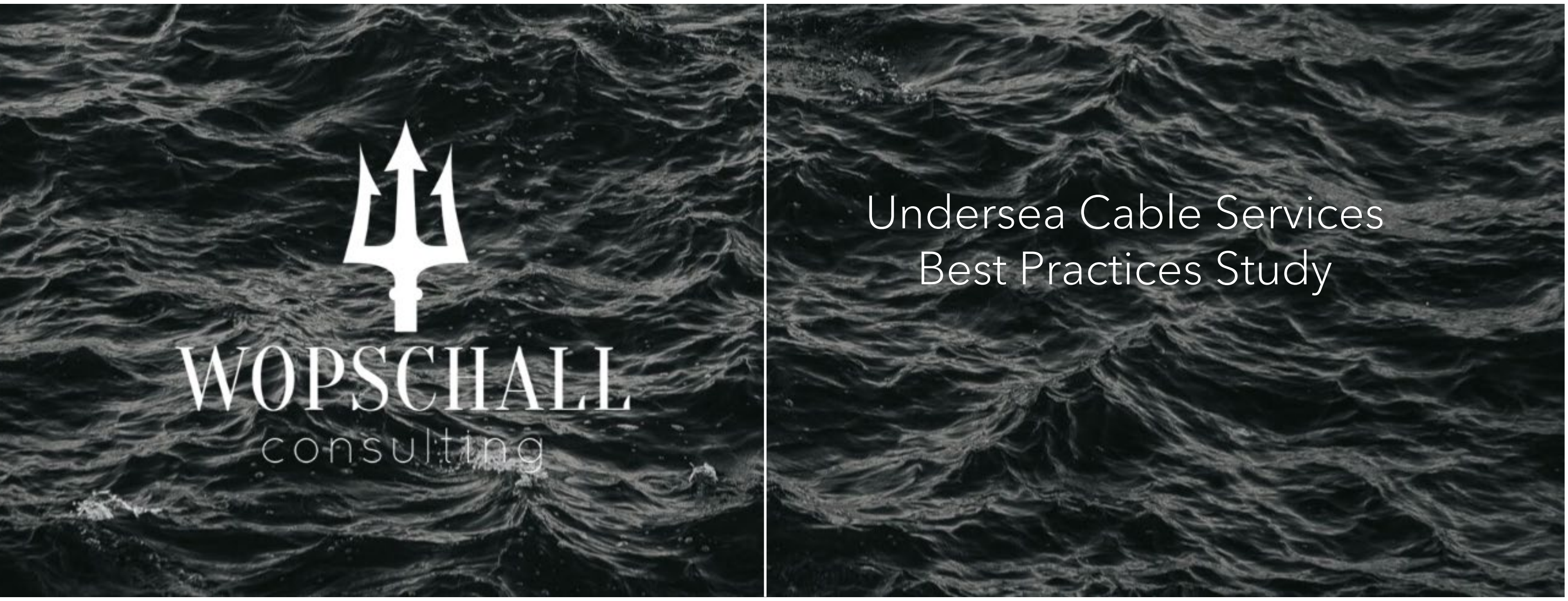

WOPSCHALL
consulting

Undersea Cable Services
Best Practices Study

# Undersea Cable Placement in the United States and Abroad

Prepared For:

Oregon State Department of Land Conservation and Development (DLCD)

1 February 2023

Final Revision

Document Revision Table

| Rev | Date | Description of Revision | Author |
|---|---|---|---|
| Draft | 18 Dec 2022 | Draft Release – For DLCD Review | RW |
| Final | 1 February 2023 | Final Release – For Distribution | RW |

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# 1.0 Executive Summary & Introduction

Wopschall Consulting, LLC (Wopschall) has been contracted by the State of Oregon, acting by and through its Department of Land Conversation and Development (DLCD) to perform a best practices study on the placement of undersea fiber optic and power cables in the United States and abroad. This effort is part of the State of Oregon's House Bill (HB) 2603 which includes an evaluation of the Territorial Sea Plan (TSP) Part Four which governs uses of the seabed.

This report presents undersea cable best practices for the design, placement, installation, and maintenance of undersea fiber optic and power cable systems, as well as high-level permitting or regulatory considerations for these types of infrastructure projects. The sections of this report address the following topics which comprise the scope of this document:

- Siting cable landing sites and coordinating the offshore design with the onshore design requirements of a project
- Offshore cable route selection and engineering
- Onshore landing site construction methods
- Offshore cable installation methods
- The data that goes into the above points
- Stakeholder and other marine user interactions and coordination
- Cable maintenance and repair activities
- Cable decommissioning and removal
- Geomorphology of seabed routing and coastal landing site selection
- Common trends, permitting considerations, and risks to the planning, development and construction of cables

Some of the information presented in this report is based on best practices, guidelines, recommendations and technical brochures that are published by industry bodies, while some of the information is based on Wopschall's experience working in the undersea cable industry on both fiber and power projects. It is noted that there is no governing standards body for the physical placement and construction of undersea cables. Each project, geography, and cable system design are different and unique based on the physical location and jurisdiction where the project is being developed.

The following sections provide background information on undersea fiber optic and power cable systems, best practices for the selection of an undersea cable route, criteria for the selection of an onshore cable landing site and associated infrastructure, best practices for cable installation, protection, maintenance and repair, information on cable decommissioning and recovery, as well as public, stakeholder and marine user coordination. Each section summarizes permitting considerations relevant to each topic addressed in this report.

# 2.0 Acronyms

The following is a list of acronyms used in this study.

BMH – Beach Manhole

BU – Branching Unit

CHS – Canadian Hydrographic Service

CLS – Cable Landing Station

CPC – Cable Protection Committee

CPT – Cone Penetration Test

DA – Double Armor

DKCPC – Danish Cable Protection Committee

DLCD – Department of Land Conservation and Development

DTS – Desktop Study

DWDM – Dense Wavelength Division Multiplexing

ESCA – European Subsea Cables Association

ft – foot

GEBCO – General Bathymetric Chart of the Oceans

GIS – Geographic Information System

HDD – Horizontal Directional Drilling

HDPE – High Density Polyethylene

HO – Hydrographic Office

HVAC – High Voltage Alternating Current

HVDC – High Voltage Direct Current

ICPC – International Cable Protection Committee

in – inch

ITU – International Telecommunications Union

km – kilometer

kV – Kilovolt

LW – Light Weight

LWA – Lightweight Armor

LWP – Lightweight Protected

m – meter

MBES – Multibeam Echo Sounder

mi - mile

MPA – Marine Protected Area

MRS – Marine Route Survey

MW - Megawatt

NASCA – North American Submarine Cable Association

NEPA – National Environmental Policy Act

Nm – Nautical Mile

NMFS – National Marine Fisheries Service

NMS – Network Management Equipment

NOAA – National Oceanic and Atmospheric Administration

OSCA – Oceania Submarine Cable Association

PFE – Power Feed Equipment

PFS – Permit Feasibility Study

PVC – Polyvinyl Chloride

ROV – Remotely Operated Vehicle

SA – Single Armor

SBP – Sub-bottom Profiler

SLTE – Submarine Line Terminating Equipment

SSS – Side Scan Sonar

TSS – Traffic Separation Scheme

UK – United Kingdom

UKHO – United Kingdom Hydrographic Office

US – United States

USACE – United States Army Corps of Engineers

UNCLOS – United Nations Convention on the Law of the Sea

UQJ – Universal Quick Joint

UXO – Unexploded Ordinance

# 3.0 Background – Undersea Cable Design and Placement

Regional and international undersea fiber optic cables have been a means of communication between countries and continents since the first telegraph cables were installed in the late

1800's including the first trans-Atlantic cable between England and North America. Since that time, cables have been laid on and buried in the seabed to facilitate the growth of international communications. Communications technology has evolved since the telegraph era, most notably with the era of fiber optics in the 1980's and 1990's, as well as coherent technology in the late 2000's, which are advancements that have kept undersea fiber optic cables as the primary mechanism for global communications and digital data transmission.

The reason undersea cables, specifically fiber optic cables, have been installed on the seabed, is that a physical point-to-point connection is the quickest way to transmit data, whether it be voice, video or other forms of digital data. Routing cables through the world's oceans is the only way to obtain that point-to-point connection with other locations, which have facilitated over 99% of all international communications for decades (Brake, 2019). Compared to satellite technology, which came much later than the first advent of an undersea cable, fiber optic cables have lower latency in transmitting data and can do so at much higher capacities than satellites. These days, undersea fiber optic cables are being developed to transmit data at tens of terabits per second per fiber contained within the cable. New cables are deployed each year and these projects are barely keeping up with the global demand for broadband that has been realized with the use of social media, video streaming, video conferencing, and personal and enterprise cloud services, as well as the growth and use of data centers and data center-to-data center communications/data transfer. The demand for broadband, international connectivity, as well as overall network redundancy is driving the undersea fiber optic cable market and will continue to do so into the future.

As of 2022, there are approximately 530 active and planned undersea fiber optic cable systems (Telegeography, 2022). From this total, approximately 80-85 cables land in the United States on both the east and west coasts. Specific to Oregon, 13 submarine fiber optic cable segments land in the state at approximately 6-7 landing locations. At the time of this report, several new cable systems are also planned to land at existing and new cable landings, including submarine power cables associated with Oregon's PacWave project.

Global communications have relied on hundreds of active undersea cables for decades. As of the last ten years, undersea cables have started to be recovered when decommissioned to remove them from the seabed as part of a permitting or regulatory requirement, as well as for the recycling of raw materials contained in the cable such as copper and steel. In other instances, undersea cables are left in-situ after decommissioning so as to not disturb the seabed by removing buried cables or in the instance of surface laid cables, to not disturb marine life that has colonized the cable (Carter, et al 2009).

The figure below is a schematic representation of the world's major in-service undersea fiber optic cables system.

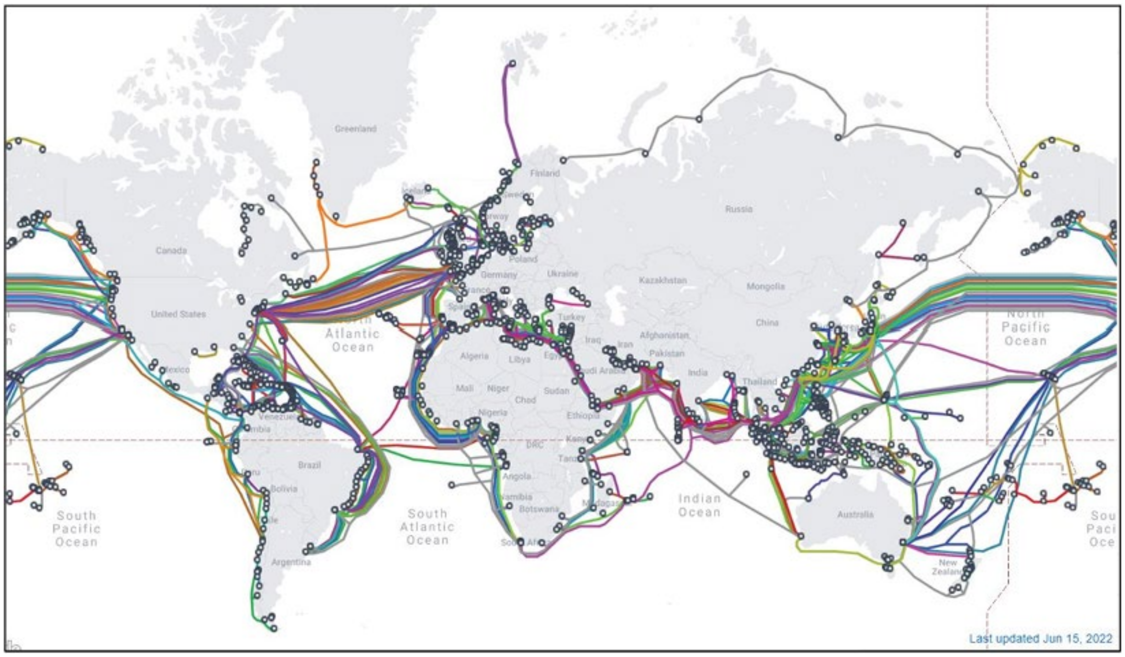


*Figure 1: Global Map of In-Service Undersea Fiber Optic Cable Systems, Source: Telegeography, Submarine Cable Map, 2022, https://www.submarinecablemap.com*

The figure below illustrates the in-service undersea fiber optic cables that land in Oregon at various landing locations. .

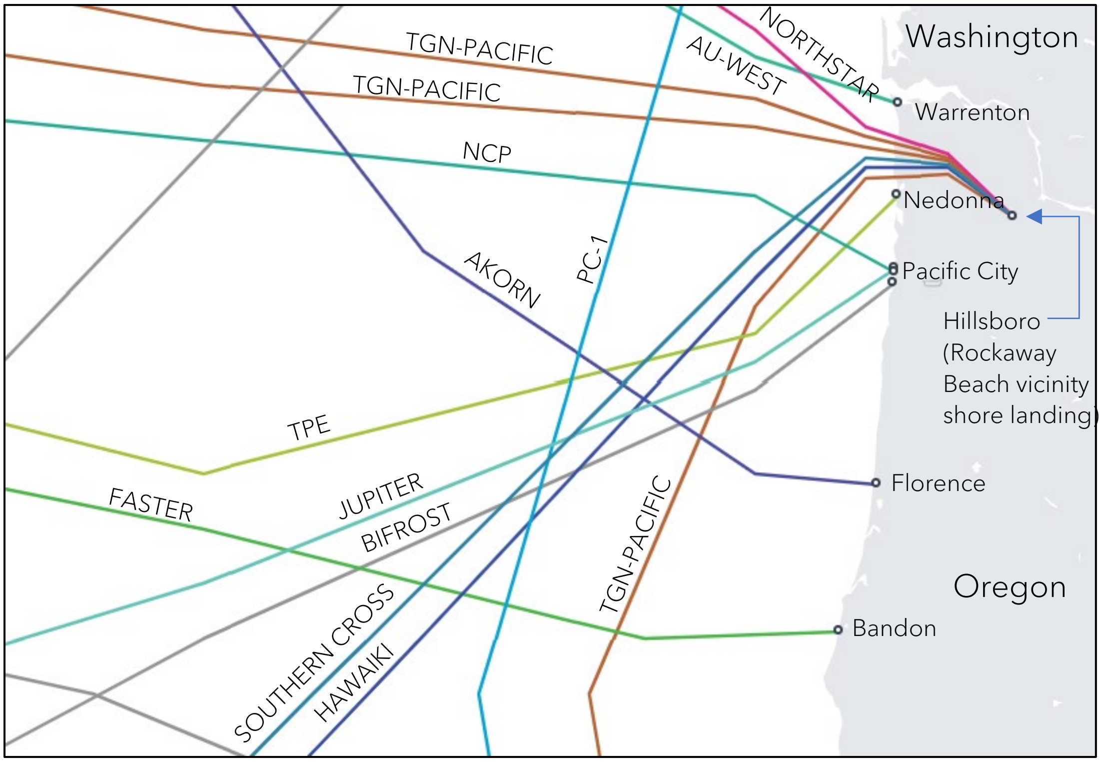


*Figure 2: Map of In-Service Undersea Fiber Optic Cable Systems Landing in Oregon, Source: Telegeography, Submarine Cable Map, 2023, https://www.submarinecablemap.com*

The development of new undersea fiber optic cables is a factor of demand for global broadband connectivity. The figure below illustrates two of the world's major undersea fiber optic cable markets, the Trans-Pacific and Trans-Atlantic markets, which drive fiber optic cable landings on the US east and west coasts. Exponential demand is a factor of increases in video conferencing, video streaming, social media applications, as well as private and commercial broadband connectivity.

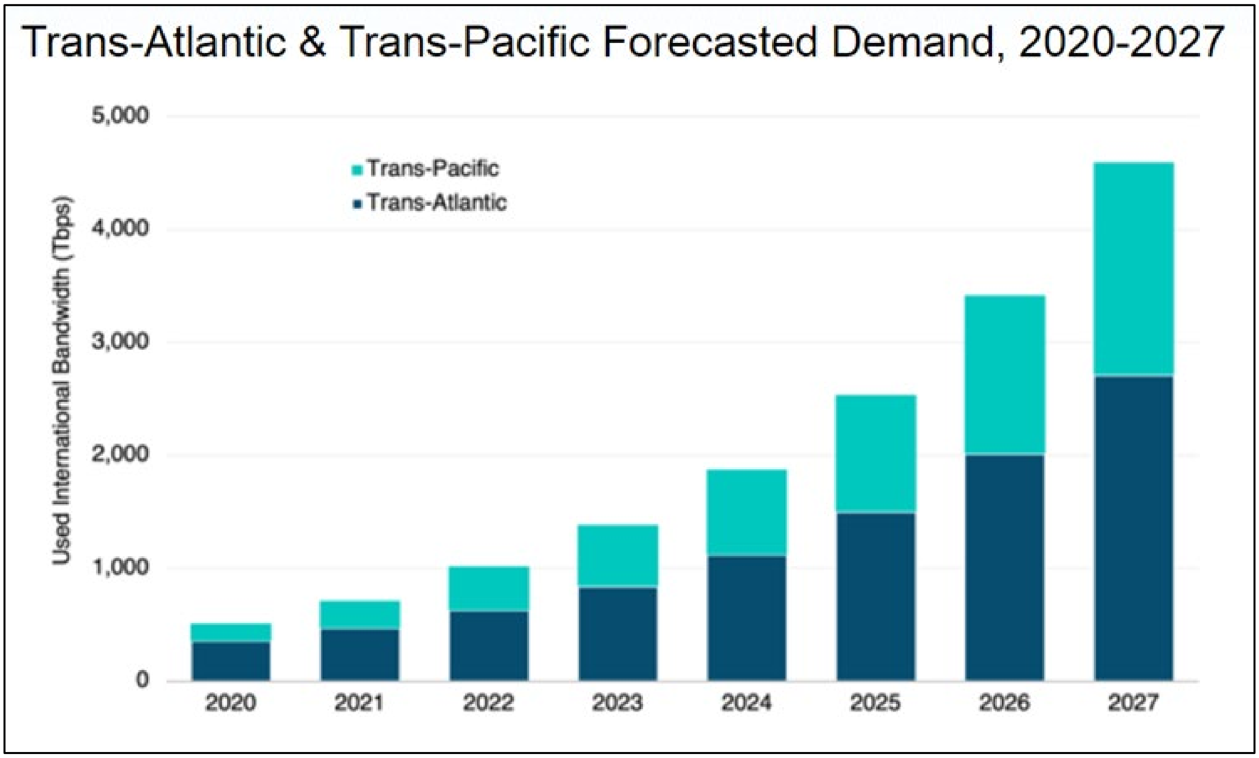


*Figure 3: Forecasted Broadband Demand for the Trans-Atlantic and Trans-Pacific Markets through 2027, Source: Telegeography, 2022 https://www.submarinecablemap.com*

Compared to undersea fiber optic cable systems, undersea power cables typically serve regional demands for power transmission including point-to-point transmission and renewable energy applications such as offshore wind. Undersea power cables, both high voltage alternating current (HVAC) and high voltage direct current (HVDC) cables have different physical characteristics than a fiber optic cable, most notably their diameter, but much of the physical siting and installation considerations and best practices are very similar between fiber optic and power cables.

Undersea fiber optic cable systems, and to a lesser degree power cable systems, get damaged each year. The primary cause of damage is bottom contact fishing and vessel anchors with over 70% of fiber optic cable damages resulting from these occurrences globally (Telegeography, 2022). As a result, protecting undersea cables has always been a priority for the cable industry. A consistent theme in industry best practices revolves around the protection of digital and power infrastructure assets both onshore and offshore and drives the placement, installation methods, as well as operations and maintenance of undersea cables.

The following sections provide a more specific overview of industry bodies that promote best practices and the protection of undersea cables, as well as providing a design overview of fiber optic and power cable systems from a physical infrastructure point of view.

## 3.1 Industry Organizations

The undersea fiber optic cable industry and the power cable industry have trade organizations that look after and promote the protection of undersea cables. This also includes promoting cable infrastructure resilience which covers all aspects of a cable's lifespan including design and siting, installation, operations, maintenance and decommissioning and recovery. From these organizations are publications promoting best practices, guidelines, recommendations, and technical brochures. For the purposes of this report, these various publication forms can be thought of as disseminating best practices for undersea cables.

### 3.1.1 International Cable Protection Committee (ICPC)

The International Cable Protection Committee (ICPC, www.iscpc.org) was founded in 1958 as a cable protection committee focused on protecting and maintaining undersea communications cables. The organization has since also included undersea power cables. As a membership-based organization headquartered in the United Kingdom, the ICPC comprises about 190 member companies in over 60 countries including cable owners and operators, cable suppliers and installers, vessel operators, marine survey companies, professional services companies, as well as governments. The ICPC is at the forefront of best practices, both technical and regulatory, for the protection of cables.

The ICPC publishes 'Recommendations' that cover a wide variety of technical and other topics to promote awareness of these best practices. These documents can be requested from the ICPC at the following website address: https://www.iscpc.org/publications/recommendations/

The list below summarizes the Recommendation titles from the ICPC.

- Recovery of out-of-service cables
- Cable routing and reporting criteria
- Telecommunications Cable and Oil Pipeline / Power Cables Crossing Criteria
- Co-ordination Procedures for Repair Operations Near In Service Cable Systems
- Recommendation for Common Format for Cable Awareness Charts
- Recommended Actions for Effective Cable Protection (Post Installation)
- Offshore Civil Engineering Work in the Vicinity of Active Submarine Cable Systems
- Procedure To Be Followed Whilst Offshore Seismic Survey Work Is Undertaken In The Vicinity Of Active Submarine Cable Systems
- Minimum Technical Requirements for a Desktop Study
- The Minimum Requirements for Load and Lay Reporting and Charting
- Recommended Common Format for Electronic Formatting of Route Position Lists
- Mechanical Testing of Submarine Telecommunications Cables
- The Proximity of Offshore Renewable Wind Energy Installations and Submarine Cable Infrastructure in National Waters
- Basic Power Safety Procedures that are to be followed by Marine Repair Operators and Terminal Station Personnel during Subsea Cable Repair Activities

- Procedure to be Followed Whilst Marine Aggregate Extraction, Dredging or Mining is Undertaken in the Vicinity of Active Submarine Cable Systems
- Considerations for Marking Submarine Cables
- Submarine Cable Operations in Deep Seabed Mining Concessions Designated by the International Seabed Authority
- Minimum Technical Requirements for the Acquisition and Reporting of Submarine Cable Route Surveys
- Preparatory Actions for Civil Claims Development for Cable Damage

The ICPC also publishes 'Best Practices' which are intended to be government facing publications to promote regulatory best practices that can be adopted by governments to help protect undersea cables as critical infrastructure (ICPC, 2022). These best practices are discussed later in this report and are included as Attachment A, for reference.

These best practices present topics including:

- Fishing and anchoring risks [to cables]
- Spatial separation
- Charting
- Domestic cable protection laws; penalties for damage
- Marine spatial planning and inter-industry coordination
- Single point of contact
- Route and landing optimisation; geographic diversity
- Permitting for installation and repair
- Cabotage and crewing restrictions
- Port entry requirements
- Customs duties, taxes, and fees
- Maritime boundary claims and disputes
- Critical infrastructure designation
- Sharing of risk and incident data
- Impact of other high-seas regulatory activities

### 3.1.2 European Subsea Cables Association (ESCA) & Regional Cable Protection Committees

Where the ICPC primarily focuses on international cable protection issues and best practices from an industry wide or global perspective, much of the ICPC's work is augmented by regional cable protection committees (CPCs). Each CPC has their own focus and initiatives though they maintain close relationship with the ICPC and other CPCs. Some CPCs publish best practice documentation done so in coordination with the broader industry.

Listed below are some of the regional CPCs around the world:

- European Subsea Cables Association (ESCA, www.escaeu.org)
- North American Submarine Cable Association (NASCA, www.n-a-s-c-a.org)
- Danish Cable Protection Committee (DKCPC, https://dkcpc.dk)

- Oceania Submarine Cable Association (OSCA, www.oscagroup.com)

There are also regional CPCs in Indonesia and West Africa.

Of these organizations, it is ESCA that also promotes industry best practices by publishing 'Guidelines' which are similar to the ICPC's Recommendations. Some of the guidelines are working level guidance that don't necessarily pertain to the topics of this report.

Guideline topics published by ESCA include the following:

- Principal UK Fishing Organisations
- Principal Operational Regulations
- Fishing Claims forms & Guidance Notes
- Guidance Fishing Reps
- Guidance Notes for Guard Vessels
- Telecom Cable Works Notice
- Fishing Liaison
- UKHO Liaison
- Submarine Cable Navigational Aids
- Offshore Liaison
- Inclusion of ESCA Recommendations
- Proximity of Wind Farms
- Rock Placement
- Typical Decommissioning Summary Report
- Submarine Cable Decommissioning
- Interfaces During Cable Fouling Incidents
- Research Vessel Safe Working Distances
- Reporting Faults Caused by Anchors to the MAIB and MCA
- Fishing Compensation
- Power Cable Installation
- Power and Renewable Energy Cable Repair
- Testing of AC and DC Subsea Power Cables
- Marine Aggregate Extraction Proximity
- Notifications to vessels operating in close proximity to subsea assets

### 3.1.3 CIGRE

CIGRE [https://www.cigre.org] is the International Council on Large Electric Systems and is a global delegation of members who are committed to knowledge development and sharing of power systems expertise, which includes undersea power cable systems. While CIGRE covers a large topic area relating to power systems, the organization recently published for its members a Technical Brochure on the installation of undersea power cables which includes best practices for these activities.

CIGRE's Technical Brochure (TB) 883 – Installation of Submarine Power Cables is a 241-page document that covers the following topics:

- Consents and Permitting
- Submarine cable installation engineering
    - Engineering process
    - Engineering studies
    - Cable routing
    - Cable protection
    - Landfall and offshore asset design
    - Cable and accessory designs and impact on installation
    - Tool and vessel selection
    - Cable installation engineering
- Seabed survey and site investigations
- Installation tools, vessels, and considerations
- Execution of installation including remedial work
- Operation, maintenance, and decommissioning

### 3.1.4 Cable Awareness – Maps & Data

Essential to cable protection is promoting the awareness that cables exist on the seabed. There is no single consolidated set of existing cable information, as much of this information is held by individual cable owners and is considered confidential. However, cable systems are reported to relevant hydrographic offices (HOs) for charting on nautical charts. Other resources exist to promote the awareness and presence of cables.

One map resource is Telegeography's submarine cable map (https://www.submarinecablemap.com/) which depicts schematic routes of existing in-service telecommunications cables. This resource is used as a reference for where cables exist, their ownership, and other information but is not used for accurate route positioning of cables.

Another resource promoted by ESCA is Kis Orca's website which depicts the routing of cables in Europe (https://kis-orca.org/map/).

Other organizations such as DKCPC, NASCA, and governmental data sources like NOAA's Marine Cadaster publish cable route information in various forms as well.

Having access, even regionally, to accurate cable information is very helpful not only to the cable industry, but also to other marine and shoreline user groups who are planning other infrastructure in the vicinity of undersea cables.

## 3.2 Undersea Fiber Optic Cable Systems

Undersea fiber optic cable systems are designed for a twenty-five (25) year design life though some systems are operated longer. Often a cable is decommissioned either because the cost of ownership and maintenance no longer makes sense for the service the cable provides, or because the cable exceeds its ability to be further upgraded with modern transmission equipment, or the cable route or network path is replaced with a new cable, or a combination of these factors.

A cable system that exceeds the distance of approximately 250 – 500 km (155 – 310 miles) is required to have repeaters spaced along the cable at intervals of approximately 70 – 120 km

(43.5 – 74.5 miles) to amplify the signal so that data traffic can continue to be transmitted along the cable for its entire length. As a result of these repeaters, as well as other submerged cable bodies such as branching units (BU), these cable systems are powered with power feed equipment (PFE) housed on land at each end of the cable system.

An overview figure of a repeatered cable system is provided below. This figure illustrates the end-to-end design of a cable system. The undersea portion of a cable system is typically designed from a beach manhole (BMH) or utility vault at a beach. The undersea cable is anchored to the BMH and is installed on the seabed to another location where the cable makes landfall. If a cable system is not a point-to-point system but lands in multiple locations, BU's are installed so the fiber cable can "branch" out to other locations, allowing a cable to serve many different locations from one system.

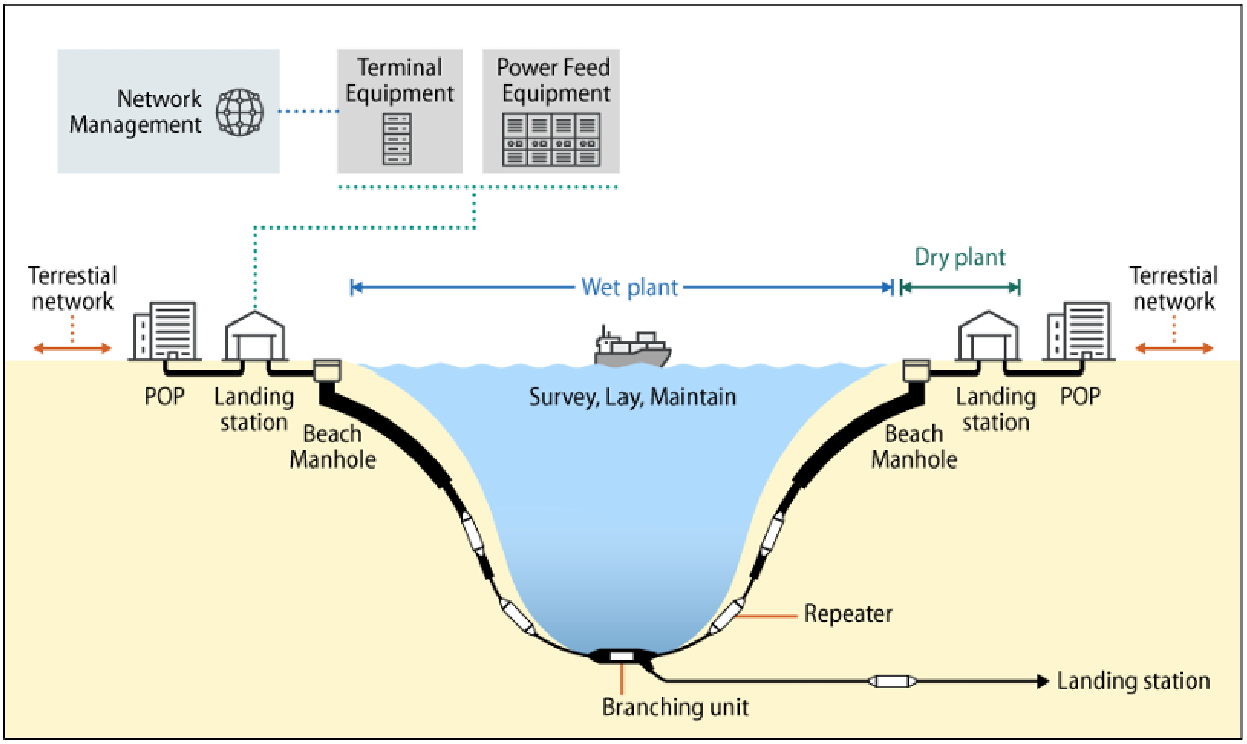


*Figure 4: Illustration of an Undersea Fiber Optic Cable System Source: Congressional Research Service (CRS), https://crsreports.congress.gov/product/pdf/R/R47237*

From the BMH, the undersea cable is typically spliced to a land cable that is installed along a fronthaul path to a cable landing station (CLS) or a PFE hut with fiber running onwards to a data center. The CLS is a telecommunications facility that houses the transmission equipment, or submarine line terminating equipment (SLTE), PFE, network management equipment (NMS), and other ancillary systems required to keep the undersea cable system up and running. From the CLS, the fiber from the undersea cable is connected to terrestrial backhaul fiber that carries traffic further inland to either a Point-of-Presence (PoP) like a carrier hotel, or to a data center. The "on-land" portion of the network is referred to as the dry plant, while the undersea cable portion is referred to as the wet plant. In some cases, and typically only when a PoP or data center is in relatively close proximity to a cable landing, will the undersea cable be spliced directly to a land cable that terminates in a data center, as an example, which houses all of the system equipment instead of using a CLS. In other cases where a CLS is located usually more than 10 - 15 km from a cable landing, a PFE hut may be constructed as a smaller intermediate facility to house the cable system's power equipment, while the fiber continues further inland to a CLS or a data center. This mitigates the issue of running power along a lengthy fronthaul route. As a result of this, CLS facilities are usually sited as close to a cable landing as possible.

A main driver for where a cable is routed along the seabed is determined by where the cable is required to come to shore for greater onward connectivity within new and existing fiber networks. This may be influenced by where existing CLS facilities are located or new facilities can be constructed, availability of backhaul fiber, locations of PoPs and data centers, and proximity to other network infrastructure including other undersea fiber optic cables. In the last ten (10) years there has been a shift in the types of companies developing cable systems. Content, social media, or internet-based companies are the primary purchasers of new cable systems rather than the traditional carriers or telephone companies who were the main purchasers in the 1990's and early 2000's (and before that). As a result of this shift and based on the growth of the data center market, undersea fiber optic cable systems are being developed to connect data centers, so the selection of offshore route alignments and landing sites is increasingly driven by connecting data centers owned by companies developing undersea cable systems, data centers that house these company's network equipment, or data centers where these company's customers are located.

The figures below illustrate the various types of undersea fiber optic cables which are predominantly characterized by the amount of armor applied to the cable for protection based on the physical environment the cable is placed in.

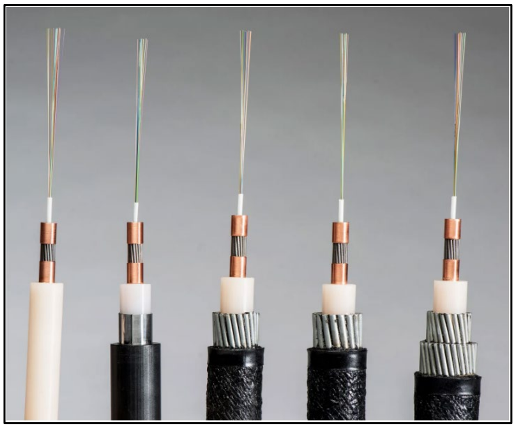


*Figure 5: Undersea Fiber Optic Cable Types made by SubCom, Source: Wired.com*

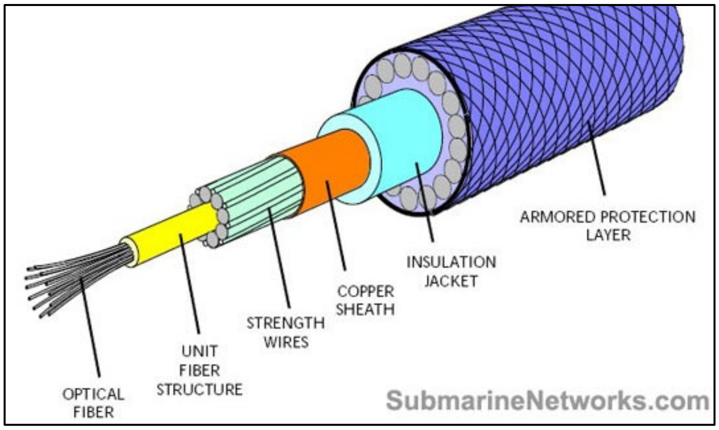


*Figure 6: Structure of an Undersea Fiber Optic Cable (Single Armor), Source: submarinenetworks.com*

Undersea fiber optic cables are typically comprised of an inner optical fiber unit that houses individual glass fiber strands. For repeatered cable systems, cables will typically have up to 12 – 16 fiber pairs (24 – 32 strands) with each fiber pair providing bi-directional communication across the system. More recently, trans-oceanic systems such as across the Atlantic Ocean are being built with 24 fiber pairs (48 strands) which is far greater than their predecessor cables built two decades ago which may only have 2 – 4 fiber pairs (4 – 8 strands).

The optical fiber unit is surrounded by steel strength wires, a copper sheath which acts as the power conductor for the cable (for repeatered systems) and insulation jacket, and layers of steel armoring. It is noted that fiber optic cables have a copper sheath to send power to repeaters and BU's and are not utilized for power transmission like undersea power cables.

The figure above illustrates various cable types that are used in undersea fiber optic cable applications, including (from left to right) Lightweight (LW), Lightweight Armor (LWA) (also known as Lightweight Protected (LWP)), Single Armor (SA), Single Armor (SA, with thicker diameter armoring), and Double Armor (DA). Cable types are often selected based on water depth, terrain of the seabed, and the risk of external aggression. It is noted that the names and physical characteristics of each cable type may vary between cable manufacturers.

The table below provides information on the water depths and applications where each cable type is typically used. LW cable is used in deep water applications and is no larger than 17 – 22 mm (0.67 – 0.87 inches) in diameter increasing to 40 – 50 mm (1.57 – 1.97 inches) diameter for a DA cable that is used as the cable approaches shore (Carter et al, 2009).

*Table 1: General Cable Types and Their Applications*

| Cable Type | Installation Depth | | Installation environment |
|---|---|---|---|
| | Typical | Max.* | |
| Double Armor<br>(DA) | 0 to 200m | 0 to 500m | Generally used in the nearshore portion of cable routes where the risks from high-energy environments and external aggression are highest.<br>Also used on rock outcrops and areas of less than reasonable sediment cover where abrasion is a risk. |
| Single Armor<br>(SA) | 0 to 1,500m | 0 to 2,000m | Generally used on the continental shelf and slope where the risks are present and the cable is to be surface laid over marginal bottom conditions. Also used in areas of rock outcrops beyond the deployment depth of DA cable. |
| Light Weight Protected<br>(LWP) | 1,500 to 4,500m | 7,000m | Used on continental slope and in deep-sea areas where extra abrasion protection might be necessary, i.e. on rocky bottom, in areas of high relief and/or steep slopes, in areas of strong currents and/or slumping. |
| Light Weight | 1,500 to 6,000m | 8,500m | Used in most benign deep ocean environments to full ocean depth. |

| | | | |
|---|---|---|---|
| (LW) | | | |

The predominant risk of damage to undersea fiber optic cables is from bottom contact fishing and vessel anchoring. Globally there are approximately two hundred (200) undersea fiber optic cable repairs that occur each year. Of these, approximately seventy percent (70%) of the damages are from fishing and anchoring (Telegeography, 2022). Two of the main methods for protecting undersea cables from these forms of external aggression include armoring the cable, as discussed with the various cable types, and burying the cable into the seabed. Both are implemented globally as a matter of standard practice.

Depending on the installation environment, particularly in deeper water or where a cable cannot feasibly be buried, cable armoring also protects the cable from abrasion against rough or rocky surfaces.

From the shore, it is standard to bury cables to a minimum depth of 1 m (3.3 ft) below the surface of the beach and seabed and typically no more than 2 m. There are exceptions to this where certain jurisdictions require deeper burial such as off Singapore and in Indonesian waters; however, these are exceptions rather than best practice. It is also standard that cables be buried to a minimum water depth of 1,000 m (3,280.8 ft), but based on a region's fishing activity, consideration of burial down to between 1,500 and 2,000 m (4,921.3 – 6,561.7 ft) water depth is also practiced. A presentation of the methods used for cable burial is discussed in Section 6.0 of this report.

A few different methods are implemented to achieve burial of the cable through the surf zone and onto shore up to the BMH, which are typically driven by local permitting requirements. The first method is a land-based direct burial method where the beach is trenched using conventional excavation equipment. The cable can either be directly installed in the trench and then buried, or a conduit made out of PVC or HDPE can be installed by which the cable is inserted through the conduit for added protection. Articulated pipe can also be installed over the cable as another method for added protection rather than using a conduit. The direct burial method has traditionally been used throughout the world for shore-end construction.

Another method that is more common in North America, among other locations, is to directionally drill a seaward conduit using horizontal directional drilling (HDD) from the landing or BMH location to a point offshore that is typically beyond the surf zone or in about 10 m (32.8 ft) water depth. The directionally drilled conduit is utilized as added protection to install the undersea fiber optic cable though to the BMH and provides for construction that does not directly disturb the beach or shore. In most cases, whether it be a buried PVC or HDPE conduit, or an HDD conduit, the diameter of the conduit is usually about 4 in (10.2 cm).

For undersea fiber optic cable systems that are equal to or less than 250 to 500 km (155 – 310 miles), modern transmission equipment can transmit data without the need for amplification in the form of repeaters along the cable. As a result, these cable systems can be unrepeatered and, therefore, unpowered. Unrepeatered cable systems are typically implemented as regional cable systems where the geography of a region allows for shorter cable spans to connect various locations, as opposed to trans-oceanic systems that span the world's major oceans. Aside from being unrepeatered, another main difference when compared to repeatered systems is the fiber count can often be much greater. It is typical that an unrepeatered system can have up to 96 fiber pairs or more, making it akin to a terrestrial fiber optic cable that has been repurposed for an undersea environment.

Unrepeatered cables are manufactured with similar cable types as repeatered cables and are often armored (DA, SA, LWP cable types) because their application lends themselves to shallower water routes. However, the methods of cable protection (armoring and burial) as well as installation and landing site construction are predominantly the same as what has been described above for repeatered cables.

### 3.3 Undersea Power Cable Systems

Undersea power cables serve the primary purpose of transmitting power through either high voltage direct current (HVDC) or high voltage alternating current (HVAC) cables. Undersea power cables are implemented to serve point-to-point connections for sustainable power transmission between sources. This can include transmitting power from one country to another, from hydroelectric sources, or other renewable energy sources such as wind farms or hydrokinetic sites.

Power cables are designed for a 40-year design life and are often manufactured as Double Armor (DA) or Single Armor (SA) cables, with armoring (and cable burial) being the primary method of cable protection.

HVDC power cables are manufactured for longer distance power transmission which typically serves point-to-point power transfer between sources such as the 525kV, 154 km (387.1 miles) offshore segment of the NordLink cable system between Norway and Germany.

HVAC power cables are manufactured for shorter distances usually less than 80 km (49.7 miles) and are often implemented as export cables from offshore wind farms or shorter point-to-point connections such as connecting hydroelectric plants to city centers.

Undersea power cables can range in diameter from 70 mm to exceeding 210 mm in diameter (ESCA, accessed September 2022). These cables are limited in the water depth they can be installed in. Due to the length limitations of HVAC cables, most are installed in shallow water applications of less than a few hundred meters water depth. HVDC cables can extend for longer distances and as a result transit deeper depths but are generally limited to around 1,000 m (621.4 ft) water depth, though some existing in-service cables have been installed to depths approaching 2,000 m (1,242.7 ft).

The figure below illustrates the cross section of a HVAC and HVDC power cable. The HVAC power cable has a three-core conductor while the HVDC cable is a single core. HVDC cables can only transmit power in one direction so require two cables for bi-directional power transmission. Oftentimes fiber is included in an undersea power cable design. For an HVDC cable the fiber is typically a separate fiber optic cable that is bundled or lashed to the power cable. For HVAC cables, the fiber is integrated in the cable using a tube or fiber optic unit.

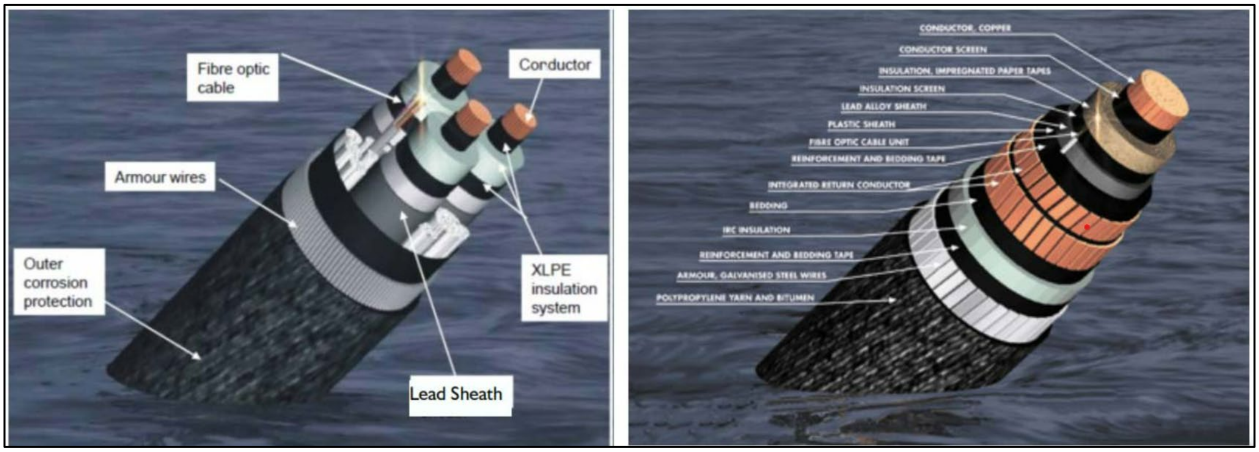


*Figure 7: 3 Phase HVAC Power Cable (Left) and Co-Axial HVDC Power Cable (Right) (Source: ESCA)*

The physical placement, installation and landing site construction of undersea power cables is very similar to that of undersea fiber optic cables. The armor types protecting the cable are determined by the water depths the cable will be installed in, as well as the seabed environment and risks of external aggression, among other factors. Similar to fiber optic cables, cable armoring also protects against the risk of abrasion from rough or rocky surfaces where the cable is not buried and is instead installed directly on the surface of the seabed. However, burial of these cables is a standard method of cable protection against threats of external aggression, the largest threats being bottom contact fishing and vessel anchoring (same threats as for fiber optic cables). A standard starting point for cable burial is 1 m (3.3 ft) below the surface of the seabed. At the shore-end, direct buried cables, use of conduit, or HDD are all methods used to install and protect an undersea power cable as it comes to shore to a beach or transition vault where the undersea power cable is anchored and jointed to land cable for onward terrestrial transmission.

A main driver for where undersea power cables come to shore is where existing power utility infrastructure is located to support the loads from the power cable and the ability to transfer to loads to other locations or within a local power grid. In the case of offshore renewable energy sites, the routing of the undersea power cable and the location it comes to shore may be more specifically driven by the location of the offshore energy site and new land-based power infrastructure may be required.

### 3.4 Permitting Overview

Undersea cables span a range of permitting jurisdictions, regulations and legislation. The figure below illustrates the complex permitting environment in which undersea cables cross.

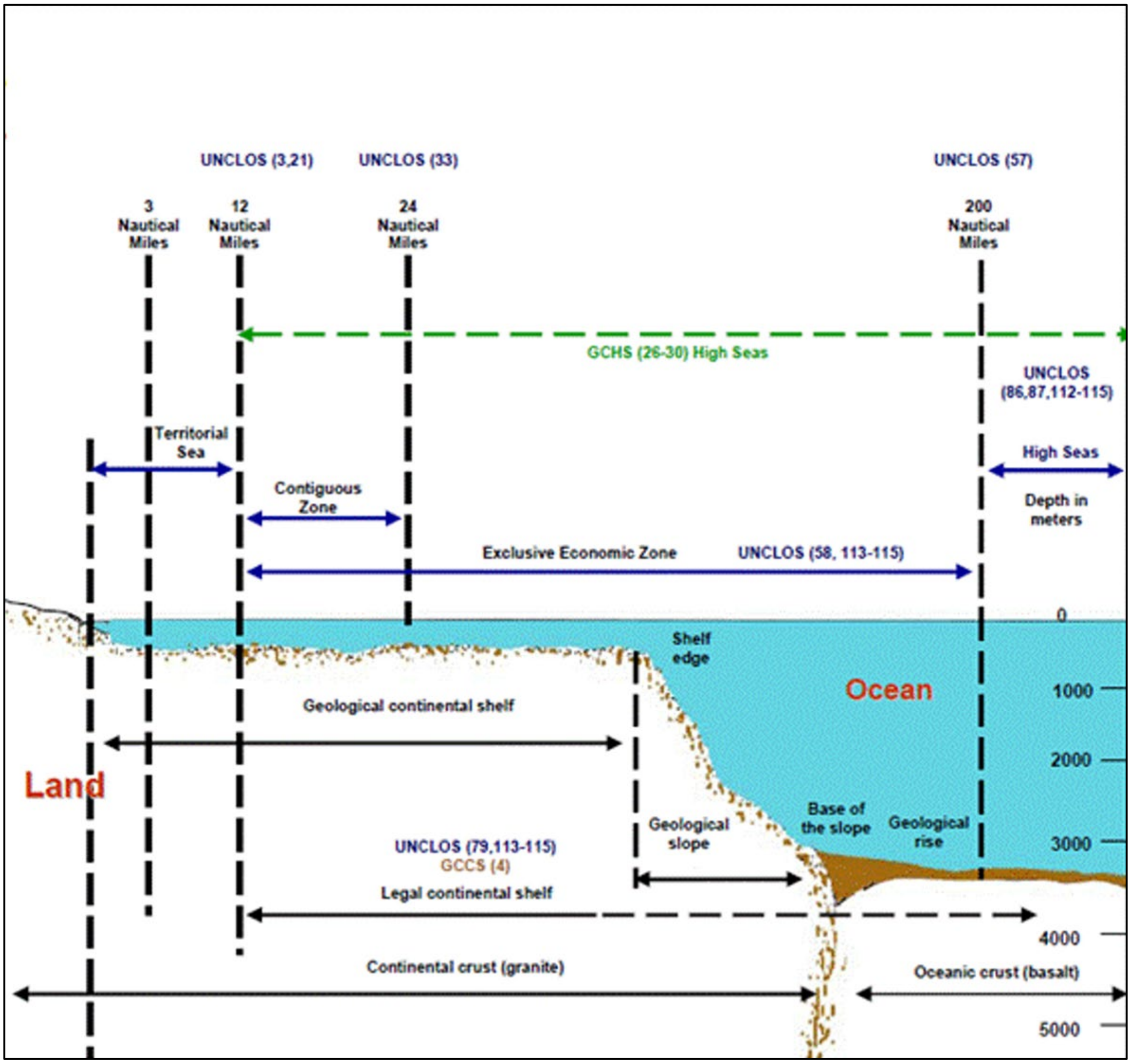


*Figure 8:Summary of Relevant Legislation Regarding Use of the Seabed (Source: Squire, Sanders & Dempsey LLC)*

From land a cable typically crosses a local city or municipality's jurisdiction as well as any ownership over the first three nautical miles offshore. In the US, the 3 nm limit seaward from shore corresponds to a state's jurisdiction or state waters. Within a state's permitting framework, there is often a permitting component that covers water quality, seabed disturbance, coastal zone management, and environmental assessment, among others. State waters are also part of the larger territorial sea which extends 12 nm from a coastal state's shoreline. Extending from the territorial sea is the contiguous zone (24 nm) and the exclusive economic zone (200 nm) as depicted in the figure above. The federal government, in particular the USACE in the US, governs the territorial sea and has oversight through the extent of the exclusive economic zone which are considered federal waters. Other federal agencies are also stakeholders in the territorial sea including NOAA, NMFS, etc.

The United Nations Convention on the Law and the Sea (UNCLOS) recognizes undersea cables as "common good that [is] the foundation of the increasing globalization and interconnectedness of the world" (Davenport, 2012). Article 21 of UNCLOS grants a coastal state the freedom to adopt laws and regulations with respect to the protection of cables and other associated activities in its territorial sea, but UNCLOS protects the ability to lay and maintain undersea cables on the high seas without restriction which is also extended to a coastal state's exclusive economic zone under Article 58. Furthermore, Article 79 extends this freedom to laying cables on the continental shelf. UNCLOS states that in the case of laying or repairing cables, all states should provide due regard to cables already in position and the possibilities of repairing existing cables shall not be prejudiced. It is viewed that unlike any other kind of seabed infrastructure, undersea cables and specifically fiber optic cables, are essentially benign infrastructure that promote the heritage and benefit of mankind by connecting us all together throughout the world (Wopschall, 2017).

In practice, however, not every coastal state is a signatory to UNCLOS (the United States included) and the United Nations does not provide any regulatory or judicial oversight of the provisions of UNCLOS. As a result, some coastal states have not extended the freedoms of laying cables in the exclusive economic zone and instead tried to implement permitting and fee requirements. These are the types of regulatory issues that organizations like the ICPC try to mitigate through direct engagement with government agencies. In addition, sometimes maritime boundary disputes, such as in the South China Sea, can also impact the regulatory and permitting landscape in a region where cables cross disputed zones.

In the application of undersea fiber optic cables, it is typical that large cable systems will cross the high seas, exclusive economic zones, territorial seas, and 3 nm limit, perhaps with multiple coastal states, due to the placement and design of this type of communications infrastructure. As a result, a project will have to apply for permits with federal, state and local level governments. Undersea power cables, which are typically regional systems and of shorter distances, may only exist in the territorial sea of one or more countries, but this will also trigger federal, state, and local government permitting requirements. As a result of these conditions, it is important to assess permitting requirements and feasibility as early as possible in a project's lifecycle and doing so in coordination with all permitting stakeholders can be very beneficial to both the project team but also the inter-agency coordination that may be required to review and assess and project.

## 4.0 Offshore Route Selection

One of the early and upfront project planning activities for a new undersea cable, whether it be a fiber optic cable or a power cable, is determining where the cable should be routed along the seabed to points on a coastline. This is usually approached by conducting a desktop study (DTS) which researches all man-made, oceanographic, geologic, environmental, and technical elements of the project's feasibility and includes the upfront effort to design the cable route(s) and select the landing(s) sites for further investigation. Once the route(s) and landing(s) have been designed and selected, these will form the pre-survey design which will form the basis of conducting visits to each landing sight and a marine route survey (MRS) over the designed route alignments.

In order to accurately define the final cable route for installation and define the adequate cable protection methods including cable types, burial, and external protection, a marine route survey is conducted to map the seabed and sub-surface conditions. This is done by utilizing a variety of acoustic survey equipment from a survey vessel which defines the seabed's bathymetry (topography of the seabed), seabed surface features and sediment types, sub-surface sediment types and structures (to assess cable burial), as well as the presence of other infrastructure or seabed obstructions.

It is best practice to perform a marine route survey over the entirety of a cable route from the landing site (land survey) and throughout the entire marine environment. The ICPC publishes Recommendations for the minimum standards in performing a DTS and MRS.

This section will discuss the factors that drive offshore route selection along the seabed while Section 5.0 will discuss the selection of onshore landing sites. Offshore route selection and landings sites, however, are not mutually exclusive activities. The selection of offshore routing can be driven by onshore landing site selection, and landing site selection can be driven by offshore routing.

## 4.1 Spatial Planning

When evaluating an undersea cable route, the use of a geographic information system (GIS) software is typically used to collect and assess electronic data pertinent to evaluating and designing a cable route. Software programs such as ArcGIS or QGIS are used, among other platforms. GIS software allows accurate spatial planning for all the factors that influence a cable route. These include offshore hazards and obstructions that are charted on nautical charts, the location of charted areas such as dumping grounds, unexploded ordinance sites (UXO), restricted areas, firing ranges, and vessel anchorages, the location of marine protected areas (MPAs), vessel traffic patterns and the location of traffic separation schemes (TSS) or vessel traffic lanes, the location of fishing activity particularly bottom contact fishing, and the location of existing and planned offshore infrastructure such as other cables, pipelines, offshore renewable energy sites, oil and gas infrastructure, etc.

A standard approach when designing a cable route is to avoid many of the features listed above, where possible. But sometimes it is not possible to avoid everything that exists in the offshore environment.

Due to the complexity of the offshore landscape, undersea cables do cross over existing infrastructure, cross through charted areas or marine protected areas, and through fishing grounds. Usually there are well established mechanisms to handle these types of crossings, which are discussed below.

### 4.1.1 Charted Hazards and Obstruction

One of the first tasks in designing a cable route is to assess nautical charts for charted hazards and obstructions. These could be outcropping rocks in shallow water, wrecks (sunken vessels or planes), buoys, piers, or any other object on the seabed or at the surface that would impact the feasibility of installing and protecting an undersea cable. Such obstructions would not only put a cable at risk but would adversely impact the vessel operations required to survey, install and maintain an undersea cable. Nautical chart information is typically sourced in the public domain, or purchased, from relevant hydrographic offices (HO). As an example, in the United States that would be the National Oceanographic and Atmospheric Administration (NOAA), in Canada it would be the Canadian Hydrographic Service (CHS), and in the United Kingdom it would be the United Kingdom Hydrographic Office (UKHO). Sometimes countries do not have a well-established HO, or it is located within the country's navy, making it difficult to obtain charted information which may not exist at all.

Charted information can be imported into a GIS software in various electronic formats, if available. Otherwise, charted information can also be imported by using raster nautical charts or electronic nautical charts. Not every country publishes electronic or raster data or charts for free so sometimes sourcing this information requires the purchase of data and/or charts.

### 4.1.2 Charted Areas

Similar to charted hazards and obstructions discussed above, nautical chart information also contains charted areas which can include dumping grounds, unexploded ordinance sites, restricted areas, firing ranges or military practice areas, port boundaries, pilot boarding areas, vessel anchoring sites, among others. Typically, it is standard practice to avoid areas that could pose risk to a cable once installed such as dumping grounds (active or inactive), UXO sites and vessel anchoring sites. Other areas can be routed through when designing a cable because they do not impact the protection of an installed cable, but an area may influence vessel operations during a marine route survey or installation, requiring close coordination with the other marine activities that occur in that charted area. These areas can include military practice areas, pilot boarding areas, port and harbor boundaries, etc.

### 4.1.3 Marine Protected Areas

It is generally best practice for a cable to avoid marine protected areas or other environmental protected areas, where possible. Having said that, some MPAs have a permitting mechanism to allow cables to cross the area. This will be dependent on the jurisdiction and the agency that manages these protected areas. Whether a cable can be permitted through an MPA or not, the purpose of avoiding these areas is generally to avoid the complexity of adding another permitting requirement to a cable project and it is not because the installation of cables necessarily have an adverse environmental impact.

### 4.1.4 Vessel Traffic

Many existing cables traverse vessel traffic lanes or traffic separation schemes. This is because vessel traffic is often located along coastlines where cables come into shore. When evaluating a new cable route, it is standard practice to look at vessel density maps to understand the flow of vessel traffic, the density or quantity of traffic over the period of a year or more, and to assess what kind of vessels transit an area and whether any vessels are anchoring in a particular area. If there is a lot of vessel traffic around a new landing, or a nearby vessel anchoring area, it is common to assess whether vessels have a historic tendency to anchor over where a cable is being planned. It is prudent to avoid areas where vessels are anchoring.

When crossing a vessel lane or a density of vessel traffic, it is best to cross the traffic perpendicular to avoid increased exposure to vessel related risks such as anchoring. It is generally not recommended to route a cable parallel and within a vessel traffic lane, though sometimes this is unavoidable for certain distances depending on a cable's routing and other constraints impacting its placement.

### 4.1.5 Fishing Activity

Assessing fishing activity is more of an exercise in stakeholder engagement when planning a new undersea cable route. At the early planning stages, certain resources can be used to assess fishing activity at a high level such as Global Fishing Watch [globalfishingwatch.org]. The predominant form of fishing that poses a threat to an undersea cable is bottom contact fishing such as trawling. Sometimes pot fishing can also pose a risk due to gear snagging a cable.

When planning a new cable, best practice protection measures are implemented on the basis that fishing will likely occur somewhere along the route in water depths generally less than 1,000 m (3,280.8 ft) and as a result, most all cables are planned to be armored and buried into the seabed sediment as the best and most standard forms of cable protection. Where fishing activity is occurring or is projected to occur in deeper depths over the twenty-five (25) year design life of a cable, burial can extent to depths in the range of 1,500 – 2,000 m (4,921.3 – 6,561.7 ft). Cable burial of 1 m (3.3 ft) below the surface of the seabed is generally deeper than trawling gear can penetrate; however, when determining depth of burial, it is usually assessed based on the specific gear used in that area. In some areas around the world, burial to 1.5 – 2 m (4.9 – 6.6 ft) is common. Achievable burial is also determined based on the burial tool being used. Most modern plows deployed from dedicated cable installation vessels can achieve 2 – 3 m (6.6 – 9.8 ft) burial.

Depth of burial is a direct result of the specific risk of damage to a cable and the consequence of that risk. On this basis, evaluating burial of a cable is different than evaluating burial of a pipeline - pipelines often being buried deeper than cables because the consequence and complexity of repair is greater.

In some areas, such as in parts of Alaska, a moratorium on bottom contact fishing exists and vessel traffic is very limited. As a result, the direct threat of external aggression towards a cable is far less than is typical in most places around the world. Therefore, cables confined to smaller regions in Alaska, or elsewhere where these conditions exist, can be surface laid directly on the seabed. These cables will typically be armored in shallow water depths less than 1,000 m (3,280.8 ft) to provide some form of protection.

Even though cables are buried to protect against fishing activity, it is best practice for cable owners to coordinate directly with fishermen operating in an area where the cable is installed. It is best practice to coordinate in such a way where bottom contact fishing does not occur over a cable even though it is buried. As a result, cables are charted on nautical charts and often cable owners form specific agreements with fishermen so that they avoid cables. If a cable is snagged by fishing gear, it is best practice for a fishing vessel to cut their gear rather than damage a cable. Inadvertent damage to a cable is grounds for a civil claim in most jurisdictions around the world. Obviously, this interaction between cables and fishermen can be impactful for both sides. As a result, in more established jurisdictions familiar with cables, fishermen form organizations that specifically work with cable owners. Within these organizations, there is sometimes a mechanism of payment from cable owners to fishermen to compensate them for lost fishing ground, any lost or damaged gear, to ensure awareness of the presence of cables, and to incentivize fishermen to avoid installed cables. These types of cable/fishermen organizations are very well established in states like California and Oregon and elsewhere around the world. The level of coordination and any mechanism for financial compensation is very region/jurisdiction dependent though that does not diminish the importance for stakeholder engagement and liaison with fishermen during the planning, installation and operational phases of a cable project.

### 4.1.6 Offshore Infrastructure and Activities

When planning an undersea cable route offshore, it is prudent to consider existing and planned offshore infrastructure as well as other offshore activities that may or may not be charted on nautical charts. These can include undersea pipelines, other undersea fiber optic or power cables, offshore renewable energy sites, dredging sites, seabed mining sites, fish havens or aquaculture sites, artificial coral reefs, and sewer or wastewater outfall pipes, etc. These can also include seabed infrastructure owned or operated by defense agencies such as the Navy in the US.

In recent years, the most impactful form of offshore infrastructure affecting the design of undersea cables is offshore renewable energy sites, specifically wind farms. Wind farms take up relatively large areas of ocean and seabed and have been located in areas where cables are traditionally routed. For example, areas around the UK and in the North Sea, as well as the Atlantic and Pacific coasts of the US (though these regions are less developed than in Europe), among other locations, have required an increasing amount of coordination between cable owners and wind farm owners. At times there are not clear mechanisms for coordination such as cables being installed through wind farm areas, which can add complexity to the installation and maintenance of each type of infrastructure. During planning stages, it is best practice for cables to avoid wind farm areas, but sometimes this may not be achievable and coordination is required.

When it comes to other existing linear infrastructure such as pipelines and other cables, these are routinely crossed by new cables simply out of necessity. Crossing other linear infrastructure, particularly other in-service fiber optic cables, can be unavoidable.

For fiber optic cable-to-fiber optic cable crossings, it is an industry standard that these crossings are allowed between owners, and the other party is simply notified through a crossing notification process. The ICPC has a standard template for a crossing notification that is used to facilitate this process and the communication surrounding a crossing. In some instances, and still for a fiber optic cable-to-fiber optic cable crossing, parties will want the leeway to provide a no-objection to the crossing. Some parties will take it a step further and want a formal agreement in order to address liability and operations and maintenance concerns, though there is typically no legal framework to prevent crossing another fiber optic cable in a country's waters and definitely not in the high seas (international waters). Some jurisdictions will require evidence of an agreement (evidence that the two parties are working together) in order to obtain a seabed easement for the installation and operations of a cable system. An example of such jurisdiction is the State of Alaska. It is noted that this is not a requirement at the federal level through US waters. Regardless of this, it is the cable industry's stance that a simple notification process is the best practice as a starting point. Anything beyond that is based on the discretion or requirements of each party or the local jurisdiction.

For fiber optic cable-to-power cable crossing (and vice versa) it can be standard to form an agreement that covers the liability of each party as well as how to maintain each cable and any potential impact to the other cable. The reason for this is that the repair of a power cable can be very costly, often estimated in the range of $10 - $100 million compared to the repair of a fiber optic cable which can be in the range of $500,000 - $3 million for a repair. In addition, other technical factors need to be considered for these types of crossings such as adding a layer of insulation over the fiber optic cable, mattressing, or other forms of protection at the crossing.

Fiber optic cable-to-pipeline crossings (and vice versa) also occur in areas of oil and gas activity. These can be more complicated to because oil and gas companies usually want a formal agreement to be in place and the potential liabilities associated with a pipeline are different than the other crossings described above. In a lot of cases, crossing an existing pipeline can be unavoidable in certain regions; however, it is generally good practice to avoid such crossings to the extent possible in order to mitigate the complexity of these agreements. If a pipeline is to be crossed, owners typically have very stringent requirements for forming a legally binding agreement.

The ICPC publishes in their Recommendations design criteria for cable crossings such as parallel proximity to cables, as well as recommended crossing angles to ensure that each cable can be maintained in the future without damaging the other cable. The ICPC also publishes an example pipeline crossing agreement for reference.

Crossing undisclosed seabed infrastructure owned or operated by defense agencies such as the Navy in the US can be much more challenging depending on the type, location and use of the infrastructure. In many cases, it is a best practice to consult directly with relevant defense agencies early on in the planning process to see if a planned undersea cable alignment and installation method conflicts with any existing defense infrastructure.

## 4.2 Bathymetry, Geology and Geomorphology

In addition to the factors discussed in the previous section, the effort to design an offshore cable route also includes the evaluation of seabed bathymetry, geology and geomorphology.

Bathymetry is the contour of the seabed, much like topography on land. Contours are assessed at the desktop study (DTS) stage of project planning based on nautical charts (contours and soundings) and publicly available electronic contour information published by hydrographic offices as well as organizations like GEBCO. This information and data can be imported into GIS for the purposes of designing an undersea cable route. The purpose in evaluating bathymetry is to avoid areas of steep slopes, undersea canyons, slumps and slides, and to target appropriate water depths for various aspects of the cable's design. As an example, a cable burial plow has a maximum slope angle that it can install a cable along. In addition, it is best practice to route cables perpendicular to a slope (parallel to the slope angle) because if that slope suffers a slump or slide the debris will flow parallel to the cable and not across it. Additionally, it is best practice to avoid undersea canyons and other such features. Cable types are also preliminarily assessed based on the rugosity of the seabed as well as water depth.

Geology is also assessed first at the DTS stage of project planning. Sediment information is compiled, where available, from publicly available sources which characterize the seabed surface sediment types. If geotechnical core data is available for an area, sediment stratigraphy is also assessed at depth for areas where a cable may be buried. Characterizing the sediment in areas of planned burial is important in order to anticipate the feasibility of cable burial. Often this consists of evaluating areas of exposed bedrock, sub-cropping rock (shallow rock covered by thin sediment layers), sand, clay, mud, as well as areas of boulders which can pose risk to a cable and its installation operations. Assessment of the geology can reveal historic undersea landslide debris or other slump/slide events. In general, soft sandy sediments are preferred for cable burial. Firm sediments such as clay are less ideal as they can act as a hard layer that is not penetrable by a cable plow, therefore not allowing for adequate burial of a cable for its protection. Once in deep water beyond the depth of planned cable burial, seabed surface geology is typically not assessed, only bathymetry, as the cable will be surface laid and not buried.

Geology at a landing site is also assessed based on geologic maps, other data, and during site visits. Favorable geology depends on the construction methods that are to be used at a landing site, but generally avoiding bedrock environments (though HDD can drill through hard rock), surface and subsurface boulders, or very loose saturated soils is best.

Geomorphology refers to the physical features of the seabed and their related geologic structures. Geomorphology can be assessed from bathymetry and geologic data and information. An example of physical features that are to be avoided when designing a cable route include seamounts, undersea canyons, ridges, pockmarks, sand waves, or features indicating an environment of mobile sediment, among others.

Sometimes, unfavorable bathymetry, geology and geomorphology is hard or impossible to avoid. As an example, a trans-Pacific cable route can be 10,000 km or greater (6,213.7 miles) and passes through many various subsea conditions. The likelihood that the cable will transit unfavorable terrain is likely. As a result, cable armor is a standard way of protecting from unfavorable terrain.

Many of the route design criteria that are based on the evaluation of bathymetry, geology and geomorphology are published in ICPC's Recommendations.

### 4.2.1 Marine Route Survey

Once a cable route has been designed in the early project planning phases, that cable route (either power or fiber) is then surveyed during a marine route survey.

The purpose of a marine route survey is to map the seabed and characterize the subsurface of the seabed. These activities provide detailed information on the bathymetry, geology and geomorphology of the seabed in order to determine a final route for the cable that will ensure the feasibility of its protection, operations, and any future maintenance. Determining the final route also includes final engineering of cable types, cable lengths, cable bodies and other technical parameters of the overall design. The marine route survey and final cable information will be handed over to the contracted cable supplier for manufacturing and the installer for installation planning and execution.

A marine route survey uses acoustic equipment to collect information from the seabed. This includes multibeam echo sounder (MBES) equipment which collects bathymetric data, side scan sonar (SSS) which collects seabed imagery which is interpreted by geologist and/or geophysicists for geology and sediment types and surface features or obstructions, as well as sub-bottom profiler (SBP) data which collects subsurface information to help assess burial feasibility. A magnetometer is also used to identify ferrous (metallic) objects on the seabed that can be obstructions for cable installation or pose risk to the cable, as well as to help identify crossing points of other metallic infrastructure. The portion of a marine route survey that utilizes acoustic equipment is also referred to as the geophysical survey.

A geotechnical survey is also carried out, usually from the same geophysical survey vessel. The geotechnical investigation includes collecting core samples and/or cone penetration tests (CPTs) which help geologists characterize the seabed surface and subsurface sediment, which aides in determining the feasibility of cable burial. The geotechnical data also helps "ground-truth" the geophysical interpretation of the side scan sonar data.

Marine route survey activities are usually conducted from a main vessel starting from 15 m (49.2 ft) water depth (safe operating limit of larger vessels) and extending to the full depth of a cable route. Beyond the limit of cable burial, only MBES is collected. Smaller vessels are utilized for surveying water depths shallower than 15 m (49.2 ft) and divers are utilized for survey operations through the surf zone. Land surveys are also carried out on land at each landing site using traditional land survey techniques.

The ICPC publishes a Recommendation on the minimum standards for a marine route survey to help provide guidance to the industry.

### 4.3 Trends in Siting Cables

The offshore cable route is largely driven by where the cable will land onshore. In many cases, the offshore route is a factor of the specific landing sites selected for a project. While the offshore route has to be feasible, the landings are often evaluated first based on a cable owner/developer's larger network requirements. For undersea power cables, this may be strictly driven by where on land a cable can be integrated into the power grid or such new land-based infrastructure can be built. For undersea fiber optic cables, there has been a trend in the recent years for these cables to connect data centers in the various locations where cables come to shore in a country. One cable owner may have data centers in one location, which will drive where they want to land undersea cables, while another cable owner may want to route data traffic to another location where that particular company has data centers. This determination may be driven by the location company-owned data centers, third party data centers, or the location of customers. As a result, new undersea cables often have relatively strict requirements for where the cable should land in order to meet the larger objectives of that cable system.

One additional trend that has introduced variability in where cables land, particularly for fiber optic cables, is that companies are seeking route diversity, and therefore landing site diversity.

Large network operators develop what are called "mesh networks" which is a web of fiber routes both on land and offshore to ensure that if one fiber route is damaged, data traffic can be offloaded on other routes. This is a fundamental strategy in building and operating a resilient network. But as more cables are routed or come to shore in close proximity to one another, as is often the case when landing site infrastructure has been built out in a particular location, there develops a need to start to diversify digital infrastructure to support cable resilience. Major builders of undersea fiber optic cable systems have started over the last few years to plan for future, diverse landing sites. As an example, on the east coast of the US this can include landing cables in states where cables have not traditionally come to shore before. This diversity will then drive new offshore route alignments. In the case of the west coast of the US, as an example, this will include coastal cities where cables have never landed simply as a means to avoid congestion at other existing landing sites.

Perhaps not applicable in North America, but geopolitical factors also influence where companies build undersea cables. Staying out of certain country's waters, as well as the need for network diversity in general, are trends driving undersea fiber optic cable routes in locations such as Asia and Southeast Asia, as well as the South Pacific, among other places.

A more detailed review of onshore landing site selection is presented in Section 5.0 of this report.

### 4.4 Risks

There are many risks to the offshore placement of undersea cables, both power and fiber. Many of these risks are similar between the two types of cables and are based on the physical and technical parameters of offshore routing. Some of these risks include the following:

- Too long of a cable route equating to increased cost
- Steep slopes where burial installation is not feasible or there is a risk of suspensions in the installed cable
- Hard bottom (rock) which poses a risk for cable abrasion and prevents cable burial where burial is required
- Inadequate route options to avoid charted areas, protected areas, or other features that will add project or permitting complexity
- Congestion of existing seabed infrastructure
- Fishing and vessel anchoring
- Lack of coordination or cooperation from other seabed users to deconflict spatial separation or crossing issues
- Multiple offshore jurisdictions (country's waters) adding to increased project complexity
- Geopolitical issues

In the US, state and federal agencies get involved through the permitting process for new undersea cable projects, but they do not have scrutinizing oversight over the offshore route selection unless a cable route crosses an MPA or other similar area. Though factors that may impact project complexity are the presence or migration of marine mammals, impacts to protected species, or other such issues that may have associated operational requirements for vessel related operations. These are largely evaluated by NOAA and NMFS in the US.

## 4.5 Permitting Considerations

It is standard that undersea cable projects in the US are principally permitted activities and are categorically excluded under the National Environmental Policy Act (NEPA) and will receive a Nationwide Permit 57 (used to be 12) for the construction of an undersea cable. Due to the application of a Nationwide Permit 57, the USACE is typically the lead federal agency though other agencies like NOAA and NMFS will have jurisdiction over elements of the project concerning impacts to marine habitat and protected species in federal waters.

US states have jurisdiction over state waters where a seabed easement is usually the mechanism for granting space on the seabed for the installation of an undersea cable within the 3 nm limit. Each state has their own process to verify and grant a seabed easement, but generally states do not get involved in the precise placement of an offshore route unless there is a conflict with other seabed users/land owners or other existing easements or it is determined there is some environmental impact with the specific routing. Easements are usually first granted through an early entry authorization which allows the construction of the cable and then the final easement is determined based on the as-laid positions of the cable post-installation. Each state has their own fee structure for a seabed easement which may consist only of a one-time payment or can consist of a recurring annual payment. It is common that easements are granted for the operational life of the cable, but once the cable is decommissioned, removal of the cable is required. There is a growing trend towards the removal of cables at decommissioning, which is a requirement that already exists in many states like California, Oregon, Alaska, Rhode Island, etc.

### 4.5.1 Hard Bottom Habit

When siting an undersea cable along the seabed, it is best practice to identify and select as favorable of conditions as possible. But sometimes the constraints of routing a cable (i.e. the landing site location, the start and end point of a cable, etc.) result in that cable not being able to avoid all of the factors that have been discussed in this section. Additionally, the more congested an area is with other cables or offshore infrastructure, it can be more difficult to adhere to the best practices for cable siting.

As discussed in this section, it is a best practice to avoid areas of hard rock where seabed habitat can exist, and the marine route survey specifically characterizes the sediment (including rock) on the seabed so that appropriate routing decisions can be made. Hard bottom is not only a potential risk to a cable, but generally most jurisdictions want cables to avoid areas of sensitive habitat (which can exist on hard rock) to the greatest extent possible. However, as mentioned, sometimes it can be difficult to impossible to avoid all hard bottom areas.

Depending on how developed a jurisdiction's oversight is on cable routing, the crossing of hard bottom habitat is handled in a variety of ways. Some jurisdictions do not have requirements to avoid hard bottom areas, some jurisdictions manage these areas only if there is demonstrated habitat on the outcropping rock, some jurisdictions will not allow the crossing of hard bottom areas unless it is proven there is no alternative and the cable cannot be relocated elsewhere, and some jurisdictions will allow the crossing of these areas but require a monetary compensation as a result.

On the west coast of the US, there is a variety of ways each state handles this, but most notable is probably California where a cable developer pays the state (California Coastal Commission) a monetary compensation for the crossing of hard bottom where it cannot be avoided. Based on past projects this compensation funds the U.C. Davis Wildlife Health Center's California Lost Fishing Gear Recovery Project or other conservation programs. As of 2019, the amount of the hard bottom mitigation fee is calculated by applying a 3:1 mitigation ratio to the total square footage of impacted hard bottom and multiplying that square footage by a compensation rate of $14.30 per square foot (RTI Infrastructure, Inc., 2019).

Where mitigation fees are collected for the use of a project or conservation program, it is important that a state incorporates a mechanism for accountability to that program to ensure the funds are used for a productive purpose that can be demonstrated to cable owners.

### 4.5.2 Cable Protection Corridors

Some countries such as Australia (off Sydney) have implemented cable protection corridors that are meant to protect undersea cables by prohibiting activities in the corridor that pose risk to a cable such as fishing, anchoring, and dredging. Discretionary cable protection zones offer protection should a developer choose to install a cable in the zone. Mandatory cable protection zones require that new undersea cables be installed in the zone. In the case of Australia, the protection zone is discretionary, but in the case of landings in New Zealand, the zone is mandatory.

States with cable protection zones enforce them with air and sea patrols and infringement penalties and where zones exist, cable owners tend to favor discretionary zones rather than mandatory zones. While cable protection corridors offer protection for cables, they also promote clustering and congestion of cables which adds to the difficulty of maintaining and repairing this infrastructure as well as adding to the risk that a single human or natural event could damage multiple cables.

At a global level, cable protection corridors are the exception rather than the norm and the cable industry prefers to maintain freedom in the selection of an offshore cable route.

If a state or country is to consider implementing cable protection corridors, it would be important for a regulator to understand from the cable industry what the main drivers are in their jurisdiction for cable placement and landing site selection, including the requirements for current and future diversity. Undersea cables are economic enablers that extend beyond just the cable itself. They also enhance terrestrial fiber/power routes and networks and data center development. Coordination and balance of offshore use and placement of cables relative to other regulatory initiatives, requirements and objectives is important.

## 5.0 Onshore Landing Site Selection

This report has discussed the interdependencies between the offshore route design of undersea cables, the selection of the landing site, and the terrestrial factors that drive the selection of a landing site. As mentioned in the previous section, it is often the terrestrial factors that first drive the selection of a landing site such as substation locations or grid connections for power cables or backhaul fiber availability and data center locations for fiber optic cables. The landing site then dictates the required offshore route alignment for an undersea cable, which must be vetted against the topics listed in Section 4.0 of this report.

This section explores the factors that go into landing site selection. While this section is written mostly from the perspective of undersea fiber optic cables, much of the factors also pertain to undersea power cables and where differences exist, they are pointed out under each topic.

## 5.1 Landing Site

A landing site generally refers to the location where an undersea cable comes to shore where it then transitions to terrestrial cable infrastructure. Whether it be an undersea power cable or an undersea fiber optic cable, the cable must be installed across a beach to a point onshore where the cable is anchored within a buried utility vault that is accessible at-grade. This vault, commonly referred to as a beach manhole (BMH), beach vault or transition vault, is the location where a cable is usually spliced/jointed to a land cable that extends further inland to either a substation or power facility or a cable landing station (CLS), as is the case for fiber optic cables. While there can be exceptions to this, the BMH is the transition from wet plant to dry plant.

Landing sites are selected based on a cable systems overall design. In the case of a fiber optic cable, a landing site may be selected based on where data traffic would ultimately terminate, like at a data center. A landing site may be selected because a cable owner already has existing landing site infrastructure at a particular location or is leasing existing infrastructure from another owner. Or a landing site could be selected because it offers diversity away from a cable owner’s other undersea infrastructure adding to the resilience of their overall network. Regardless of a company’s specific requirements, the selection of a landing site goes beyond simply the design of the undersea cable and includes factors like available space and power at existing CLS sites, feasibility to construct a new CLS including availability of land and suitable commercial power from the grid, availability of backhaul fiber, locations of data centers or PoPs, as well as the overall permitting feasibility for construction in a city, county and state jurisdiction.

Today, the trend is to develop a landing site to accept multiple cables. There is tremendous demand for undersea fiber optic cables globally (broadband demand) so developing sites suitable for several cables is an approach being taken in California, Oregon, Alaska, and in states on the east coast, among other locations around the world. Additionally, landing sites for undersea power cables such as export cables from offshore renewable energy sites, are being contemplated and developed for multiple cables. There are synergies in developing one landing site that can serve multiple needs, so a natural aggregation of export power cables from multiple offshore sites is a trend that developers lean towards. As a result, it should not be surprising for any state agency to see plans to build out a landing for multiple cables planned to be constructed over time.

The following sections go into each of these factors that govern landing site selection, as they would be evaluated during an actual site selection process. The evaluation starts at a desktop study (DTS) phase of project planning, or perhaps earlier than that. Once a landing site has been identified, as well as alternative options, a project team will visit the site(s) to vet the technical feasibility in-person. At this time, it is also common to meet with local agencies to discuss permitting processes and overall acceptance of the project at a local level. This effort may coincide with a broader permit feasibility study (PFS) in which the project team also engages state and federal agencies about the feasibility of the project.

## 5.2 Beach Manhole Placement

A BMH is one of the first physical pieces of infrastructure that is sited when evaluating an undersea cable landing location. In a way, it is the “anchor” for a landing site, and everything else is based around this location. The BMH needs to be close to shore to make the seaward construction feasible and positioned where a fronthaul route can extend inland. The BMH also needs to be outside of areas of coastal erosion and ideally sea level rise, though the BMH itself, as well as the cable(s) within it can stand to get wet.

Dimensions for BMH’s vary, but generally a rectangular concrete vault that is approximately 10 ft x 6.5 ft (3 m x 2m) is a standard starting point. The vault may have a rectangular or circular vault lid as an entry point. All BMH’s are buried with the surface at or just below grade. Once a BMH is installed, there is very rarely ever a need to go into the vault for maintenance. Most BMH’s utilized for undersea cables go completely unnoticed by most people and the general public would have no idea that an undersea cable comes to shore.

The figure below shows examples of a BMH lid at grade at the seaward terminus of a beach access road, as well as vault placement at the time of construction.

A beach manhole lid cover at an undersea fiber optic cable landing in Rhode Island (credit: Wopschall Consulting, LLC)

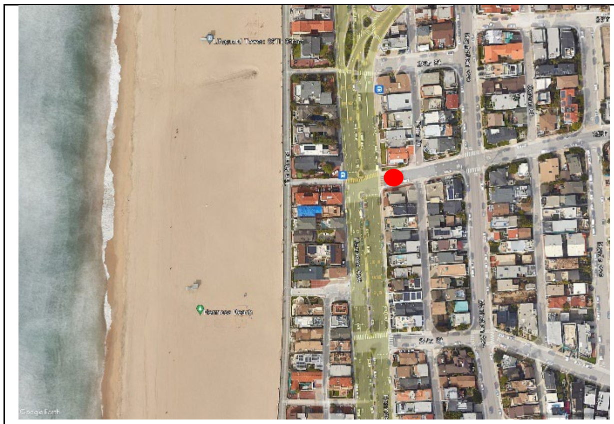
Placement of a BMH at an undersea fiber optic cable landing in Alaska (credit: AP&T)

*Figure 9: Undersea fiber optic cable beach manholes*

Standard locations for BMH placement can be at the landward terminus of a beach, at the seaward terminus of a road, in a parking lot located on the coast such as a beach access parking lot or at a park, or sometimes BMH’s are placed in parks or on private property. An important factor in siting a BMH is assessing land ownership and the feasibility to obtain permits, approvals, and easements for the project's construction. Because of the importance of siting a BMH location, it is best practice to engage landowners as early as possible in the planning processes of an undersea cable project.

Risks to BMH placement typically involve lack of engagement with local stakeholders, landowners and the public. Constructing a landing site and BMH is a temporary activity with infrastructure that will be completely buried and is very rarely needed to be maintained. Most landing site infrastructure including a BMH go "untouched" for years after installation. But failure to engage the public about the project, particularly where a BMH is to be placed in areas of public recreation, businesses or residential areas, can lead to complication and ill-will towards the project developer. Most local cities will want to see some form of public engagement before and during construction with project information posted including contact information.

The figure below shows some existing BMH locations in California and Oregon and illustrates the types of locations BMH's are typically placed.



Existing Hermosa Beach, CA BMH location (BMH in red)

Corresponding street level view of the BMH vault lid in Hermosa Beach, CA (BMH in red)

Existing Morro Bay, CA BMH locations at beach access parking lot

Corresponding street level view of two BMHs at Morro Bay, CA

Florence, Or BMH location with direct street access at public beach parking lot adjacent to homes and businesses (BMH in red)

Corresponding street view of the Florence, Or BMH location at a public beach parking lot

Warrenton, Or BMH location at seaward terminus of beach access road (BMH in red)

Rockaway Beach, Or with BMH location sited at seaward terminus of road adjacent to parking lot, businesses and residents

*Figure 10: Examples of Existing BMH Locations in California and Oregon*

The above BMH locations are illustrated approximately based on publicly available information and highlight the variability of suitable sites that are standard for undersea cable construction. While these sites are for undersea fiber optic cables, much of the same evaluation criteria and types of locations are suitable and commonly selected for undersea power cables as well.

### 5.3 Fronthaul

For an undersea fiber optic cable, fronthaul is a term used to refer to the route from the BMH to a CLS. Oftentimes the route is merely dictated by the location of a BMH and a CLS, though it is important to assess how a fronthaul may be feasibly routed on land to connect these two locations.

A fronthaul route typically involves constructing buried conduit or ducts, each being approximately 4 – 6 inches in diameter (10.2 – 15.2 cm) depending on the application. Each conduit can then be sub-ducted for various purposes such as installing multiple cables within one duct. Ducts are usually made out of PVC. A buried fronthaul route is preferable compared to an aerial route on poles because it is better protected and less susceptible to damage from natural or man-made events. Constructing a fronthaul is no different than most buried utility work common to see on city streets, and can include plowing, trenching, or directional drilling to install conduit. The exact method of construction is determined by the type of sediment and/or rock the route encounters, whether the route is within a paved area of a street or off on a shoulder or in green space, and whether any sensitive areas are encountered such as streams or rivers. Directionally boring for the installation of conduit under streams, wetlands, or rivers is the preferred method to mitigate impacts to these areas.

In most standard cable system designs for long-haul repeatered systems, a fronthaul route will run fiber, power, and a ground cable from the BMH to the CLS. As discussed in this report, there are variations to this design, but this is most common.

Fronthaul conduits are usually installed 36 – 48 inches (91.4 – 121.9 cm) deep and may be concrete capped to protect the conduits and their cables from external aggression such as land-based construction activities (i.e. a backhoe inadvertently digging into the fronthaul route).

In vetting a possible fronthaul route, it is best to meet with the local city or municipality to understand their permitting and easement requirements for accessing existing utility easements, constructing along new easements, as well as obtaining as-built information for existing utilities to deconflict planned routes and construction.

The same "fronthaul" terminology does not necessarily apply to undersea power cables; however, once an undersea power cable reaches a BMH, it can be a standard design to anchor the power cable in the vault and joint it to a land cable in order to run power transmission inland to a substation or other facility that will connect to the greater power grid. It is preferred that such a route be buried and constructed in a similar manner as described for an undersea fiber optic cable; however, the conduit sizes may be larger. Inland, terrestrial power can also be routed aerially from a BMH.

In some regions, and based on standard construction methods for existing utilities, it may be feasible to attached fronthaul cable(s) (power or fiber) to existing poles and run these cables aerially back to a CLS or substation. In this case, a fronthaul route may be buried from the BMH to the nearest existing or new riser pole and then will be attached along a pole line before reaching a final destination. However, in most cases it is not preferred to run cable aerially because it is more exposed and prone to damage from human activity and natural/environmental events.

### 5.4 Cable Landing Station

If an existing CLS is to be utilized for a new undersea fiber optic cable, or if an existing substation or power facility is to be used for an undersea power cable, this will drive the general location where a BMH should be located. In instances where a new facility will be constructed, cable owners may have an idea of what city or area they want to develop a new CLS or power facility based on broader factors like the availability of terrestrial fiber or connectivity to the power grid. But from a process perspective, many times a BMH will be selected first to ensure a feasible location to bring a cable to shore, and then a project team will evaluate where they can build a new facility. This section primarily discusses the case of an undersea fiber optic cable and the siting of a CLS.

A CLS is a telecommunications facility that is typically located no more than 10 km (6.2 miles) from a BMH. A CLS building can accommodate one or more undersea cable depending on its purpose and design. The CLS houses the equipment to operate and monitor the undersea fiber optic cable system including PFE (if powered), NMS, SLTE, among other equipment types. Transmission equipment such as DWDM equipment is also placed in the CLS for connection to backhaul fiber to bring data traffic further inland to data center or PoP destinations.

These facilities will also have ancillary equipment that helps support the facility including backup batteries, generators, fire detection and suppression equipment, temperature and humidity sensors, and security equipment. There may also be office space, conference rooms, and restrooms for staff working at the facility. A CLS property is often fenced with controlled entrance(s) and access. The building or its façade may have to adhere to local building requirements, among other local building requirements to account for seismicity or other natural factors.

A CLS property can be half to one acre in size, minimum, for older systems. For older systems, the building itself may be around 3,000 to 5,000 square feet (278.7 – 464.5 square meters). Generally, these would be minimum parameters for existing older systems though there is a lot of variability to this depending on how many cable systems go to a particular CLS, among other factors. Recent undersea fiber optic cable systems, as well as future systems, are now being developed with more fiber strands in the cable. There is also a trend to future-proof landings by ensuring it is feasible to bring multiple cables to one landing, built out over time. More cables and more fiber require larger facilities to house the equipment necessary for modern systems. With more equipment, the power draw at a CLS is more than it has been historically. For reference, a new CLS that is intended to serve two or three trans-oceanic undersea fiber optic cables may be on the order of 15,000 to 25,000 square feet (1,393.5 – 2,322.6 square meters) or more with a 2 – 4 MW power requirement. Older CLS' may only require less than 1 MW. These are only general figures to be used for reference.

CLS' are usually sited in light industrial zoned areas, but these facilities have been built in all types of zoning locations including also commercial and residential areas.

In some cases, depending on overall cable system design and distances to data centers, an undersea fiber optic cable may be spliced to a land cable in the BMH which extends all the way to a data center which will then serve the purpose of a CLS. In Oregon, this is done by some cables in the Pacific City vicinity with fiber running directly to data centers in Hillsboro. Another location in the world where this is typically occurring is in Singapore where the distance from a BMH to a data center is relatively short. This is also driven by demand for data center-to-data center connectivity. In these cases, and for powered/repeatered undersea fiber optic cables, the PFE may be housed in a separate "PFE hut" close to the landing, which removes the need to run power the entire distance from the BMH to the data center. Overall, the design of running fiber to a data center is not a standard method and is project/location dependent, also based on the preferences and requirements of the cable owner.

### 5.4.1 Environmental Factors

When siting a CLS, many environmental factors are evaluated to determine a feasible location for these types of facilities. Undersea fiber optic cable systems and their cable landing stations are viewed as critical infrastructure. Fiber optic networks are measured by their up-time and any downtime due to damages to cables or failure of equipment can be impactful to a cable owner's business, the services they provide, and even to a region's connectivity including broadband service to homes and businesses. Many small or developing nations rely on undersea fiber optic cables to obtain international IP transit to bring internet service to its residents. As a result, ensuring protection of cables and protection of CLS facilities is critical.

To mitigate environmental risks that could pose a threat to a CLS and the equipment inside, CLS sites are assessed for flood zones, tsunami inundation zones, wetlands impacts, sea level rise, and landslides, among other factors. It is best practice to site a CLS outside of these risks. As a result, sites at a higher elevation above sea level are most suitable. The elevation doesn't need to be extreme and a CLS doesn't need to be on a hillside. Sometimes only a 5 – 10 m (16.4 – 32.8 ft) elevation above sea level is adequate to remain outside of these environmental risks.

## 5.5 Backhaul

Backhaul is a consideration mainly for undersea fiber optic cable systems and refers to fiber that connects from a CLS to a PoP or data center. This can also apply to any end point or interconnect point in a network where traffic carried on an undersea cable is routed to. Backhaul is important because it is the terrestrial fiber that carries undersea data traffic to its ultimate destination and beyond. If traffic simply terminated in a CLS, there is virtually nothing anyone can do with it. It has to extent further through a terrestrial network.

As a result, landing points and their corresponding CLS locations are selected in part by where terrestrial backhaul fiber is located or where it can be constructed. Often, however, backhaul routes are very long, easily exceeding 100 km (62 miles). Construction of new backhaul routes that terminate at an existing interconnect point for onward connectivity to a PoP or data center can be challenging and costly. As a result, preference is always to utilize existing fiber routes, where available.

In Oregon, as an example, undersea fiber optic cable traffic would typically be routed to a data center in Hillsboro or further east in Oregon, northward to a PoP like the Westin Building in Seattle, WA, southward to a data center in the Bay Area, or to a data center or PoP in Los Angeles. The desired destination is dependent on a cable owners' network, the type of traffic their system carries, and where their existing traffic and transmission equipment congregates, among other factors.

An additional consideration is the large amounts of capacity that undersea fiber optic cable systems are capable of. In order to carry traffic terrestrially, owners prefer to have access to backhaul fibers (dark fiber) that they can use in their entirety to handle the amounts of traffic being transmitted across a network. Sometimes backhaul routes have aging fiber or limited or no available dark fiber which can impact the design for an overall network. Further to this, cable system owners have varying degrees of backhaul requirements. For example, some backhaul routes are more susceptible to damage than others from natural or human events like landslides or construction activities. As a result, having redundant backhaul routes may be desired for undersea cable systems to connect to. Having two separate backhaul routes can be difficult, especially through remote coastal areas.

There is not a single consolidated resource that maps out where terrestrial fiber routes are located. There are some public websites and paid services to get after this information, but often times backhaul routes are assessed through direct relationships with the companies that own and/or operate the terrestrial fiber. Sometimes fiber providers will provide maps or diagrams of their network, but there is generally a trend towards keeping this information, particularly for strategic infrastructure, confidential and not accessible in the public domain.

## 5.6 PoPs and Data Centers

Undersea fiber optic cable systems will transmit data traffic along a backhaul route that typically terminates at a PoP or data center. In the last ten years, there has been a trend to connect data centers globally and steer away from routing traffic to traditional PoPs or carrier hotels, though there is some variability to this depending on the requirements of an undersea cable developer, their network and the region where a cable system is to be constructed.

Just as other factors are interdependent and not mutually exclusive for the siting of cables and landings, the location of data centers or PoPs drive the requirements for the backhaul route, i.e. to connect the CLS to these locations. Furthermore, the requirements to go to a particular end location is driven by a company's network, their customers, where they house their network equipment, and other factors like maintaining network diversity as well as redundancy. Generally, however, a cable developer will know exactly where they want their undersea cable traffic to end terrestrially which will drive a lot of the other elements outlined in this report.

Additionally, data centers may be owned by the same company developing an undersea cable system, or that developer may lease space with one or more third party data center operators. As mentioned before, common locations for undersea cables to connect to along the west coast of the US include the Westin Building (carrier hotel) in Seattle, WA, data centers in Hillsboro or further east in Oregon, data centers in the San Francisco Bay area, and Los Angeles at the carrier hotel and data center(s) location at 1 Wilshire Blvd. As an example, it is estimated that one third of all internet traffic from the US to Asia passes through the building at 1 Wilshire Blvd in Los Angeles, representing a major interconnect point for IP transit and the reason so many trans-Pacific undersea fiber optic cables land in the Los Angeles area and elsewhere in California – they generally all go to 1 Wilshire (Fortune.com, accessed Sept. 2022)

## 5.7 Landing Site Construction Methods

Constructing a landing site first and foremost includes placing the BMH and installing an undersea cable across a beach to the BMH. While landing site construction also includes the fronthaul build, this section of the report is primarily focused on beach and BMH construction.

BMH's are typically precast concrete vaults that are placed on site using an excavator/backhoe to dig out, lift, place, and backfill the vault site so that the vault lid is at or slightly below grade.

There are two primary methods for installing an undersea cable across a beach or landing site to a BMH. One method is direct trenching where excavation equipment is used to dig a trench across the beach to the BMH. The trench may be shored up in sandy conditions and is typically a minimum of 1 m (3.28 ft) deep below the surface of the beach but usually no more than 2 m (6.56 ft). The other method is utilizing horizontal directional drilling (HDD) to drill seaward from the BMH to install a seaward conduit to a point offshore in the ocean. Where the HDD conduit "daylights" or punches out in the ocean, an undersea cable is installed in this conduit and is pulled back to the BMH.

Conventional land-based trenching is generally the traditional method of landing site / beach construction and is still used around the world including in some US states like Alaska. This method is used for both undersea fiber optic cables and undersea power cables. While an undersea cable can be installed directly in the trench, it is also common that the cable is further protected using articulated pipe, or the cable is installed in a conduit that is placed in the trench. These methods add further protection to the cable beyond just burial of the cable. Excavation will typically occur during a low tide in order to extend the buried section of cable to the lowest point accessible by land-based equipment.

HDD construction directionally drills a borehole along a designed profile out to a point in the ocean. Typically, an HDD conduit is installed from the BMH seaward for a distance of 1 km (0.62 miles). This distance is dictated by the water depths offshore from a landing. It is advantageous to have the HDD conduit punchout from the seabed in a water depth around 10 m (32.8 ft). This water depth is accessible by divers to assist with installation of a cable into the HDD conduit and is close to the shallow water operating limit of a cable installation vessel. Depending on a target water depth for HDD punchout, the length of the HDD can change, but usually these bores are no longer than about 1.5 km which is near the distance limit of this construction method. HDD construction is the standard method of landing site construction in most US states and elsewhere in the world, though at a global level trench excavation is more common.

In order to adequately assess subsurface conditions and plan a profile for HDD construction, geotechnical/geophysical investigations are often required at or along the beach in order to characterize the sediment layers that are to be anticipated during drilling. Geotechnical investigations can include hollow stem auger boring at a BMH location and at points along the beach. Geophysical/remote sensing techniques can also be used from the BMH and along the beach. The goal of characterizing the subsurface conditions is to de-risk the construction/HDD boring.

There are benefits and challenges for each landing site construction method. The table below presents the benefits and challenges of each method, direct trenching and HDD.

*Table 2: Landing Site Construction Methods – Benefits and Challenges*

| Landing Site Construction Method | Benefits | Challenges |
|---|---|---|
| Direct Trenching | • Cost-effective construction method<br>• Construction equipment is common and easily accessible | • Limitation on achievable burial depth<br>• Can impact environmentally sensitive areas (or add design |

| | | |
|---|---|---|
| | • Low risk construction method from an environmental impact perspective | challenges to avoid such areas)<br>• Diver burial is required through intertidal zone |
| HDD | • Drilling can reach deeper depths, offering better cable protection from external aggression, beach and shallow water erosion, etc.<br>• Drilling reaches further offshore through the intertidal zone, providing better cable protection<br>• Mitigates the risk of impacting environmentally sensitive areas on the beach and offshore<br>• Can accommodate more challenging landing site conditions/terrain such as cliffs, variable geology, etc.<br>• Avoids having to trench a beach | • Higher cost method of construction<br>• Equipment/personnel may not be available in certain regions/countries<br>• Risk of frac-out exists (release of drilling fluid due to excessive down-hole pressure or presence of a seepage pathway)<br>• Temporary noise impacts to neighboring residents/businesses<br>• Sites to be assessed for sediment/land stability during construction |

Based on the above table, it is noted that frac-outs from HDD are relatively common and do not prevent drilling a successful directional bore. Having said that, characterization of the subsurface conditions that an HDD are anticipated to drill through is important in order to mitigate the risk of a frac-out. In the event of a frac-out, or in the event the HDD drill encounters conditions that it cannot pass through, the drill is typically backed out of those conditions and redrilled in a different alignment.

Different diameter HDD bores can be drilled for the installation of both undersea fiber optic cables and undersea power cables. An HDD conduit for an undersea fiber optic cable is usually about 4 inches (10.16 cm) in diameter. Conduits for power cables can be a minimum of 8 inches (20.3 cm) or more in diameter and is determined by the diameter of the power cable, which varies based no the transmission capacity of the cable.

## 5.8 Risks

Many of the risks or evaluation factors associated with landing site selection have been outlined in this section but generally include finding a site where land can be acquired or land use is permitted, sites are outside of environmental risk factors, sites are permittable, backhaul connectivity exists, and the public is in general acceptance of the project. These factors are evaluated as early as possible in the planning stages of a project in order to de-risk the project from a developer's perspective.

Permitting agencies are typically also concerned over the same risk factors with interest that undersea cable landing infrastructure is sited appropriately. For both cable developers and permitting agencies, early discussion and coordination over a project ensures that these risks are looked out for, addressed, and mitigated to the greatest extent possible.

As mentioned in this section, there is a trend that new cable landings be assessed for multiple future cables. There is also a trend to re-use existing landing site infrastructure and cable landing station facilities where older cables are being decommissioned. As a result, where cables have landed before, there will always generally be a trend to try and land cables at the same locations except for where diversity is a larger governing factor in cable design.

### 5.9 Permitting Considerations

Based on experience, it has been found that inter-agency coordination regarding the overall permitting of an undersea cable from the offshore placement to the landing site can be very beneficial for a cable developer and permitting agencies. Joint agency pre-application meetings are a useful mechanism for this, though often the consultation approach with various local, county, state and federal agencies is siloed with lack of coordination. This can work in jurisdictions that have well established mechanisms to permit undersea cables, but generally the more coordination among all stakeholders the better.

In the process of evaluating permitting feasibility of a landing site, it is also useful to a cable developer to have local engagement with agencies regarding a public engagement approach for the project. There is a trend for the public to want to know about and understand everything going on in a local community and more often than not a local city or city council will have the best understanding of how local residents will accept a project.

From a permitting perspective, it is usually not permissible for a cable developer to construct multiple seaward bores whether by direct trenching or HDD to future-proof a cable landing. Constructing a seaward bore needs to have a purpose for a named project. However, considering the trend to develop landing sites for multiple cables, to reduce any risks or impacts (technical, environmental, social) of multiple iterations of landing site construction, it is worth considering how much landing site infrastructure can be permissible given an overall master buildout plan for a site. There is a trend in California to buildout multiple seaward bores at a landing location by naming generic cable projects that are to serve the trans-Pacific axis that will be built out over a several year period of time. It is generally accepted that if a seaward bore is built out for an undersea fiber optic cable system, it will be utilized. The risk that it sits vacant is very low given the demand for fiber optic cable systems globally.

Given the trend that new cables will also target existing landings based on the presence of existing landing site infrastructure and cable landing stations that could be available for use or re-use, it is worth noting that the permitting regime that may have existed 20 + years ago could be different than the permitting regime that exists today and concerns over the environment, coastal erosion, water quality and other factors tend to change over time. While this may be the case, a state or country should have interest in the sustainable re-use of existing infrastructure rather than abandoning these assets, where there is an acceptable and permittable way forward for new cables to come into existing landings.

# 6.0 Cable Installation

Undersea cables are installed by purpose-built or modified vessels that are capable of storing, handling, laying and burying undersea fiber optic cables and power cables. There are many dedicated cable vessels operating around the world. A list of most of the major cable installation vessels worldwide is provided on ICPC's website, for reference [https://www.iscpc.org/information/cableships-of-the-world].

Some of the world's largest cable vessels are purpose-built for fiber optic cables and can store approximately ten thousand (10,000) kilometers (6,213.7 miles) of cable and are used for the installation of the longest trans-oceanic fiber optic cable systems around the world.

For both undersea fiber optic cables and power cables, dedicated cable vessels are also supported by smaller vessels and barges for shallow water cable installations, among other marine resources that support installation activities.

Most dedicated cable vessels have burial tools which typically include a cable plow. For fiber optic cables, burial plows are built to bury cables to around 1 – 3 m (3.3 – 9.8 ft) depth below the surface of the seabed. Cables buried with a plow are simultaneously laid and buried at the same time with the plow being towed behind a vessel. Some vessels are also equipped with remotely operated vehicles (ROV) that can bury cables. An ROV is used as a post-lay burial tool which buries cables after a cable is laid on the surface of the seabed. Post-lay burial can occur in areas where a cable plow cannot safely operate such as for short sections of burial or near crossings of other infrastructure.

In shallower water applications, and depending on seabed sediment types, other plow burial tools are used such as jet- or vibra- plows that use water or vibration, respectively, to assist the plow through the sediment to bury the cable.

## 6.1 Vessels

The figures below show some indicative undersea cable installation vessels.

| | |
|---|---|
|  |  |
| Dedicated fiber optic cable installation vessel (source: submarinenetworks.com) | Modified power cable installation barge (source: offshorewind.biz) |

| | |
|---|---|
| <br>Dedicated fiber optic cable installation vessel (source: iscpc.org/information/cableships-of-the-world) | <br>Dedicated power cable installation vessel (source: thenavalarch.com) |

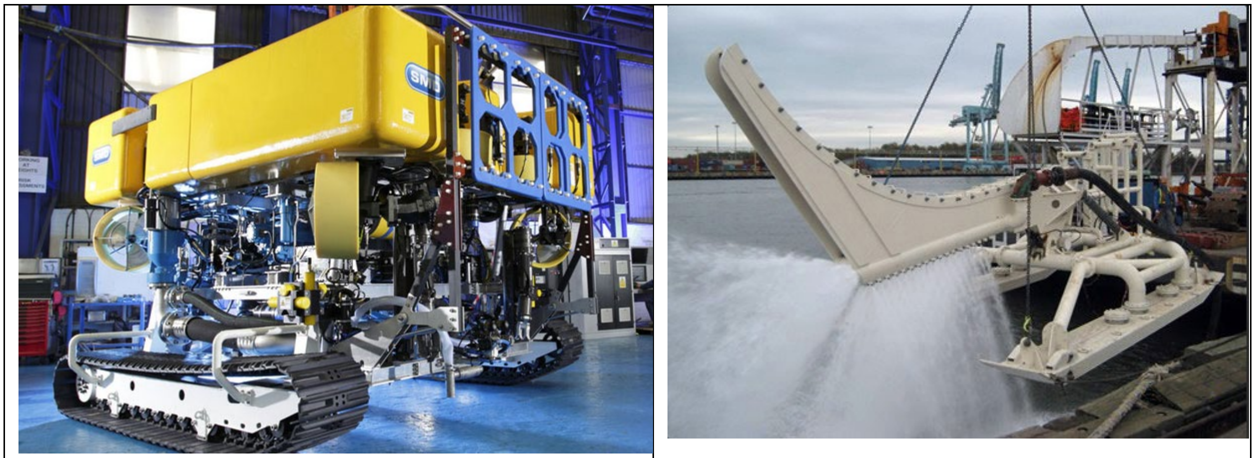
*Figure 11: Examples of Undersea Cable Installation Vessels*

Cable vessels can be purpose-built or modified vessels and/or barges.

### 6.2 Burial and Burial Tools

The figures below show some indicative undersea cable burial tools

| | |
|---|---|
| <br>Fiber optic cable plow (source: submarinenetworks.com) | <br>Power cable plow (source: subsea-rov.com) |



Post-lay burial ROV

Submarine cable jet-plow tool (source: eta-ltd.com)

. *Figure 12: Examples of Undersea Cable Burial Tools*

The methods and tools used for burying fiber optic cables and power cables are much the same, but are specifically constructed based on the diameter of the cable.

## 6.3 Permitting Considerations

Vessel-based installations and burial of cables are the most common and necessary means to install an undersea cable. From a permitting perspective, these activities are typically viewed as benign to the environment with only a temporary impact to the seabed over a relatively small footprint. It is also common that permitting agencies prefer cable infrastructure to be buried in order to mitigate the risks of other seabed infrastructure or activities impacting cables and vice versa.

For undersea cables, it is noted that the depth of cable burial and extent of cable burial is evaluated and dictated by the actual threats towards that cable. Consensus on the best practices for cable installation, burial and protection have been developed globally through decades of installing and maintaining cables. However, there is a general trend towards sector creep, primarily initiated by the offshore renewable energy industry which has adopted, in part, installation practices derived from the oil and gas industry. As a result, even in the US there is a trend that some permitting agencies or regulators are requiring cable installations to adhere to requirements that are more stringent or excessive than those necessary for undersea fiber optic cables and power cables. This could include requirements for deeper burial, as an example.

Sector creep is not just occurring in the US but is a very pertinent trend in Europe and in other parts of the world. As a result, cable developers and the industry at large do make attempts to educate regulators on these best practices and the reasons for them, as well as the concept that not all offshore infrastructure is the same. Educational outreach towards regulators can be a recurring activity due to turnover of agency staff.

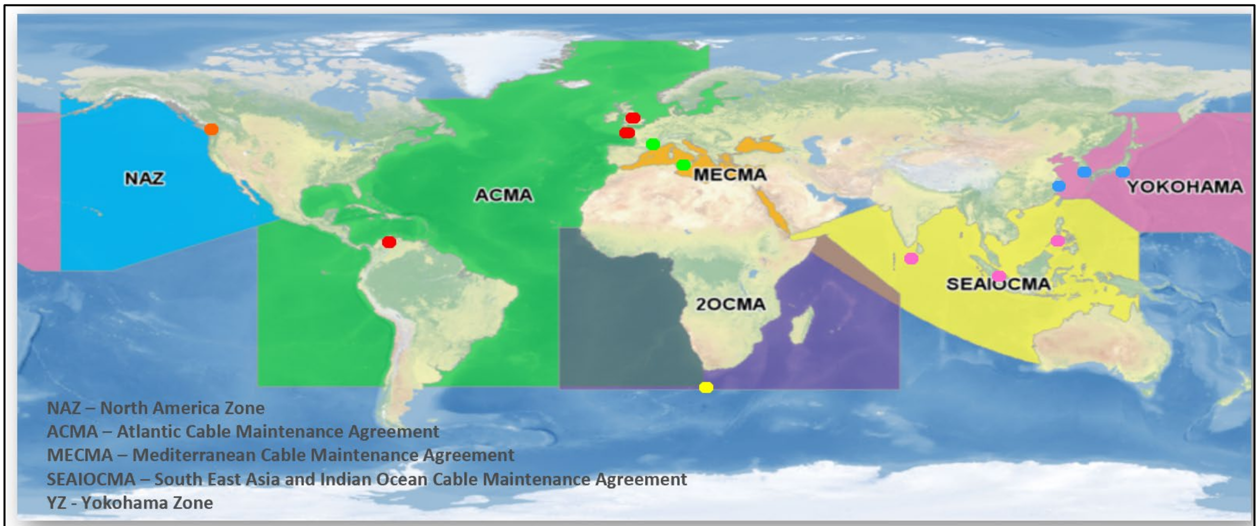
# 7.0 Cable Protection, Maintenance & Repair

It's been presented in this report that undersea cables are critical infrastructure and, as a result, their protection is critical. Standard protection measures include cable burial beyond the threat of human and natural events, cable armoring, as well as stakeholder engagement and cable awareness. Cable protection drives the methods of installation.

It has also been presented in this report that cables, predominantly undersea fiber optic cables, are inadvertently damaged each year and this has occurred ever since cables were first installed on the seabed. As a result, the maintenance and repair of cables is very important to the overall operations of undersea cables.

For undersea fiber optic cables, owners organize under maintenance "zones" that divide up the world with dedicated maintenance vessels that are on call to repair fiber optic cables.

The figure below illustrates the various maintenance zones that provide maintenance coverage across the world for undersea fiber optic cables. This figure does not show private agreement for cable maintenance.



| **Companies/Zones** | **Base Ports** |
|---|---|
| 🔴 = Orange/GMSL *(ACMA)* | Brest, France; Portland, UK; Curacao |
| 🟢 = Orange/Elettra *(MECMA)* | La Seyne Sur Mer, France; Catania, Italy |
| 🟡 = Orange *(2OCMA)* | Cape Town, South Africa |
| 🟠 = GMSL *(NAZ)* | Victoria, Canada |
| 🔵 = KCS/KTS/SBSS (YZ) | Yokohama, Japan; Keoje, Korea; Wujing, China |
| ● = ACPL/IOCPL/GMSL *(SEAIOCMA)* | Singapore; Colombo, Sri Lanka; Manila, Phillipines |

Map courtesy of GMSL

*Figure 13: Undersea Fiber Optic Cable Maintenance Zones (source: ICPC)*

When an undersea fiber optic cable is damaged, a standard method of maintenance involves a maintenance vessel sailing to the location of damage and using a grapnel hook to retrieve the cable and its damaged section. The damaged section of cable is cut out and a spare section of cable is spliced and jointed into the cable system before it is laid back down on the seabed. If the cable was originally buried, the repaired cable section can be post-lay buried with an ROV, if required. Once retrieved, an undersea fiber optic cable usually takes a few days to repair. Due to the use of spare cable for this activity, undersea fiber optic cable owners store spare cable at strategic depot locations specifically for the repair of their system(s), if damaged.

The figure below shows an undersea fiber optic cable "universal quick joint" (UQJ) which is used to splice/joint an undersea fiber optic cable.

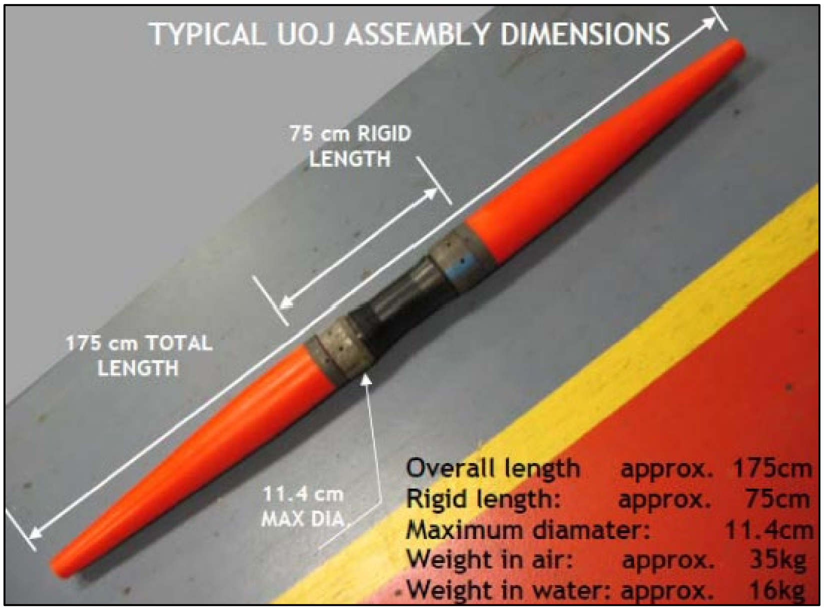


*Figure 14: Undersea Fiber Optic Cable Universal Quick Joint (UQJ) (source: ujconsortium.com)*

Maintenance of undersea power cables is different from undersea fiber optic cables for a variety of reasons. First, undersea power cables are typically regional systems due to their purpose and distance limitations for power transmission. As a result, there are not pre-arranged maintenance regimes serving the industry. Maintenance strategies are usually company dependent and based on spot-market resources at the time of cable damage. In some instances, power cable owners may have arranged agreements with third party companies in the event a cable has to be repaired.

Similar to undersea fiber optic cables, it is standard for an owner to store spare cable for use in a repair, but unlike fiber optic cables, repair joints are very large in dimension due to the size of power cables themselves and can take much longer to install over a damaged cable. Power cable joints can take one- to two- weeks to install over a damaged cable or longer and requires very specialized personnel that are not necessarily available in all parts of the world.

The cost to repair an undersea power cable can vary widely depending on the complexity of the repair and the time required. Generally, it is estimated that a repair can cost between $10 – 100 million US dollars. Given this cost, a repair may not actually be as cost effective as it would be to replace the cable in its entirety, which is a strategy that has been implement in different part of the world including places on the west coast of the US like in Alaska. The cost for the repair of an undersea power cable is significantly higher than average estimates for the cost of repair for a fiber optic cable system which can be between $500,000 and $3 million US dollars per repair. These are just estimates for indicative reference to the cost of each type or repair.

The figure below shows a typical power cable joint and its dimensions.

*Figure 15: Undersea Power Cable Repair Joint (source: NKT)*

Unlike undersea fiber optic cables which have a relatively global footprint and therefore maintenance resources have a global footprint as well, undersea power cables congregate where there are power transmission applications, which tend to be regional. Currently, these activities exist in areas such as in Europe, Asia, and to a growing extend in North America.

### 7.1 Permitting Considerations

Cable damage typically occurs in shallower water and as a result, these locations exist in a country's waters. Due to this, a maintenance vessel is required to obtain operational permits to go and repair a cable. Permitting lead times for vessels to repair cables in a coastal states waters can vary significantly from a few weeks to several months. Meanwhile, the cable can be out of service for that entire time which can have a tremendous impact on power or broadband deliver in a state or country.

Organizations like the ICPC have always advocated for shorter permitting timeframes for cable repair and, in fact, it should be viewed as being in a country's interest to have these infrastructure repaired as quickly as possible though rarely is cable maintenance a principally permitted activity, which would significantly lower the time-to-repair for vessels.

In the US, the west coast and east coast are relatively low fault (cable damage) zones, but due to the limited distance of state waters, most repairs occur either in the territorial sea or exclusive economic zone, making repair activities an activity under federal and not state jurisdiction.

## 8.0 Cable Decommissioning & Recovery

Undersea cables are usually decommissioned at the end of their useful or operational/design life. For example, undersea fiber optic cables are built for a twenty-five (25) year design life but may be operated for a shorter or longer duration. Undersea power cables are similar but with a forty (40) year design life. Once decommissioned, undersea cables have typically remained in-situ. As a result, there are out-of-service cables, both fiber and power, on the seabed all over the world. In some cases, marine habitat has grown on undersea cables where those cables are laid directly on the seabed in only a matter of a few years after installation (Carter et al, 2009). In other cases where cables are buried, it has been viewed that the cable is best left buried rather than pull it up from the sediment.

Some jurisdictions require the removal of a decommissioned cable whether or not it is surface laid or buried and there is a current growing trend towards sustainability efforts where removal of decommissioned infrastructure is a sustainable activity in terms of the use of a country's waters (or the world's oceans for that matter). Oftentimes, however, removal of undersea cable infrastructure may only be required in a coastal state's waters (i.e. state and/or federal waters in the US). Once in the high seas or international waters, there is no governing body that dictates or requires cable removal.

In the last ten (10) years, commercial companies have been able to develop business plans that make it commercially viable to recover and recycle undersea cables due to the quantity of steel and copper contained in these cables. These efforts can be irrespective of any jurisdiction's requirements to recover a decommissioned cable and is more often than not conducted in international waters due to the ease of marine operations from a permitting perspective (no permits required) as opposed to recovery operations in a country's waters where permits would then be required. This type of recovery operation is conducted by companies who have purchased the rights to out-of-service cables. Typically, an entire cable won't be recovered in its entirety, but rather recovered in sections so as to avoid areas where the recovery operations could potentially damage nearby or overlapping (crossing) cable infrastructure.

In both scenarios, jurisdictional requirement or commercial activity, cables are retrieved from the seabed and usually removed by pulling the cable from a vessel. In shallow water areas, this activity may need to be assisted to some extent with divers or other support vessels.

In the US, the jurisdictional requirement to recover a decommissioned cable is a state-by-state decision/requirement. Recovery is required in California, Oregon and Alaska by virtue of the seabed easement granted to a cable owner. Cable recovery is also required by a handful of east coast states. Recovery is usually conducted not just in state waters but throughout federal waters as well. On the east coast, some state's that do not currently have undersea cable infrastructure coming to their shores may not have a recovery requirement simply for lack of precedent in dealing with such cases, but other state's have requirements to recover decommissioned cables. With the growth of offshore renewable energy, and the continued growth of the trans-Atlantic fiber optic cable market, state requirements are evolving through experience, again with a trend towards cable recovery.

## 8.1 Permitting Considerations

Cable recovery requires vessel operational permits in state and federal waters. While most recovery operations are benign to the environment, it is noted that there may be cases where a cable should not be recovered due to its potential impact on the environment in which it was installed. For example, cables installed over rocky or reef areas (as is the case around the world) may get snagged during recovery operations and risk damage to the surrounding habitat when a cable is attempted to be pulled up to a vessel. As a result, it may be in the best interest of all stakeholders that cables be evaluated to remain in-situ in certain conditions.

Additionally, where cables have been recovered, it is pertinent both for cable developers and permitting agencies to assess if new cables can and should be encouraged to occupy the same seabed alignment or approach to a landing site. Where feasible, this helps with sustainable infrastructure construction and presents an opportunity for future cables to utilize seabed and existing infrastructure without creating further congestion issues offshore and on land.

# 9.0 Permitting Agency, Stakeholder, and Public Coordination

Unlike the technical, design, or construction and installation related methodologies for undersea cables which have established best or common practices, engagement with other marine users, permitting and other stakeholders, as well as the public is based on a softer set of skills and methods that can often vary between undersea cable projects and the companies involved in implementing them. While the process to obtain permits and approvals to install an undersea cable can be very well defined, the manner in which a team engages people and agencies through the planning, design and implementation phases of a project is typically not based on a set methodology or best practice. Depending on the management of this process, gaps in engagement can often surface which can lead to difficulties later on.

If there were a best practice related to engagement and coordination, it would be “engage early and engage often”. While this is typically used in reference to agency engagement for permitting purposes, this should also apply to other stakeholder and public engagement. We live in an era where everyone wants to know everything all the time and transparency is an expectation. If a person or group, whether it be a permitting agency, another marine user, a landowner, or a member of the public, learns of a new undersea cable project too late due to poor engagement, there can often be a negative affect due to the perception of being excluded or left out of the engagement process, whether the engagement was actually required to construct the project or not.

Despite the above, it is common for an undersea cable project to first vet the feasibility of a project at the permitting level. This is often done at the feasibility level stage without the full commitment that a company is going to build the cable system. During this stage, all permitting stakeholders are identified and approached to discuss the project and the permits or approvals involved. There can be a tendency to focus on state and federal agencies and permits, but it is equally important to engage local city and county agencies regarding the feasibility of a landing site design, as well as any other landowners whose land is crossed by the project.

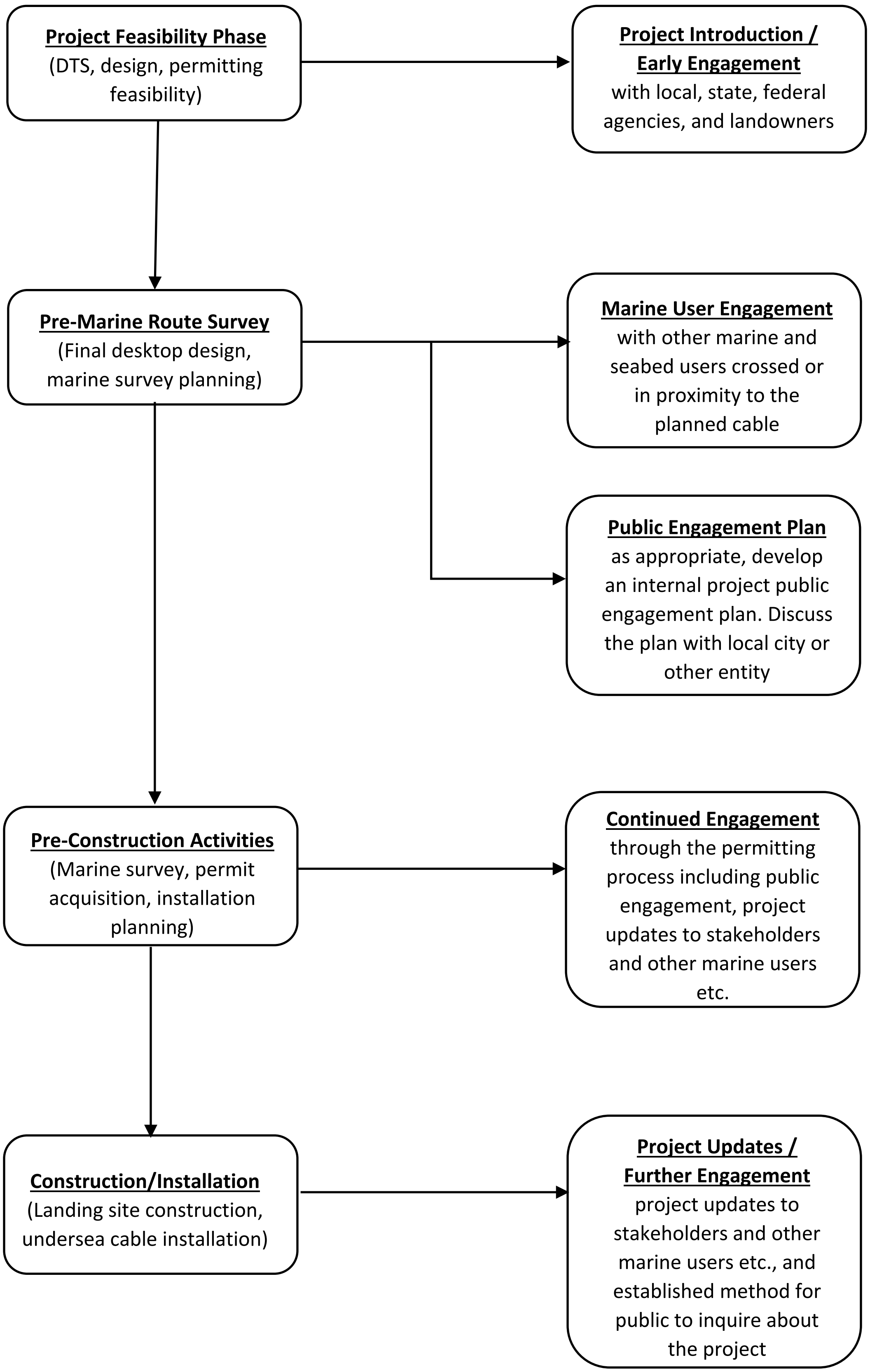
Word of a project can travel fast, and dialogue with one agency can spread by word of mouth to other agencies and landowners, making it difficult to manage the project narrative which can also impact how people receive information about a project. As a result, at an agency level it is always very useful to have joint agency meetings with local, state, and federal agencies where possible so that dialogue about the project can be coordinated with as many people present rather than having “siloed” conversations separately with each agency or project stakeholder.

Once a company has decided to develop an undersea cable project, and typically after all feasibility level investigations and early engagements have been conducted, it is appropriate to approach other stakeholders. Other marine or seabed users, for example, should be approached in advance of the marine route survey phase of the project to notify others of any crossings, discuss proximity issues, and to promote awareness of the new undersea cable project. It is at this stage that a project developer should also consider if and how the public should be engaged regarding the project. Early dialogue with the local city where the planned cable landing site is located is important not just to assess what local permits may be required to construct terrestrially (i.e. BMH, fronthaul and CLS), but also what reaction the public may have to the project. Local agencies, officials and city councils are often very attuned to their community and how a project will be received and can often advise on how and when the public should be engaged to learn more about the project. These days, if the public is being engaged for the first time at a public hearing related to a permit application, that may be too late of an engagement depending on the particular location and community where the project is located.

An additional and nuanced layer related to public or community engagement is that undersea cables, particularly fiber optic cables, are no longer being developed by the nation's phone companies. When older cables were being brought to shore in the 90's and early 2000's, they were being developed by carriers, so it made sense that a telecommunications company would be building a fiber optic cable. Today, undersea fiber optic cables are being developed by content, cloud or internet companies. The connotation or perception from the general public will be different, and this is something that should be anticipated by a project team.

The flow chart presented below is a general concept for guiding the coordination discussed in this section. It is not meant to be prescriptive nor represent every activity or phase of an undersea cable project.

*Figure 16: General Guidelines for Stakeholder Coordination and Communication*



The above figure is not a one-size-fits-all concept or guideline. Every project is different including the level of interaction with other stakeholders, marine users, and the public. Some projects are in very remote settings and do not trigger an overlap with other groups or people. Some projects are constructed in developed coastal areas or neighborhoods. Any engagement or communications plan needs to be developed appropriately for the context of the project.

Additionally, it should be noted that at the time of construction when crews are on site placing a BMH or directionally drilling a seaward conduit, or when a large cable installation vessel is positioned offshore from a landing, these activities will draw interest and curiosity from people. These events don’t occur every day. As a result, some jurisdictions require the project to post a method for the public or others to reach out and inquire about the project, whether it be a website, phone number or email address. Generally in developed areas where neighborhoods, businesses and coastal recreation exists, it is good practice that the public already is well aware of the project before they witness any on-site construction or presence of a cable installation vessel.

## 10.0 Critical Infrastructure

It is common practice for the undersea cable industry, both power and telecoms, to promote this infrastructure as critical infrastructure. Not unlike the importance of a bridge to a state’s or country’s citizens, digital and power infrastructure is a cornerstone of our society that helps facilitate our way of life and our economy. Damage to this infrastructure can have a serious impact, and as a result, the protection of this infrastructure is critical.

Whether or not a country designates undersea cables as critical national infrastructure or not, it is important to acknowledge that the global demand for bandwidth and sustainable power is increasing and will result in the development of more cables.

Best practices relating to undersea cables do not pertain solely to the technical, design and permitting elements of a project. Best practices also pertain to steps governments can take to manage and protect undersea cables. The ICPC has recently published a publicly available document titled “Government Best Practices for Protecting and Promoting Resilience of Submarine Telecommunications Cables” (ICPC, 2022). Though focused on undersea fiber optic cables, many of the same principles apply to undersea power cables.

The best practices document discusses the following topics listed below. This document should be reviewed by any government agency evaluating the management and protection of undersea cables in their jurisdiction as it provides a lot of guidance across multiple topic areas. This document has been provided as an attachment to this report.

- General Principles for Best Practices
- Fishing and Anchoring Risks
- Spatial Separation
- Charting
- Domestic Cable Protection Laws; Penalties for Damage
- Marine Spatial Planning and Inter-Industry Coordination
- Single Point of Contact

- Route and Landing Optimization; Geographic Diversity
- Permitting for Installation and Repair
- Cabotage and Crewing Restrictions
- Port Entry Requirements
- Customs Duties, Taxes, and Fees
- Maritime Boundary Claims and Disputes
- Critical Infrastructure Designation
- Sharing of Risk and Incident Data
- Impact of Other High-Seas Regulatory Activities

## 11.0 References

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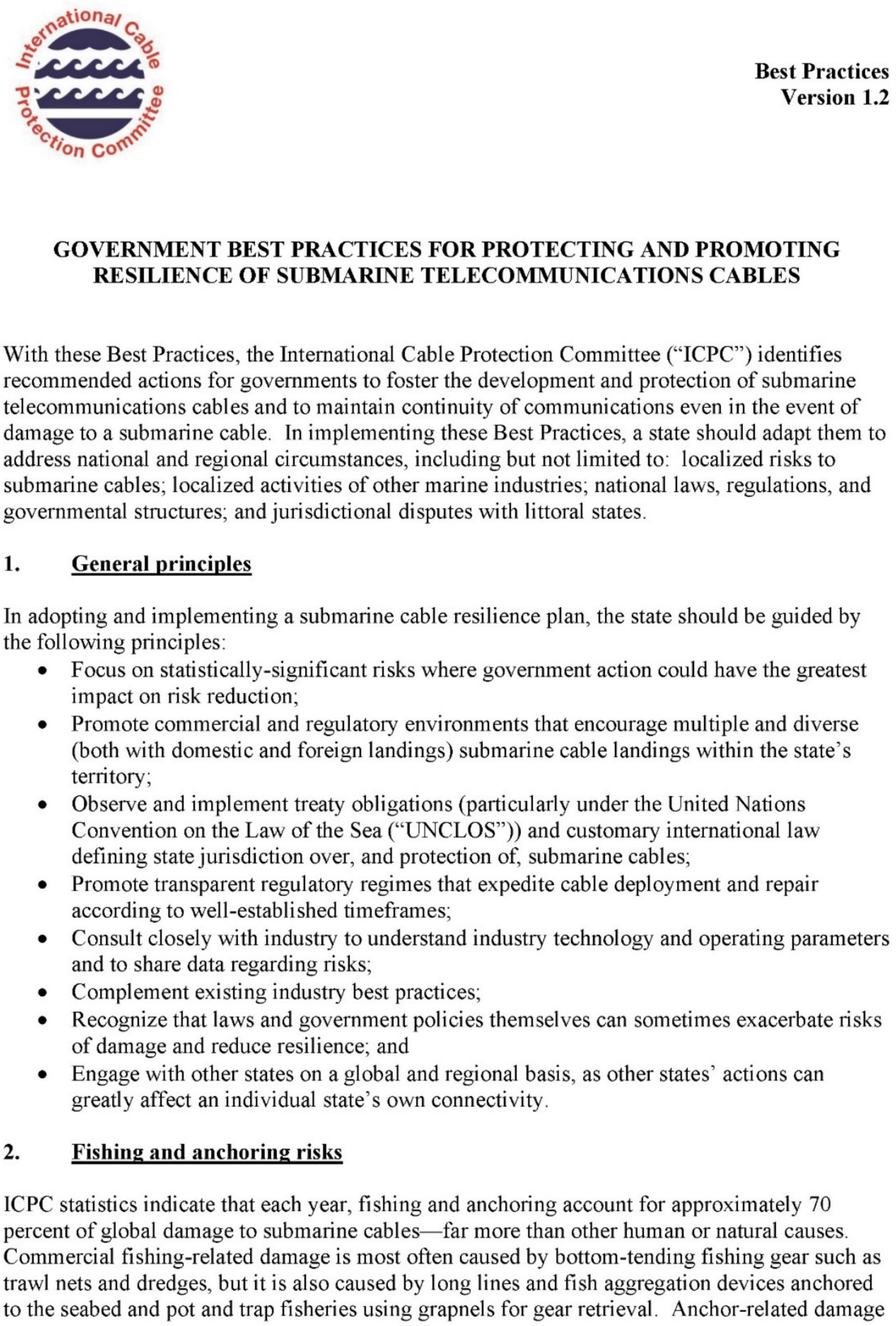
# 12.0 Attachment A – ICPC Best Practices for Governments



**Best Practices**
**Version 1.2**

## GOVERNMENT BEST PRACTICES FOR PROTECTING AND PROMOTING RESILIENCE OF SUBMARINE TELECOMMUNICATIONS CABLES

With these Best Practices, the International Cable Protection Committee ("ICPC") identifies recommended actions for governments to foster the development and protection of submarine telecommunications cables and to maintain continuity of communications even in the event of damage to a submarine cable. In implementing these Best Practices, a state should adapt them to address national and regional circumstances, including but not limited to: localized risks to submarine cables; localized activities of other marine industries; national laws, regulations, and governmental structures; and jurisdictional disputes with littoral states.

### 1. General principles

In adopting and implementing a submarine cable resilience plan, the state should be guided by the following principles:

- Focus on statistically-significant risks where government action could have the greatest impact on risk reduction;
- Promote commercial and regulatory environments that encourage multiple and diverse (both with domestic and foreign landings) submarine cable landings within the state's territory;
- Observe and implement treaty obligations (particularly under the United Nations Convention on the Law of the Sea ("UNCLOS")) and customary international law defining state jurisdiction over, and protection of, submarine cables;
- Promote transparent regulatory regimes that expedite cable deployment and repair according to well-established timeframes;
- Consult closely with industry to understand industry technology and operating parameters and to share data regarding risks;
- Complement existing industry best practices;
- Recognize that laws and government policies themselves can sometimes exacerbate risks of damage and reduce resilience; and
- Engage with other states on a global and regional basis, as other states' actions can greatly affect an individual state's own connectivity.

### 2. Fishing and anchoring risks

ICPC statistics indicate that each year, fishing and anchoring account for approximately 70 percent of global damage to submarine cables—far more than other human or natural causes. Commercial fishing-related damage is most often caused by bottom-tending fishing gear such as trawl nets and dredges, but it is also caused by long lines and fish aggregation devices anchored to the seabed and pot and trap fisheries using grapnels for gear retrieval. Anchor-related damage is most often caused by: improperly-stowed anchors, which release or fall overboard and can be dragged for great lengths along the sea floor, damaging cables along the anchor's path; anchoring outside of approved anchorages and near installed submarine cables; anchors dragged by properly-anchored vessels, depending on sea conditions; and dropping of anchors in marine emergencies. Mooring lines of fish aggregating devices ("FADs"), especially in deep-water can cause abrasion to submarine cables during installation, and FAD anchors have caused damage to deployed cables.

The submarine cable industry uses a variety of mitigation measures to limit damage from fishing and anchoring, including: route selection and design to avoid areas of particular risk (for example, routing around designated anchorages); cable armoring; cable burial (from 0.5 meters to 3 meters) for cable installed at water depths less than 1500 meters, where seabed conditions permit; cable awareness and liaison programs designed to educate fishing fleets regarding the location of submarine cables, and actions to take if gear is snagged; and programs to compensate fishermen for snagged gear (so that they abandon snagged gear rather than damage cables in trying to free it). Coordination with FAD owners and with governments to obtain FAD positions so cables can be routed around them, and/or measures to relocate or recover FADs in coordination with the owners have proven beneficial. These industry self-help measures can be effective, but they are insufficient absent additional actions to be taken by governments.

ICPC statistics confirm that state adoption and implementation of effective cable protection measures directed at fishing and anchoring risks can greatly reduce the risk of damage to submarine cables. As best practices, ICPC recommends that states therefore adopt and implement the following measures:

- Prohibit fishing in close proximity to submarine cables—including deployment of drift nets, gill nets, fish aggregation devices, and vessel anchors—consistent with default and minimum separation distances discussed in part 3 below;
- Require use of designated anchorages and establish and prosecute legal offenses for anchoring outside of designated anchorages;
- Promote the distribution and use of cable awareness charts (prepared by submarine cable operators) to fishermen;
- Promote direct engagement between submarine cable operators, including establishment of fishing-cable committees that can compensate fishermen for snagged and lost gear in exchange for not risking cable damage through gear retrieval efforts;
- Require use of automated identification systems ("AIS") and vessel monitoring systems ("VMS") on vessels at all times and establish and prosecute legal offenses where vessel operators turn off or disable AIS or VMS;
- Require that vessel operators carry appropriate insurance;
- Require use of AIS or VMS by even the smallest of vessels; and
- Direct the coast guard to issue local notices to mariners regarding submarine cable protection and to communicate with vessels operating or drifting near submarine cables.
- Limit deployment of FADs proximate to installed and planned submarine cables.

- Establish a FAD registry, requiring FAD owners to identify and update FAD locations, and make such registry available to submarine cable operators during the route planning process for new cables.
- Require removal of ropes and ghost gear in the water column and consider removal requirements for end-of-life disposition of FADs.

## 3. Spatial separation

Spatial separation of submarine cables from other marine activities is one of the effective means of cable protection. It minimizes the risk of damage from other marine activities and ensures that submarine cable operators have ready and unfettered access to their cables for installation and maintenance needs and to minimize outage time in connection with a repair. The oceans, however, are increasingly crowded spaces where ideal spatial separation might not be possible, and where marine industries make compromises regarding proximity while seeking to reduce risk through closer coordination and communication.

A default separation distance establishes a minimum separation distance between an existing submarine cable and another marine or coastal activity in the absence of any mutual agreement to allow the activity in closer proximity to the submarine cable. By contrast, a minimum separation distance establishes an absolute minimum separation distance between the submarine cable and the other marine or coastal activity. Consistent with ICPC recommendations, many countries—as diverse as China, Denmark, Russia, Singapore, and the United Kingdom—have established default or minimum separation distances to protect submarine cables.

Some states have established cable protection zones and corridors that prohibit specified activities posing risks to submarine cables—including fishing, anchoring, and dredging—within fixed geographic areas. Discretionary cable protection zones grant protections to submarine cables that choose to locate in them or that may be declared around them, as in the case of Australia. Mandatory cable protection zones (or cable corridors) require submarine cable operators to route their infrastructure in defined geographic areas (as in the case of New Zealand). States with cable protection zones enforce them with air and sea patrols and infringement penalties. Submarine cable operators generally disfavor mandatory cable protection zones and corridors because they (1) provide insufficient spatial separation from other submarine cables for installation and maintenance and (2) encourage geographic clustering of submarine cable routes and landings, which magnifies the risk that a single natural or man-made event could damage multiple cables.

As best practices to promote spatial separation, ICPC recommends that states:

- Adopt and enforce the following recommended separation distances between cable ships and other vessels in the exclusive economic zone ("EEZ," extending 200 nautical miles seaward from the shore) and the territorial sea (extending 12 nautical miles seaward from the shore):

    - In shallow water with a depth of 75 meters or less: 500 meters; and
    - In greater depts of water: the greater of 500 meters or two times the depth of water;
- Implement on nautical charts the text box specified in International Hydrographic Organization ("IHO") Resolution 4/1967 (amended April 2017), as discussed in part 4 below;
- Ensure that any cable protection zones are adopted with consultation and support of cable operators;
- Demarcate cable protection zones using nautical charts rather than buoys, as nautical charts are more effective than buoys for navigation and do not create obstructions on the seafloor, in the water column, and on the ocean surface that can interfere with cable operations, fishing, and navigation; and
- Maintain flexibility with the number and size of cable protection zones.

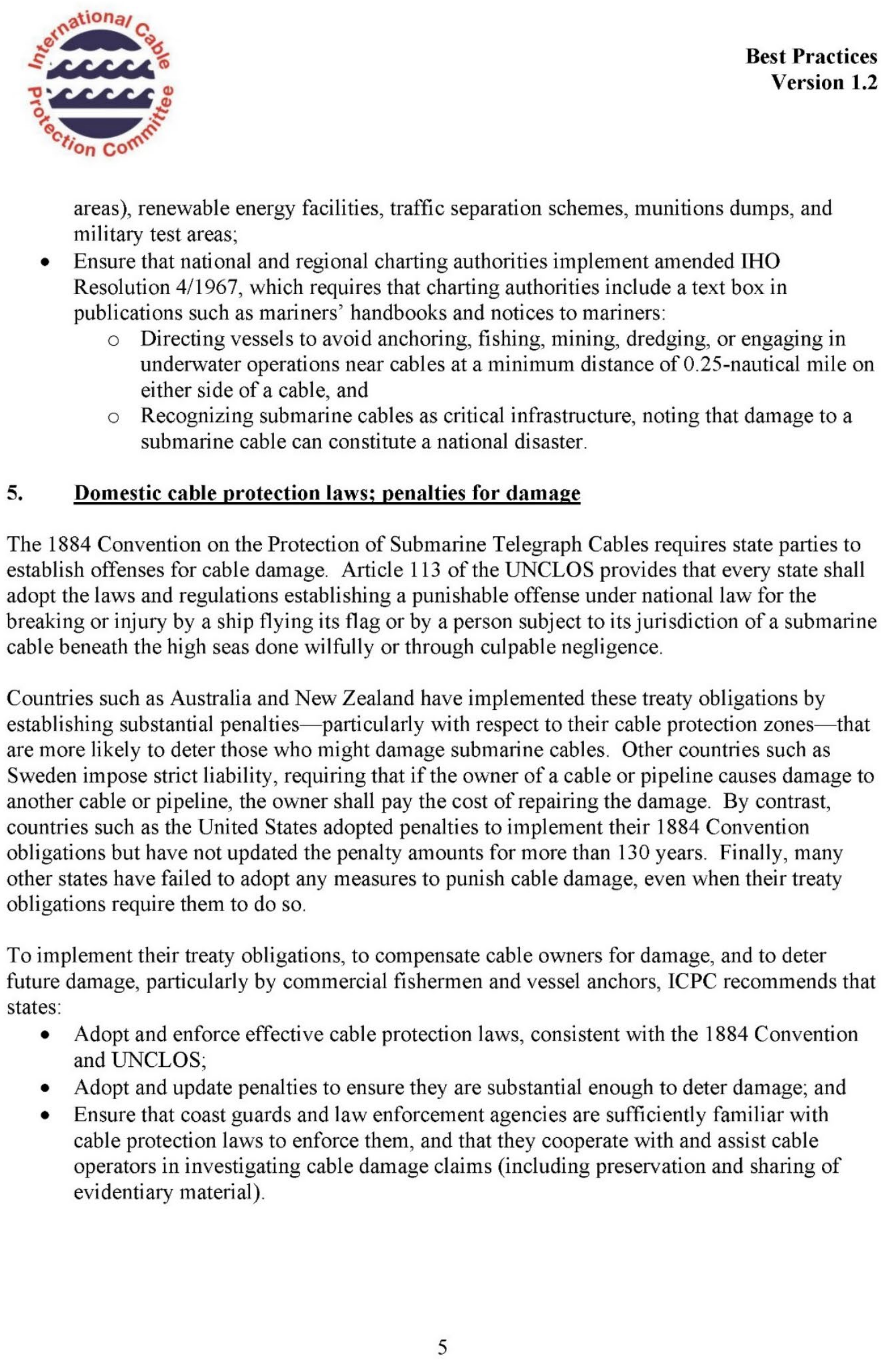
## 4. Charting

Nautical charts (such as Admiralty charts) issued by government hydrographic offices consistent with IHO recommendations are graphical representations of ocean and adjacent coastal areas showing, among other things, water depths, seabed and coastline details, tidal information, and human-made features such as harbors, munitions dumps, offshore wind farms, and submarine cables. Nautical charts aid in navigation and alert users to the presence of other ocean activities. Nautical charts were previously issued periodically in paper form, but they are now generally maintained in electronic form and available on a computer screen or using a print-on-demand function.

Submarine cables are charted using data provided by operators and their contractors to hydrographic offices (such as the U.K. Hydrographic Office, the Indian Naval Hydrographic Office, the South African Navy Hydrographic Office, and the Hydrographic Department of the Maritime and Port Authority of Singapore). Historically, the IHO recommended charting only to a depth of 2,000 meters, in light of a focus on safety at sea. Some submarine cable operators still charted their cables at all depths. In 2018, however, the IHO revised its approach, due in part to a recognition that charting of submarine cables in areas proximate to deep seabed mining could reduce the risk of cable damage. The IHO and ICPC have established a pilot program to chart cables in areas proximate to contract areas of the International Seabed Authority.

As best practices for charting, ICPC recommends that states adopt and implement the following measures:

- Update nautical charts regularly and in near-real-time;
- Show all submarine cables on nautical charts, distinguishing between in-service and out-of-service cables;
- Show on nautical charts all other human activities that could pose risks to submarine cables, including but not limited to mining areas (including sand and gravel borrow



areas), renewable energy facilities, traffic separation schemes, munitions dumps, and military test areas;
- Ensure that national and regional charting authorities implement amended IHO Resolution 4/1967, which requires that charting authorities include a text box in publications such as mariners' handbooks and notices to mariners:
    - Directing vessels to avoid anchoring, fishing, mining, dredging, or engaging in underwater operations near cables at a minimum distance of 0.25-nautical mile on either side of a cable, and
    - Recognizing submarine cables as critical infrastructure, noting that damage to a submarine cable can constitute a national disaster.

## 5. Domestic cable protection laws; penalties for damage

The 1884 Convention on the Protection of Submarine Telegraph Cables requires state parties to establish offenses for cable damage. Article 113 of the UNCLOS provides that every state shall adopt the laws and regulations establishing a punishable offense under national law for the breaking or injury by a ship flying its flag or by a person subject to its jurisdiction of a submarine cable beneath the high seas done wilfully or through culpable negligence.

Countries such as Australia and New Zealand have implemented these treaty obligations by establishing substantial penalties—particularly with respect to their cable protection zones—that are more likely to deter those who might damage submarine cables. Other countries such as Sweden impose strict liability, requiring that if the owner of a cable or pipeline causes damage to another cable or pipeline, the owner shall pay the cost of repairing the damage. By contrast, countries such as the United States adopted penalties to implement their 1884 Convention obligations but have not updated the penalty amounts for more than 130 years. Finally, many other states have failed to adopt any measures to punish cable damage, even when their treaty obligations require them to do so.

To implement their treaty obligations, to compensate cable owners for damage, and to deter future damage, particularly by commercial fishermen and vessel anchors, ICPC recommends that states:

- Adopt and enforce effective cable protection laws, consistent with the 1884 Convention and UNCLOS;
- Adopt and update penalties to ensure they are substantial enough to deter damage; and
- Ensure that coast guards and law enforcement agencies are sufficiently familiar with cable protection laws to enforce them, and that they cooperate with and assist cable operators in investigating cable damage claims (including preservation and sharing of evidentiary material).

## 6. Marine spatial planning and inter-industry coordination

Governmental bodies and other marine industries are often unfamiliar with the presence of, operational requirements for, vulnerabilities of, status as critical telecommunications infrastructure of, and statutory and treaty protections that apply to, submarine cables. In some cases, marine spatial planning activities omit submarine cables entirely. This lack of familiarity with, or neglect of, submarine cables can greatly impair their protection and resilience.

As best practices, ICPC recommends that states undertake the following to protect cables and de-conflict cable routes:

- Include and consult with submarine cable operators as stakeholders in such processes;
- Identify submarine cables in their mapping resources and tools (not just on nautical charts);
- Identify and include submarine cable operators as critical stakeholders in marine spatial planning and policymaking;
- Adopt regulatory frameworks for other marine activities, such as oil and gas development and renewable energy installations, to require coordination with submarine cables at the earliest stage of planning and development of those other projects; and
- Ensure that planning and leasing documents for oil, gas, and renewables specifically reference submarine cable protection and coordination.

## 7. Single point of contact

Submarine cable development, installation, operation, and repair implicates the regulatory and policy responsibilities of numerous government agencies, including those ministries, departments, and agencies responsible for telecommunications, maritime and shipping, environment, customs, and national security, to name a few. The dispersion of responsibilities for submarine cables can impair government action with respect to submarine cables and also make it difficult for other industries to coordinate with submarine cables. Singapore has addressed this issue by designating its telecoms regulator, the IMDA, as the point of contact for submarine cables, even if other government bodies have ultimate responsibility for a particular issue.

As a best practice, ICPC recommends that states:

- Establish a single point of contact for submarine cables—and not just for permitting purposes, but also for any issues arising with respect to installation, repair, and protection.

## 8. Route and landing optimization; geographic diversity

Submarine cable operators consider a variety of factors when choosing routes and landings, including:

- Economic need (for connections between data centers and points of presence, and on highly-trafficked routes);
- Economic opportunity (in the case of wholesale capacity sales);
- Seafloor topography (seeking flat and uninteresting seabed that avoids geographic features with steep gradients, seamounts, vents, or fracture zones);
- Geographic diversity (to minimize the impact of a single event causing damage to multiple cables);
- Proximity to other marine activities and infrastructure (which pose risks of damage);
- Access to terrestrial networks (to ensure secure, diverse, and low-cost connectivity between submarine and terrestrial networks);
- Environmental restrictions (such as marine protected areas); and
- Regulatory considerations (including length and expense of permitting).

They design routes to follow the shortest viable route between landing points exhibiting the lowest risk to the installed cable. They start with a great circle route (the shortest distance between two points on a globe), which provides the lowest latentcy for communications transmissions (the time taken for data to pass from point A to point B) and then adjust for technical, economic, and regulatory factors.

Submarine cable operators and their capacity customers increasingly seek to maximize geographic diversity of submarine cable routes and landings in order to enhance network resilience and reduce the risk of damage from a single event, whether an earthquake, a tsunami, a vessel anchor, fishing gear, or a terrorist attack. Their options may be limited by other factors, such as slow and expensive permitting, coastal landowners, and marine protected areas. Moreover, they operate in dynamic coastal and marine environments that are increasingly crowded and that lack a single landowner or a single regulator. Other activities and infrastructure are frequently authorized without regard to the potential to foreclose particular areas to future submarine cable development, increasing the potential for clustering of cables and landings, and the risks inherent in non-diverse infrastructure.

As best practices, ICPC recommends that states undertake the following to promote resilience of submarine cable networks:

- Adopt and implement regulatory frameworks to optimize routes and landings, including geographic diversity of routes and landings;
- Recognize that diversity can be impaired by government shore-end permitting, marine protected areas, and marine spatial planning (or lack thereof) that results in clustering of cables, magnifying risk that a single incident will damage multiple cables and impair connectivity; and
- Recognize that submarine cables cannot be hidden or armored and buried to guard against all malicious and non-malicious sources of cable damage.

## 9. <u>Permitting for installation and repair</u>

As noted in part 8 above, permitting can greatly affect route and landing location decisions for submarine cable operators. In many cases, coastal states apply a "one-size-fits-all" permitting regime that applies equally to polluting activities (such as oil and gas development) and environmentally-benign activities (like submarine cables), which can burden and delay the environmentally-benign activities.

Moreover, the permitting actions of one state can greatly affect the connectivity of other states. UNCLOS articles 2, 58, 79, and 87 authorizes a coastal state to impose conditions and consent requirements for submarine cables entering its territorial sea, but not beyond it in the EEZ or on the continental shelf. UNCLOS articles 2 and 51 also allow archipelagic states to impose conditions for new submarine cables entering archipelagic waters.

As best practices, ICPC recommends that states ensure that permit requirements for installation and repair:

- Are consistent with UNCLOS in the EEZ and archipelagic waters and on the continental shelf—excessive jurisdictional assertions by one's neighbors can impair installation of new cables and repairs of existing ones;
- Reflect the best available science showing that submarine cables are neutral-to-benign in the marine environment;
- Are transparent;
- Establish clear timeframes that are as short as possible; and
- Promote diversity of routes and landings.

## 10. <u>Cabotage and crewing restrictions</u>

Cabotage is the transport of goods and passengers between domestic ports. For a variety of reasons, including protection of domestic industry and national security, a number of states have restricted cabotage to domestic vessels, with varying criteria including domestically-built, domestically-owned, domestically-flagged, and/or domestically-crewed vessels. Some states have expanded their cabotage restrictions to a broader range of economic activities in their territorial seas and EEZs, including submarine cable installation and repair. Application of cabotage laws to submarine cable installation and repair is inappropriate and undermines the resilience of submarine cable networks.

Cable ships are built specifically for cable-related operations and are crewed by highly trained and experienced merchant mariners, engineers, and cable operations staff. Most of the world's countries with submarine cable landings and transits lack locally-flagged and locally-crewed cable ships. Instead, most of the world's installation and repair services are provided by a few global and regional providers with the necessary expertise and economies of scale. Submarine cable operators often pool risks and resources to contract for cable ships in regional zone agreements. These zone arrangements cover vast multinational geographic areas, meaning that there are no discrete national maintenance markets.

Cabotage and crewing restrictions render installations and repairs more expensive and can result in performance and safety problems arising from the use of inappropriate vessels and inexperienced crew. They generally impair the operation and economies of scale of maintenance consortia. Cabotage and crewing restrictions can also greatly delay critical repairs, as a submarine cable operator must wait to qualify a foreign-flagged/crewed vessel through an exemption or waiver process. Cabotage and crewing restrictions can harm the connectivity of other neighboring countries.

Within the EEZ and on the continental shelf, cabotage and crewing restrictions are inconsistent with UNCLOS articles 79 and 87, which provide for the freedom to install, maintain, and repair submarine cables in those maritime zones. Within archipelagic waters, cabotage restrictions on repair of existing cables that merely transit the state are inconsistent with UNCLOS article 51. Although permissible within the territorial sea, cabotage and crewing restrictions are inadvisable.

As best practices, ICPC recommends that states:

- Refrain from defining submarine cable installation and repair as cabotage, as they do not involve the transport of goods or passengers between domestic ports;
- Refrain from applying cabotage or crewing restrictions on vessels engaged in installation or repair, whether in the territorial sea, archipelagic waters, or EEZ/continental shelf.

## 11. Port entry requirements

Based on installation or repair work within the territorial sea, archipelagic waters, or EEZ, some states require that a cable ship enter a domestic port for regulatory clearance purposes, even when crew members would not otherwise embark or disembark. Such requirements disrupt operations and delay installation and repair.

As best practices, ICPC recommends that states:

- Refrain from requiring port entry for cable ships conducting installations and repairs beyond the territorial sea; and
- For work within the territorial sea and archipelagic waters, establish annual pre-clearance procedures for cable ships and crews.

## 12. Customs duties, taxes, and fees

Some states view the entry of new submarine cables into their jurisdictions as an opportunity to extract revenue from the operator in the form of customs duties, taxes, and fees. Such charges increase the cost of capacity to users and in some cases can deter landings, thereby undermining government policies designed to foster new cable landings. Such charges can also serve as a source of disputes that delay installation and repair.

As noted in part 9 above, UNCLOS articles 2, 58, 79, and 87 authorizes a coastal state to impose conditions for submarine cables entering its territorial sea, but not beyond it. UNCLOS articles 2 and 51 also allow archipelagic states to impose conditions for new submarine cables entering archipelagic waters. Some states, however, have sought to impose customs duties, taxes, and fees for activities and infrastructure in the EEZ and on the continental shelf, in contravention of UNCLOS.

As best practices, ICPC recommends that states:

- Refrain from imposing customs duties, taxes, and fees on installation activities beyond the limits of the territorial sea, and on cable ships merely transiting an EEZ;
- Reduce or eliminate customs duties on submarine cable equipment imported into a state's territory, in order to foster submarine cable deployment and facilitate quick access to spare plant for repair; and
- Refrain from imposing importation requirements and customs duties on cable ships conducting installation or repair.

## 13. Maritime boundary claims and disputes

Competing maritime boundary claims and boundary disputes can impede installation and even foreclose certain routes. Such disputes can also greatly delay repairs due to duplicative and time-consuming permit requirements. In some cases, boundary disputes pose a danger to the cable ship and its crew due to the threat of military action.

As best practices, ICPC recommends that states:

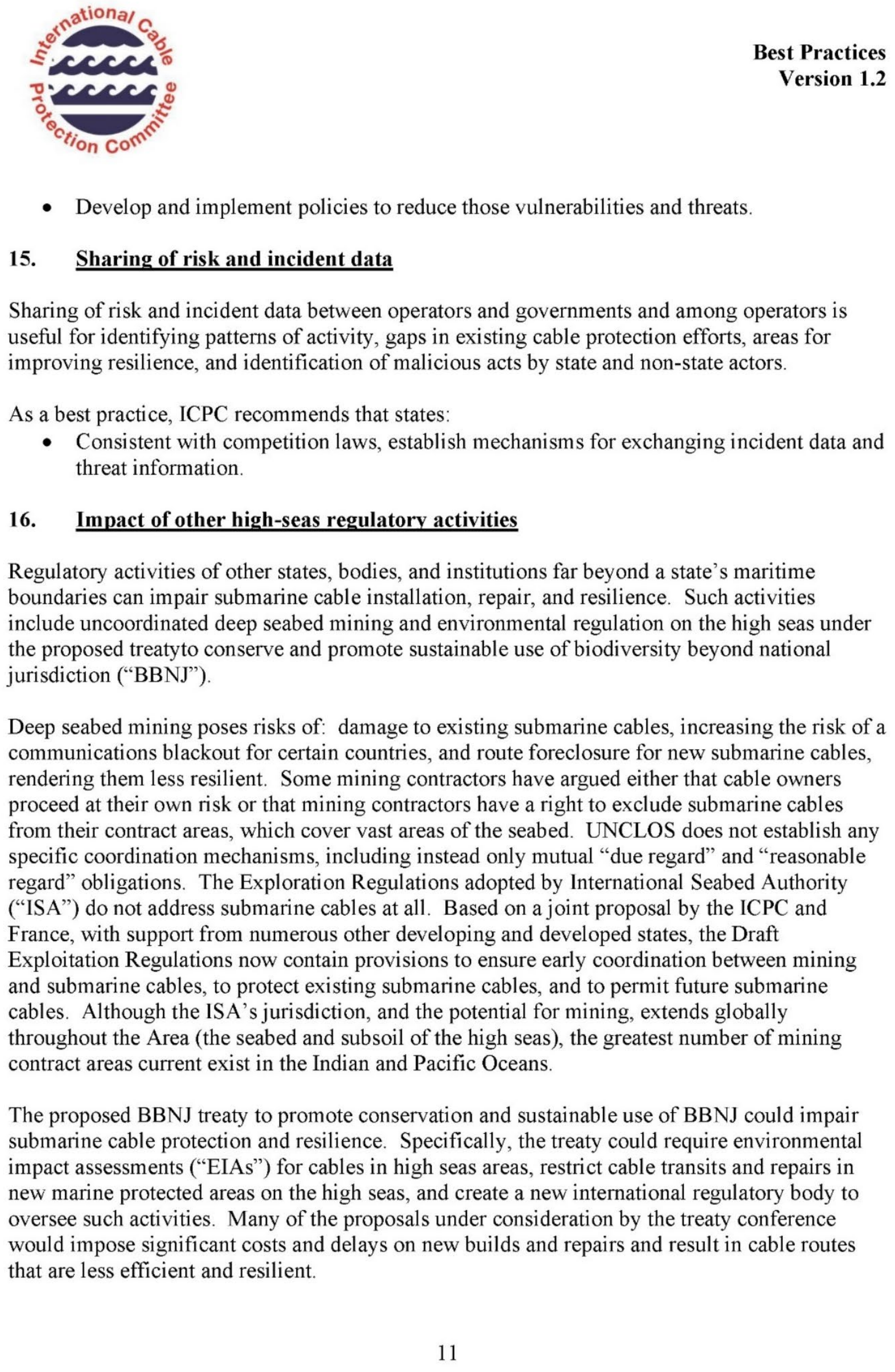
- Facilitate installation and repair without prejudice to any maritime boundary claim; and
- Recognize that submarine cable operators seek to remain neutral in boundary disputes and seek to conduct their activities without prejudice to such disputes.

## 14. Critical infrastructure designation

Critical infrastructure is generally understood to include assets that are essential for the functioning of society and the economy, and damage or destruction of which would harm national and economic security, public health, and public safety. Governments use critical infrastructure designations to highlight asset criticality and to identify and mitigate vulnerabilities and threats through specific laws and policies.

As best practices, ICPC recommends that states:

- Designate submarine cables as critical infrastructure;
- Gather and assess data regarding vulnerabilities of, and threats to, submarine cables; and



- Develop and implement policies to reduce those vulnerabilities and threats.

## 15. Sharing of risk and incident data

Sharing of risk and incident data between operators and governments and among operators is useful for identifying patterns of activity, gaps in existing cable protection efforts, areas for improving resilience, and identification of malicious acts by state and non-state actors.

As a best practice, ICPC recommends that states:

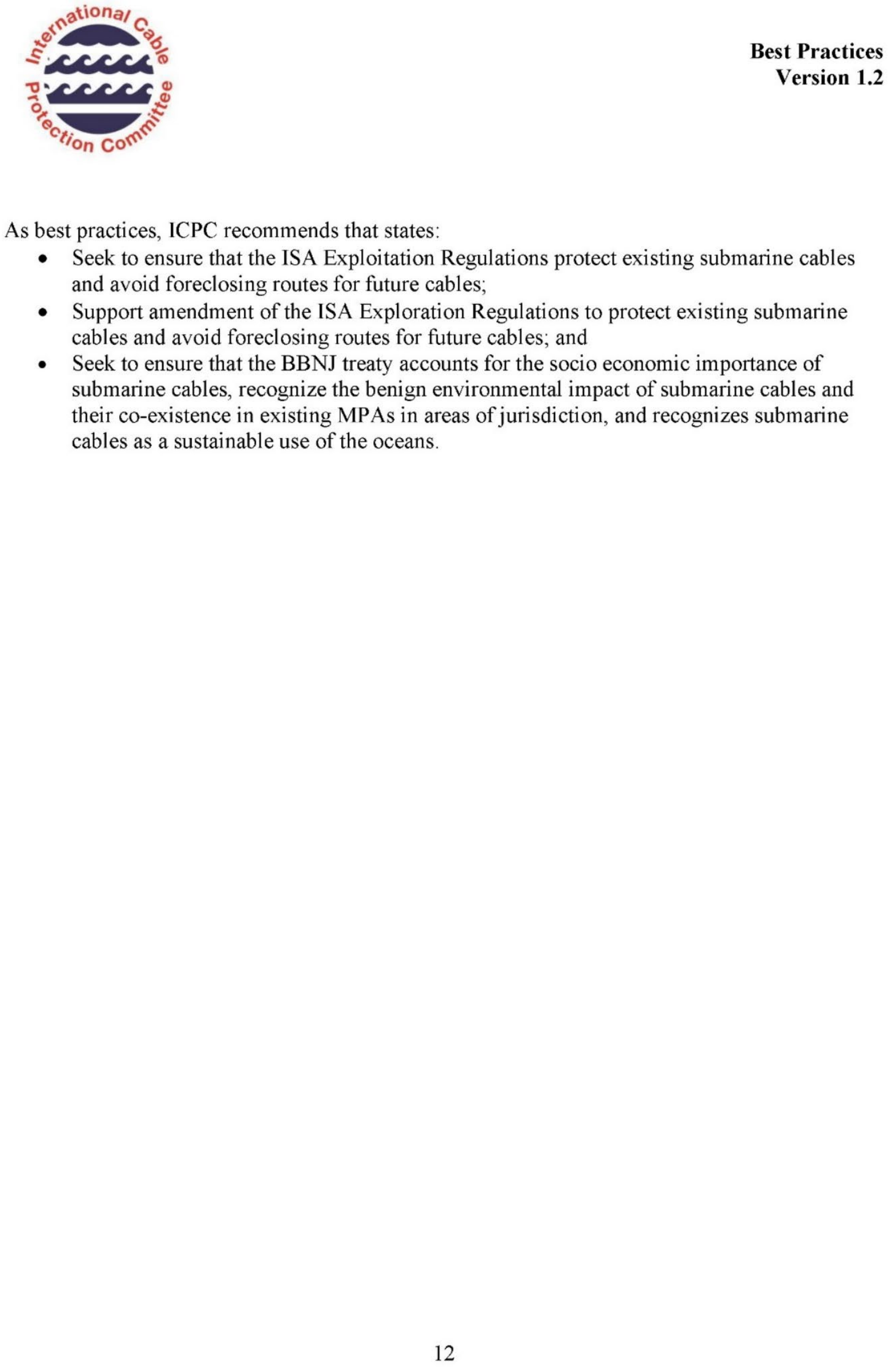
- Consistent with competition laws, establish mechanisms for exchanging incident data and threat information.

## 16. Impact of other high-seas regulatory activities

Regulatory activities of other states, bodies, and institutions far beyond a state's maritime boundaries can impair submarine cable installation, repair, and resilience. Such activities include uncoordinated deep seabed mining and environmental regulation on the high seas under the proposed treatyto conserve and promote sustainable use of biodiversity beyond national jurisdiction ("BBNJ").

Deep seabed mining poses risks of: damage to existing submarine cables, increasing the risk of a communications blackout for certain countries, and route foreclosure for new submarine cables, rendering them less resilient. Some mining contractors have argued either that cable owners proceed at their own risk or that mining contractors have a right to exclude submarine cables from their contract areas, which cover vast areas of the seabed. UNCLOS does not establish any specific coordination mechanisms, including instead only mutual "due regard" and "reasonable regard" obligations. The Exploration Regulations adopted by International Seabed Authority ("ISA") do not address submarine cables at all. Based on a joint proposal by the ICPC and France, with support from numerous other developing and developed states, the Draft Exploitation Regulations now contain provisions to ensure early coordination between mining and submarine cables, to protect existing submarine cables, and to permit future submarine cables. Although the ISA's jurisdiction, and the potential for mining, extends globally throughout the Area (the seabed and subsoil of the high seas), the greatest number of mining contract areas current exist in the Indian and Pacific Oceans.

The proposed BBNJ treaty to promote conservation and sustainable use of BBNJ could impair submarine cable protection and resilience. Specifically, the treaty could require environmental impact assessments ("EIAs") for cables in high seas areas, restrict cable transits and repairs in new marine protected areas on the high seas, and create a new international regulatory body to oversee such activities. Many of the proposals under consideration by the treaty conference would impose significant costs and delays on new builds and repairs and result in cable routes that are less efficient and resilient.



**Best Practices**
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As best practices, ICPC recommends that states:

- Seek to ensure that the ISA Exploitation Regulations protect existing submarine cables and avoid foreclosing routes for future cables;
- Support amendment of the ISA Exploration Regulations to protect existing submarine cables and avoid foreclosing routes for future cables; and
- Seek to ensure that the BBNJ treaty accounts for the socio economic importance of submarine cables, recognize the benign environmental impact of submarine cables and their co-existence in existing MPAs in areas of jurisdiction, and recognizes submarine cables as a sustainable use of the oceans.