KETCHIKAN - PETERSBURG - WRANGELL
SEAPA
Southeast Alaska Power Agency

Submarine Cable Update Report

Incident: Stikine Cable 1 (C-Phase) Failure/Fault Event

Date: 12/9/2019

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Background

A fault occurred on the Stikine Cable crossing between the islands of Woronkofski and Vank on Sunday September 29, 2019. On September 30, SEAPA staff performed visual line inspections and prepared a safe work electrical clearance to reconfigure the Stikine cable crossing and perform resistance measurement tests on the C-Phase cable sheath. Test results (Megger) indicated a low impedance fault on the cable. The cable was hydraulically locked to prevent fluid leakage and/or water ingress.

SEAPA performed Time Domain Reflectometer (TDR) tests on October 9 (Figure 1). Test results conclusively indicated that the fault was located approximately **2000 feet** from the Woronkofski marine terminal, in approximately **300-400 feet of water**.

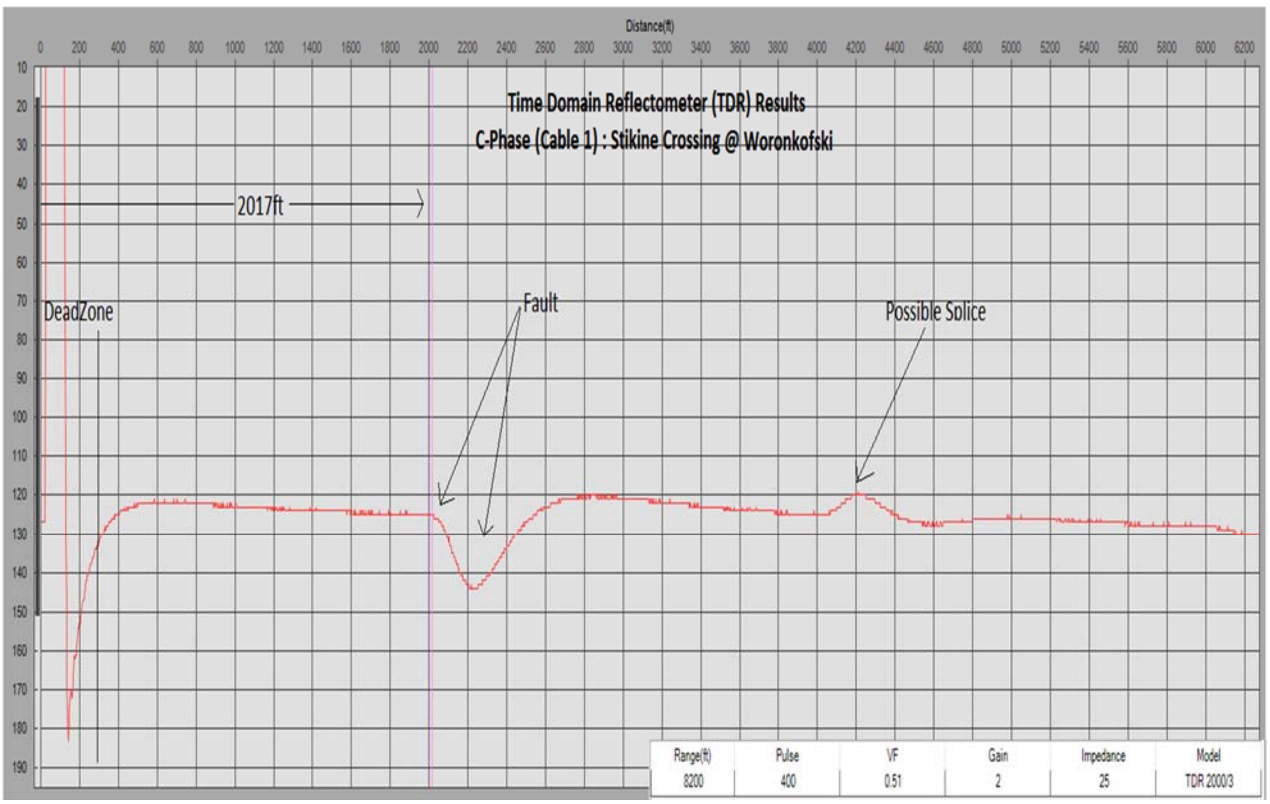

Figure 1: TDR Results

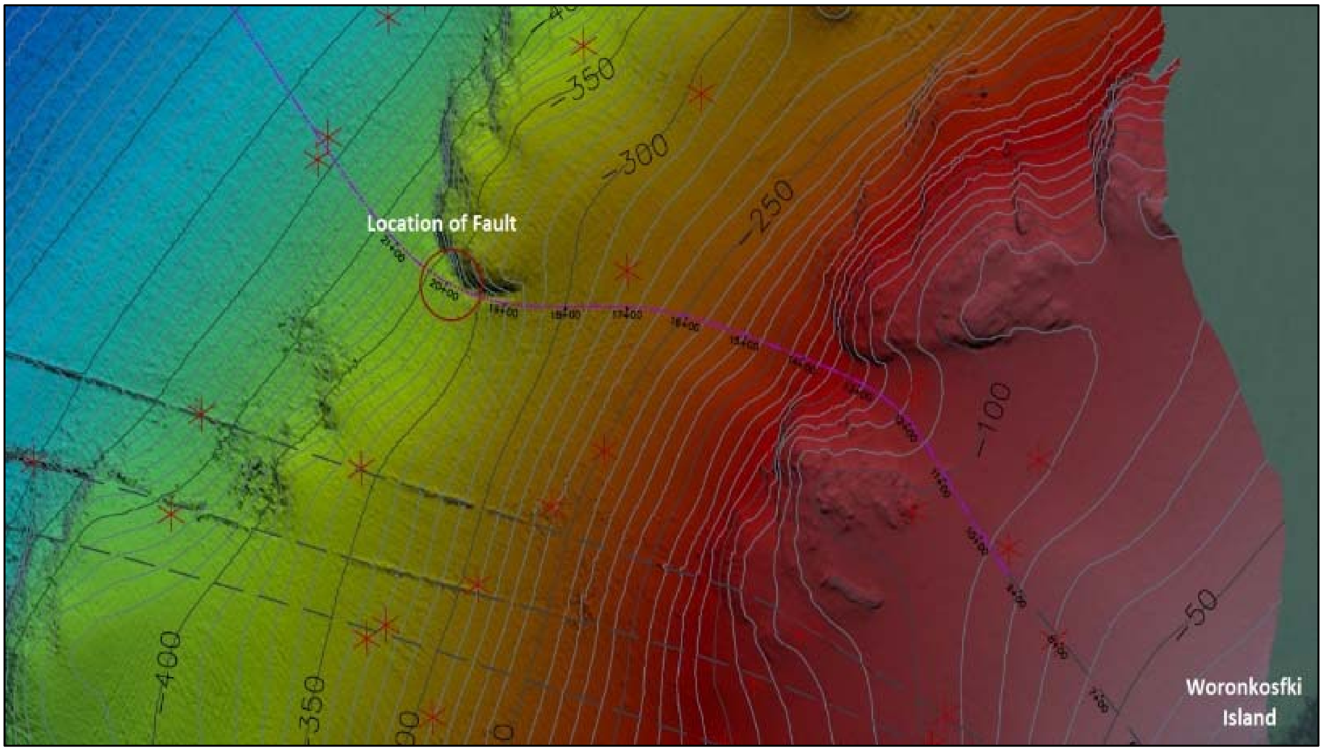

Figure 2: Bathymetric Survey

On October 12, SEAPA contracted a hydrographic survey company (eTrac) to perform bathymetric, side scan and magnetometer surveys. The results of the survey(s) provided existing routing of the Stikine cables to help determine root cause of failure and the path forward for repair or replacement. Figure 2 illustrates the existing location of Cables 1-4 off the shore of Woronkofski Island.

SEAPA awarded a Task Order to Center Marine on October 29 as the Agency's cable consultant. The scope of work to be performed by the consultant is:

1) Analyze all available datum to date and make recommendation(s) on repair/replacement
2) Develop a cost estimate(s) for repair/replacement
3) Develop a timeline for recommended repair/replacement
4) Develop repair/replace technical specifications and
5) Perform duties during the repair/replace contract as SEAPA's cable expert

SEAPA held a special board meeting on October 30. During the meeting, an update on the Submarine Cables was presented. The intent of this report is to provide an update on the Stikine crossing submarine cables since the October 30 board meeting.

Repair Analysis

A number of factors correlate to the success of a repair on the Stikine submarine cable. The length of damaged cable due to water ingress is a crucial factor due to the limited amount of spare cable that SEAPA has available. Inventory and subsequent field verification indicate that there is approximately 2,000 feet of spare cable on a cable reel located at the Wrangell Switchyard Warehouse. If the amount of damaged cable is greater than 2,000 feet, a repair is likely not possible.

Figure 3: 2000ft reel of spare submarine cable

Determining the length of compromised cable is challenging however there are methods to increase the probability of success. With known densities and pressures at shoreside bellows, a change in pressure over time can be an indication of how much water has entered the cable. As indicated in Figure 4 (below), SEAPA cable consultants have concern with water ingress due to the location of the fault (depth). Because the fault occurred at 350ft depth (2,000ft offshore) and the deepest lay of the cable is at 650ft depth (4,000ft offshore), migration of water from the fault location to the deepest cable lay by diffusion is possible.

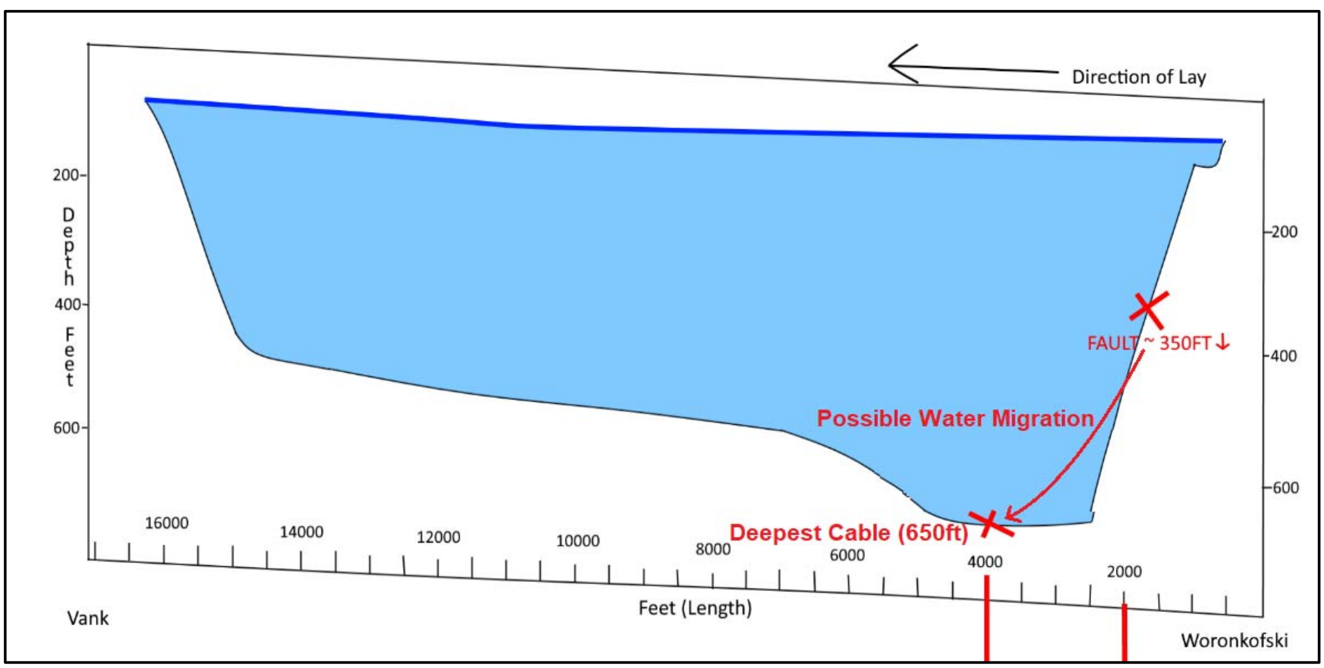

Figure 4: Fault Location vs. Deepest Cable Lay

Another method to determine water ingress is to perform a second TDR test. If water ingress has occurred, changes over time in TDR impulse readings could identify how far down the cable water migration has occurred. Figure 5 illustrates documented TDR test results changing as a function of time as water migration occurs. Considering the initial TDR test occurred on October 9, enough time has now passed to give accurate readings to compare changes in results and determine whether water ingress (if any) has occurred.

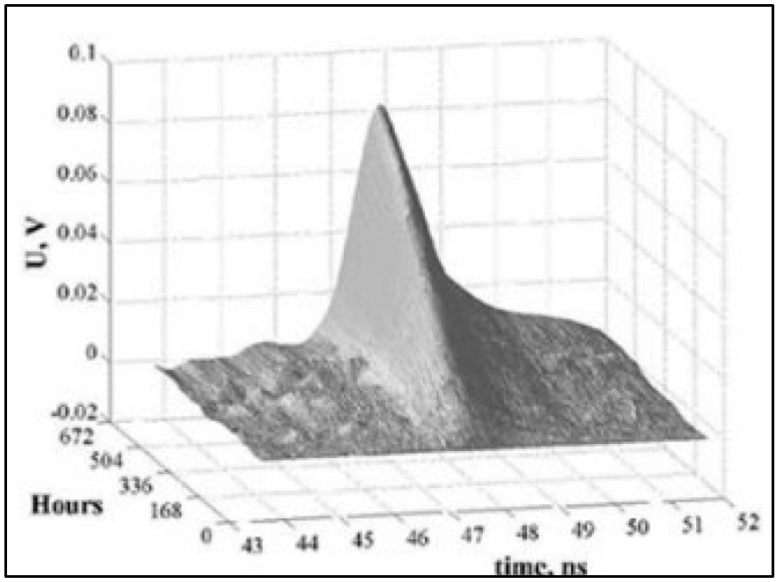

Figure 5: Changes in TDR over time due to Ingress

Aside from water ingress and the length of spare cable available to make a repair, another important factor for the success of a repair is the depth of cable burial. From the bathymetric survey data as shown in Figure 2, it is apparent that cables 2-4 are above surface for much of their lay profile. Cable 1 however, does not appear in the bathymetric survey, which indicates that it is buried below the subsea floor. As the depth of burial increases, the risk of damaging the cable during retrieval due to excessive forces also increases. In general, depths of over 3ft (under silt) are risky. SEAPA has initiated the following to further identify risk of repair with regard to water ingress and depth of burial:

A) A task order with eTrac to perform Sub-bottom surveys has been issued. A survey of this type requires specialized equipment and a specialized survey vessel (with hydraulic reels). The survey vessel has currently been mobilized to Seattle WA from Anchorage and is in transit (by barge) to Wrangell. Sub-bottom surveys are set to take place the week of January 6, 2020.
B) Follow up testing to include measurements of pressures at shoreside bellows and a second round of TDR tests as discussed is anticipated to occur in January 2020. The testing will be performed by Submarine Cable Expert Calin Micu. Calin is a member of the Institute of Electrical and Electronics Engineers and has 30 years of experience in Power Engineering.

Repair Cost Estimate

ITB was contacted for a rough order of magnitude (ROM) on a potential repair of the Stikine crossing faulted cable. The cost of a repair if all the aforementioned risks are alleviated is as estimated below:

Scope: Cable Repair	Unit	Rate	# Items	Total	Comments
Equipment Mobilization	Lump	$550,000	1	$550,000	Based on technique (high level)
Cable Repair Spread (High level)	Day	$153,600	20	$3,072,000	Splicers, ROV, Dive included
Living Out Allowance	Day	$200	400	$80,000	Per Person per Day (20x20 persxdays)
Total Repair Estimate:				$3,702,000	

Replacement Analysis

Replacement of the Stikine submarine cable(s) has multiple options. The cost difference associated with each option can be quite different. The first consideration for replacement is determining required ampacity and the voltage ratings of new cables. Higher ampacity ratings equate to higher costs of copper. Higher voltage ratings equate to higher costs of insulation. The existing submarine cables are rated for 138kV and are sized at 500MCM. A typical 500MCM cable is rated for approximately 450 amps. The fundamental power equation demonstrates the rated capacity of the existing submarine cables as follows.

$$P_{3\theta} = \sqrt{3} * V_{LL} * I$$
$$P_{3\theta} = \sqrt{3} * 138kV * 450A$$
$$P_{3\theta} = \mathbf{107.4MVA}$$

SEAPA has a total capacity from all available hydro of only 50MVA. Petersburg has a transformer size of only 20MVA. At a rating of over 100MVA, the existing submarine cables are oversized by over twice the total SEAPA capacity and over 4 times the rated capacity of the Petersburg transformer.

Oversizing cables can have a benefit of reducing heat at full loads and can extend the life of a cable. The general rule of thumb (Arrhenius relationship) is that for every 10 ˚C increase in temperature of a polymer, the life expectancy is decreased by a factor of two[1]. As an example, a cable rated for 90 ˚C and rated for 40 years will only last for 20 years if operated at 100 ˚C (for 20 years straight).

If a cable is not operated at full loads, life expectancy does not necessarily increase. For example, submarine cables are far more likely to fail due to biofouling, environmental conditions, natural events (landslides/earthquakes) or fishing activities than due to thermal aging (see Table 1).

Failure causes of subsea power cables		**Number of failures**	**% of total**
Environment	Armour Abrasion	26	21.7
	Armour corrosion	20	16.7
	Sheath failure	11	9.1
Total [Environment]		**57**	**47.5**
Third-party damage	Fishing	13	10.8
	Anchors	8	6.7
	Ship contact	11	9.1
Total [Third-party damage]		**32**	**26.7**
Manufacturing/ design defects	Factory joint	1	0.8
	Insulation	4	3.4
	Sheath	1	0.8
Total [Manufacturing/design defects]		**6**	**5.0**
Faulty installation	Cable failure	2	1.6
	Joint failure	8	6.7
Total [Faulty installation]		**10**	**8.3**
Not fault found (NFF)	Unclassified	10	8.3
	Unknown	5	4.2
Total [NFF]		**15**	**12.5**
Total		**120**	**100**

Table 1: Root causes of Subsea Cable Failures between the years 1991 and 2006 (Source: SSE PLC)

Table 1 illustrates that only 3.4% of submarine cables fail due to insulation (thermal aging). A probable reason for the small number of failures due to thermal aging is likely due to the ambient temperature of operation. A 90 ˚C rated cable is rated to operate at 90 ˚C (ambient plus heat rise) for the rated life expectancy of that cable (40 years for example). Most all submarine cables are in environments (subsea floor) with ambient temperatures of only 12 ˚C (52 ˚F). For the reasons stated above, SEAPA anticipates a replacement (if required) to be engineered closer to the full load requirements of Petersburg and not oversizing a replacement cable (at a substantial cost savings). For general reference, the required ampacity for Petersburg is 167.5 Amps at 69kV (20MVA transformer). A 69kV, 250MCM cable is rated for 37MVA (310A) and is half the size of the existing cable (500MCM), reducing copper costs significantly.

$$P_{3\theta} = \sqrt{3} * 69kV * 310A = 37MVA$$

[1] *SAE Standard AS4851A, Relative Thermal Life and Temperature Index for Insulated Electric Wire, sae.org*

Replacement Cost Estimates

Three separate submarine cable manufacturers and ITB were contacted for cable and installation cost estimates. Estimates were quoted for both replacement of like size/voltage ratings and for a size/voltage rating that is closer to actual load requirements of Petersburg. The Table below illustrates rough order of magnitudes for cable replacement. SEAPA is still waiting on quotes from Furukawa and additional quotes from Prysmian.

		Voltage Rating	Size	Cost
		138kV	**500MCM**	
Cable Cost	Sumitomo			$3,176,640
	Prysmian			$2,832,500
	Furukawa			
		69kV	**500MCM**	
	Sumitomo			$2,863,980
	Prysmian			$1,787,500
	Furukawa			
		138kV	**250MCM**	
	Sumitomo			$2,721,240
	Prysmian			
	Furukawa			
		69kV	**250MCM**	
	Sumitomo			$2,424,960
	Prysmian			
	Furukawa			
Installation Cost	ITB	153,600 per day	20 days (est)	$3,072,000
Removal Cost	Estimate	153,600 per day	10 days (est)	$1,536,000
	Low Estimate (69kV, 250MCM)		**$6,395,500**	
	High Estimate(138kV, 500MCM)		**$7,784,640**	

The above quotes are high level estimates. The quotes are for laying a single, 3-phase conductor across the Stikine crossing as a spare. SEAPA has additional quote requests pending and will update as information becomes available.

Permitting

SEAPA has contracted the services of PND Engineers Inc. to perform permitting duties as it pertains to either repair or replacement. A summary of the tasks that may be required is as stated below (PND submittal):

- U.S. Army Corps of Engineers (USACE): The cable repair will most likely fall under USACE Nationwide Permit (NWP) No. 3 (Maintenance) or No. 12 (Utility Line Activities), and require pre-construction notification. The pre-construction notification is usually a 3- to 6-week process, contingent on NMFS consultation.
- Depending on onshore activities, wetland impacts potential may also need to be assessed. There are potential coastal and freshwater wetlands in the region, but we would want to review aerial imagery more closely if and when we determine that any shoreside work is required and what that footprint would cover. It is sometimes more cost-effective to assume wetlands in areas where they are suspected than to perform a physical delineation that would require a site visit.
- If project design precludes the use of an NWP, individual USACE permitting may be required. This would require additional consultation and State water quality analysis. Design elements that might trigger this include impact areas larger than minimum footprints or construction impacts beyond the norm. The suitability of the NWP can be further assessed when we receive your design details.
- National Marine Fisheries Service (NMFS): The project is within the range of humpback whales and Steller sea lions and will require NMFS consultation for endangered species impacts, usually a 3- to 6-month process, as part of the USACE review. If it is determined that the project will impact marine mammals, the project could require an Incidental Harassment Authorization (IHA). Obtaining an IHA is usually a 9- to 12-month process. The need for an IHA is typically a result of construction noise or habitat impacts and seems unlikely for this project, pending additional details.
- We are not aware of any need or mechanism for FERC permitting for this project. FERC regulatory involvement could be triggered if there is interstate sale of energy from this project. The involvement of a different lead federal agency in any project can delay permitting due to the need for coordination.
- The tidelands lease should not require any modification for the repair unless the cable is to be moved outside of the lease area. There is some language in the lease requiring approval from ADF&G. This will most likely be taken care of in the USACE process.
- There may need to be some coordination with GCI as the fault is near their fiber-optic cable crossing. The GCI easement was recorded in 2017. SEAPA's cable has the senior easement. We are not sure what private agreement exists between SEAPA & GCI.

Easements

SEAPA has an easement with the Department of Natural Resources (DNR) dating back to 1985. In 2017, GCI attained an easement that crosses SEAPA's submarine cables (Figure 6). SEAPA council drafted a notice about easements to GCI for awareness and coordination.

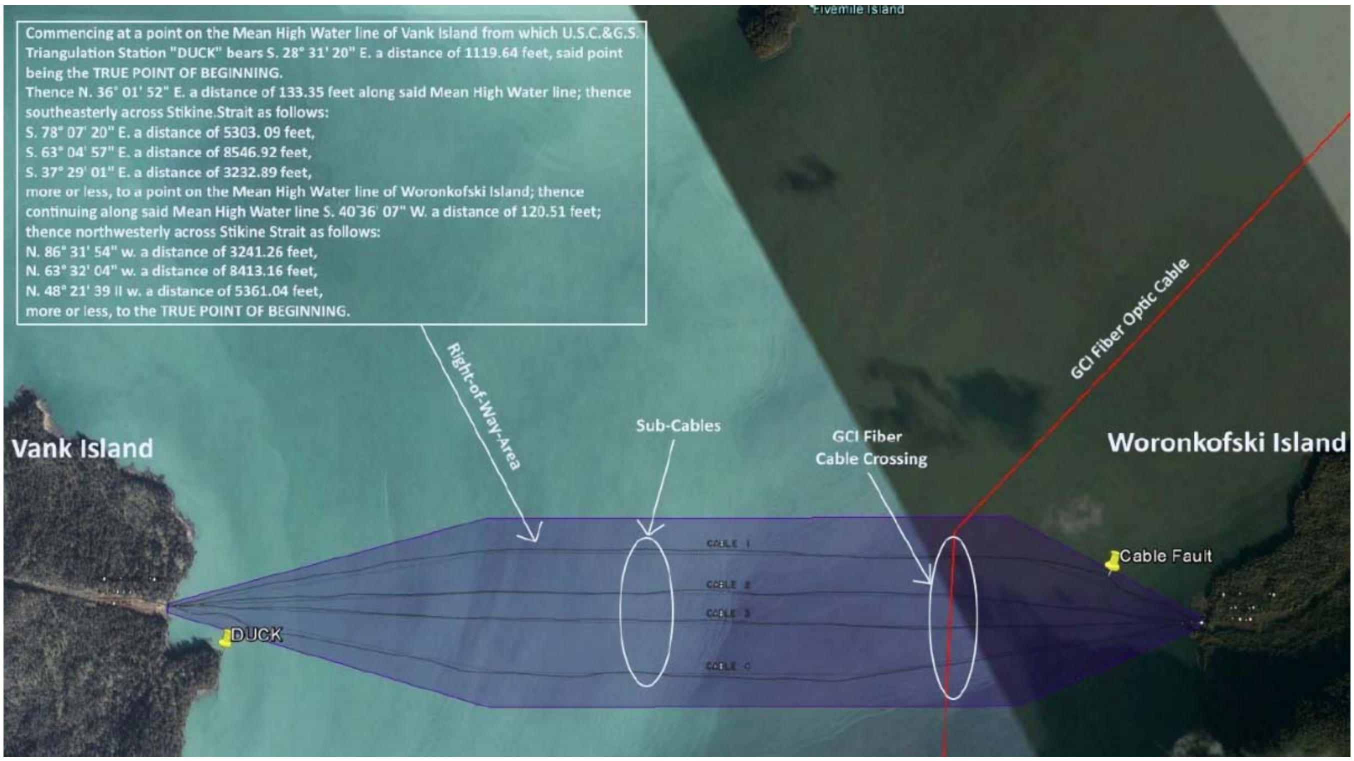

Figure 6: SEAPA Stikine Crossing Easement overlay w/ GCI