigmaea), Red titi monkey (Callicebus cupreus), Red howler monkey (Alouatta seniculus), White-fronted capuchin monkey (Cebus albifrons). All of these species are important seed dispersers and critical in maintaining forest diversty on both sides of the pipeline ROW.

**Fig. 9 – Red titi monkey (Callicebus cupreus) in a canopy bridge.**

The cost of installing the canopy bridges and applying the other provisions in the EMP represented less than two percent of the total cost of the project. An approval by the Ecuadorian government would have been difficult or perhaps impossible to obtain if this benchmark technique of canopy bridges had not been applied. The best result is that exotic and expensive technologies were not necessary to achieve the primary goals of the EMP.

Other operators in Ecuador have adopted this solution for their development plans in the mature rainforests of the Ecuadorian Amazon. This technique could be duplicated in other tropical rainforest environments where migration of arboreal mammals are impacted by habitat fragmentation.

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