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DISASTER-RESILIENCE OF UNDERSEA COMMUNICATION CABLE SYSTEMS IN INDIA

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The criticality of internet-based data is increasing in terms of penetration as well as volume and is no longer an urban phenomenon. As sectors such as agriculture (both land-based and fisheries), transport (road, air, and sea), healthcare, and rural development become ever more reliant upon timely information flowing over the internet, the demand for enhanced capacity and speed will drive an exponential increase in the number of undersea communication cables. For a country such as India, which is on the cusp of moving from a three trillion-dollar economy to a seven-trillion dollar one in less than a decade from now, the growth of submarine cables will be dramatic. Paradoxically, the degree of vulnerability of the country vis-à-vis this critical infrastructure will increase equally rapidly. While discussions on the threats-to and vulnerabilities-of the submarine communication infrastructure have gained traction, much of the it has centred around the anthropogenic factors of disruption.

Although anthropogenic factors such as anchoring and bottom trawling fishing, etc., account for a majority of cable disruptions, natural hazards — particularly climate change induced ones — are a growing concern. Hazard-related disruptions constitute nearly 20 per cent of reported disruptions to undersea cable infrastructure, and this percentage value is very likely to grow given the increasing frequency and intensity of natural hazards.[1] Further, given the concentration of cable systems at particular landing points, hazard-related disruptions can wipe out a larger number of cables in one go, thereby inflicting disproportionately high damage to the entire communication system.[2] In 2009 for instance, Typhoon Morakot broke nine cables off Taiwan by generating sediment-laden flows that damaged cables at depths of up to 4,000 metres and over 300 kilometres from the site of formation of the sediment flow.[3] Likewise, in 2011, a massive *tsunami*, which rocked north-eastern Japan, resulted in multiple submarine cable cuts and the isolation of the Kita Ibaraki and Ajigaura

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[1] MA Clare et al., "Climate Change Hotspots and Implications For The Global Subsea Telecommunications Network", *Earth-Science Reviews 237* (2022) https://www.sciencedirect.com/science/article/pii/S0012825222003804?ref=cra_js_challenge&fr=RR-1

[2] Ibid. **Also See:** Christof Gerlach, "*Economic Impact of Submarine Cable Disruptions*", (Singapore, Asia-Pacific Economic Cooperation Policy Support Group, 2013) https://www.apec.org/docs/default-source/Publications/2013/2/Economic-Impact-of-Submarine-Cable-Disruptions/2013_psu_-Submarine-Cables.pdf

[3] Lionel Carter, "*Submarine cables and the oceans: connecting the world*", (United Kingdom, UNEP-WCMC, 2009)

cable landing stations.[4] Such scenarios are hardly scarce and history is replete with examples of cable damage from natural hazards.[5] More recently, four major undersea cables serving Africa were damaged near the Ivory Coast and this was suspected to be due to seismic activity on the seabed. They took more than two months to be restored.[6] Island-States are particularly vulnerable to natural hazards as many of them are located on tectonically active margins that are subject to cyclones, earthquakes/tsunamis, and fluvial sediment discharge which often exacerbate matters.[7] This is compounded by the low redundancies within their communication networks, thereby increasing the vulnerability of these networks. For instance, the underwater volcanic eruption in Tonga in 2022[8] and the passing off Typhoon Chan-Hom through the Mariana Islands in 2015 completely severed — in both cases — a sole submarine cable connection, severely limiting connectivity.[9] Therefore, identifying the role of natural hazards in the matrix of submarine communication cable vulnerabilities, is not only important, but assumes crucial significance in the face of increasing frequency, intensity and duration of adverse weather events. This paper — written by the authors, who have been awarded the Coalition for Disaster Resilient Infrastructure (CDRI) Fellowship for 2024-25 for their project entitled "Enhancement of Disaster-resilience of Critical Infrastructure relevant to India's Undersea Communications Cables"— accordingly seeks to identify potential natural-hazard risks to submarine cable infrastructure in India, highlighting the imperative need for policy intervention *vis-à -vis* the planned/existing onshore cable landing infrastructure, and makes a compelling case for a contextualised disaster-risk assessment to be undertaken with respect to the cable landing stations in India.

Submarine Cable Infrastructure and their Hazard-Vulnerabilities

The submarine communication cable system comprises not only the optic-fibre cable (the "wet plant") but also a "dry plant" that includes the cable-landing station and the beach manhole.[10] Beach manholes are structures set into a beach, whereby the subsea cable is connected to a terrestrial fibre-optic cable to be carried into the cable landing station.[11] Hazard-related disruptions may occur either where the cable is submerged underwater or at the associated onshore infrastructure. Hence, the vulnerabilities may either exist onshore or offshore. In fact, both the continental shelf and the

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[4] https://www.submarinenetworks.com/en/nv/news/cables-cut-after-magnitude-89-earthquake-in-japan
[5] Ibid
[6] "Damage to undersea cables is disrupting internet access across Africa", *The Economist,* 21 March 2024 https://www.economist.com/middle-east-and-africa/2024/03/21/damage-to-undersea-cables-is-disrupting-internet-access-across-africa Also See: Niva Yadav, "WACS subsea cable off West Africa repaired after landslide damage" *DataCentreDynamics,* 07 May, 2024. https://www.datacenterdynamics.com/en/news/wacs-subsea-cable-off-west-africa-repaired-after-landslide-damage/
[7] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network",
[8] Chris Stokel-Walker, "Tonga's volcano blast cut it off from the world. Here's what it will take to get it reconnected", *MIT Technology Review,* January 18, 2022. https://www.technologyreview.com/2022/01/18/1043790/tongas-volcano-internet-reconnected/
[9] Gaynor Dumat-ol Daleno, "CNMI disconnected: Cut cable shuts down phones, banking", *Pacific Daily News,* 08 July 2015 https://www.guampdn.com/news/local/cnmi-disconnected-cut-cable-shuts-down-phones-banking/article_eabebf7f-9988-5b8f-820f-49e15847d074.html
[10] Jill C Gallagher and Nicole Carter, "Protection of Undersea Telecommunication Cables: Issues for Congress", *Congressional Research Service,* 07 August 2023. https://crsreports.congress.gov/product/pdf/R/R47648
[11] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network"

coast, which is where the cable landing stations are situated and where a majority of the cables congregate, have a higher incidence of natural hazards.[12] This notwithstanding, it is in waters deeper than 1,500 metres that nearly 30 per cent of faults are caused as a result of natural hazards.[13] This stems from the twin facts that in shallow depths, cables are armoured and are often buried beneath the seabed, thereby affording them some degree of protection from damage. On the contrary, the weight of the armour-sheath and the technical challenges of successfully burying cables in cases or conduits where the seabed is at a considerable depth from the sea surface, precludes such protective measures being adopted in deep waters.

Natural Hazards

Insofar as natural hazards are concerned, they may further be characterised as either instantaneous events — which are essentially one-off disruptions — or long-term hazards that manifest over large periods of time, such as sea-level rise.

Instantaneous Events. Instantaneous events occur as one-off events and have tremendous destructive force. Such events may occur either underwater or onshore, often with spillover effects from one onto the other. Underwater instantaneous events primarily damage the 'wet plant' of the cable system, i.e., the submarine cable itself. Damage could entail the exposure of previously buried cables, excessively burying cables beneath the mobilised sediment, or the cables suffering from abrasion or chafing.[14] On the other hand, onshore instantaneous events pose a greater hazard to onshore infrastructure such as the beach manholes and the cable landing stations. The following hazards are considered to be primary hazards:

> **(1) Submarine Landslides**. These are essentially downslope movements of sediment or rock when stresses acting downslope exceed the sediment strength on the slope.[15] They mobilise hundreds to thousands of cubic kilometres of sediment volume and rock along slopes, and frequently occur in active river deltas, submarine canyons, volcanic islands, and on the open continental shelf.[16] Submarine landslides may be triggered by events such as earthquakes, volcanic eruptions, cyclones and major storms, rapid sediment-deposition by river floods, gas pressures, human activity, etc. They may even occur without instantaneous triggers due to factors such as weakening sediment strength and increasing stresses.[17] It is often the submarine landslide that is the primary cause of damage to underwater cables, and it is other factors such as earthquakes, cyclical wave action, etc., that are usually responsible for the occurrence of submarine landslides. The impact of submarine landslides on seabed

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[12] Lionel Carter, "*Submarine cables and the oceans: connecting the world*"
[13] Ibid
[14] Ibid
[15] H J Lee et al, "Submarine mass movements on continental margins", Continental Margin Sedimentation https://www.preventionweb.net/understanding-disaster-risk/terminology/hips/gh0031
[16] Ibid
[17] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network"

infrastructure is so large and relatable that researchers have developed a methodology to study submarine landslides using historically available cable-break data.[18]

(2) Turbidity Currents. Another form of sediment flow are turbidity currents. These involve the downslope transport of a dilute suspension of sediment grains, i.e., a mix of sediment and water, with speeds ranging from 28 metres per second at mid-slope to 6 metres per second in abyssal plains.[19] Turbidity currents may begin as submarine landslides and then transform into more fluid sediment flows after mixing with seawater capable of travelling much longer distances.[20] As a result, they can have a significantly larger impact on seabed infrastructure both at distance and at depth. In 2006, the Pingtung earthquake, whose epicentre lay offshore from southwest Taiwan, generated powerful turbidity currents that damaged fourteen cables at depths ranging from 612 metres to 3250 metres over a period of fourteen hours.[21] The formation of turbidity currents depends on factors similar to the formation of submarine landslides, with earthquakes, tropical cyclones, storm waves, cyclical wave action, and river sedimentation, being primary causes.[22] The velocity of the turbidity current depends upon the bathymetric slope across which it is moving and can have a significant destructive influence on cable systems.

(3) Earthquakes. Earthquakes, as a natural hazard, threaten not only the submarine cable underwater infrastructure but also associated onshore infrastructure. Much depends upon the position of the epicentre — focal point — of the earthquake. Earthquakes can give rise to submarine landslides and turbidity currents which, as highlighted above, have a significant impact on underwater cables, especially those unarmoured ones that are located at greater depths.[23] Earthquakes can also damage the beach manhole or cable landing station either from direct impact or from the creation of powerful *tsunamis*. History is replete with examples of extensive damage caused by earthquakes, from the 1929 Grand Banks earthquake, and the 2003 Boumerdès earthquake off Algeria, to the 2006 earthquake off Taiwan, which disrupted multiple cables at once.[24]

(4) Cyclones and Storm Surges. Cyclones (also known as hurricanes and typhoons) are associated with extreme rainfall and high wind speeds. They have particularly adverse impacts upon coastal infrastructure associated with submarine communication cables. This manifests in the form of storm surges and high wind speeds. A storm surge is the abnormal

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[18] Ed L Pope, Peter J Talling, and Lionel Carter, "Which earthquakes trigger damaging submarine mass movements: Insights from a global record of submarine cable breaks?" *Marine Geology 384* (2017) 131-146 https://doi.org/10.1016/j.margeo.2016.01.009

[19] Shu-Kun Hsu et al, "Turbidity Currents, Submarine Landslides and the 2006 Pingtung Earthquake off SW Taiwan", *Terrestrial, Atmospheric and Oceanic Sciences Journal 19* (2008), 767-772 http://tao.cgu.org.tw/index.php/articles/archive/geophysics/item/808

[20] Lionel Carter, "*Submarine cables and the oceans: connecting the world*"

[21] Ibid

[22] Ed L Pope, Peter J Talling, and Lionel Carter, "Which earthquakes trigger damaging submarine mass movements: Insights from a global record of submarine cable breaks?"

[23] Christof Gerlach, "*Economic Impact of Submarine Cable Disruptions*"

[24] Ibid

rise of seawater level during a storm caused by powerful winds pushing water onshore.[25] The inundation caused by the storm surge can flood — and potentially damage — local infrastructure.[26] This was observed in Puerto Rico after Hurricane Maria (a Category 5 hurricane) flooded a cable landing station due to a storm surge of 1.8 to 2.7 metres. The cable network had to be powered down to prevent equipment damage.[27] This led to loss of connectivity not only in Puerto Rico but also in other South American States that relied on this cable landing station as a gateway for transit.[28] Since the beach manhole(s) and cable landing station(s) form a point of congregation for multiple cables, any significant damage to these will have a serious impact on the national and regional communication network than might be the case where damage occurs to individual cables.[29] The study, in fact, noted that "*storm surges are among the most costly and deadly natural hazards, and can episodically raise coastal water levels by up to 4 metres due to extra-tropical weather systems, and over 9 metres when caused by tropical systems*".[30] A substantial portion of critical infrastructure is susceptible to coastal flooding and climatic-prediction models indicate that this susceptibility is likely to increase.[31] The study also noted that the "e*ffect of cyclones on shipping can also pose a risk to subsea cables. Roughly 13 percent to 40 percent of ships that that attempt to "ride out" typhoons off major ports have been estimated to drag their anchors. As such they plough the seabed, endangering cables in the vessels' path. For example, in 1979, anchor dragging during Typhoon Hope damaged five subsea cables in Hong Kong Harbour.* In fact, storm surges and cyclones have impacts beyond just flooding, especially in the form of enhanced coastal erosion.

(5) **Coastal Erosion**. Coastal erosion has an impact on shore-based infrastructure especially the beach manhole segment. This can erode the beach manhole cover and expose cables to wave action, the terrestrial portions of which may not be as resistant to seawater as their submerged counterparts.[32] Further, cable landing stations right on the shore could also face significant structural challenges in the face of a receding shoreline. In Argentina, due to the amount of erosion, a beach manhole had to be relocated farther inland and re-buried deeper in the beach to reduce chances of exposure.[33] Coastal erosion can occur up to several metres per year, with south Asia figuring as one of its hotspots.[34] Given the proximity of cable landing stations to the mean sea-level, roughly 37.6 per cent of cable landing stations were found to lie within ten metres of the present mean sea-level, and 4.9 per cent lie within

[25] "What is storm surge?" Facts, National Ocean Service, last accessed 12 June 2024 https://oceanservice.noaa.gov/facts/stormsurge-stormtide.html
[26] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network"
[27] Doug Madory, "Puerto Rico's Slow Internet Recovery", *Medium,* 07 December 2017
[28] Ibid
[29] Christof Gerlach, "*Economic Impact of Submarine Cable Disruptions*"
[30] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network"
[31] Job C M Dullaart et al, "Accounting for tropical cyclones more than doubles the global population exposed to low-probability coastal flooding", *Communications Earth & Environment 2,* (2021) https://www.nature.com/articles/s43247-021-00204-9
[32] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network"
[33] https://www.datacenterdynamics.com/en/analysis/the-tide-comes-in-for-subsea-cable-networks/
[34] Ibid

two metres, with the majority of cable stations (80.6 per cent lying on slopes less than four degrees[35]— this threat acquires significant proportions.

Climate Change and Sea Level Rise. Climate change and sea level rise are not classified as instantaneous events as their effects are felt progressively over a period of time. The impact of climate change also manifests itself in the increasing intensity and frequency of current hazards.[36] Therefore, disaster-resilience needs to not only factor the occurrence of the hazards but also the manner in which it be impacted by climate change. Due to greater variations in sea level at times of tropical cyclones and storm surges, climate change and sea level rise will particularly affect onshore cable landing infrastructure. Similarly greater rates of coastal erosion occasioned by higher sea levels threaten the beach manhole cover. Climate change additionally affects and modifies human behaviour, since rising oceanic temperatures are affecting entire food chains from phytoplankton upwards, forcing their horizontal and vertical migration, thereby compelling humans to fish in deeper and more distant waters, where seabed cables lie unarmoured and are therefore more vulnerable.[37] Hence, each scenario of climate change variability will be associated with a corresponding risk, and an analysis factoring projected scenarios of climate change needs to be conducted.

A recent paper, entitled, *"Climate Change Hotspots and Implications for the Global Subsea Telecommunications Network"* has specifically identified and discussed natural hazards to the global telecommunications network with climate change having been factored. One of the key insights of the paper is that there is "*wide geographical variability in climate-driven changes…and it is essential to determine site-specific environmental conditions…*" to more accurately gauge and predict climate change-accentuated natural disaster risk.[38] Therefore, not only is it necessary to undertake a risk assessment of natural hazards adjusted for climate-change realities but to be truly effective this assessment must also factor site-specific conditions. This holds especially true for onshore cable landing infrastructure. It may be appreciated that the congregation of multiple cables presents a unique vulnerability that is compounded by the fact that the cable landing infrastructure has not received requisite focus vis-à-vis natural-disaster risks. This onshore segment, in fact, is particularly well suited for policy interventions involving national security and jurisdictional issues. Implementation of legal and policy tools for cable landing stations and beach manholes will accordingly be more effective and far reaching. National instruments allow for policy options such as mandating localised climate assessment as part of the planning and designing process. Therefore, such analyses must be conducted and policy response options developed.

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[35] Ibid

[36] H Lee and J Romero, "Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" (Geneva, IPCC, 2023) https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

[37] https://openknowledge.fao.org/server/api/core/bitstreams/9aeb8ade-a623-4954-8adf-204daae3b5de/content
Also See: Mike Clare, "Submarine Cable Protection and the Environment", *International Cable Protection Committee No. 6,* May 2023 https://iscpc.org/publications/submarine-cable-protection-and-the-environment/ICPC_Public_EU_May%202023.pdf

[38] MA Clare et al., "Climate Change Hotspots and Implications for The Global Subsea Telecommunications Network",

Relevance to India

India currently has 17 international cable landing stations spread across five cities of the country, viz., Mumbai, Chennai, Kochi, Tuticorin, and Thiruvananthapuram.[39] Additionally, domestic submarine communication cables land in seven islands of Andaman and Nicobar chain, and eleven islands of the Lakshadweep chain.[40] It is pertinent to note that of the 17 cable landing stations in India, as many as eight are based in Mumbai and four are based in Chennai.[41] Consequently, any damage to cable landing infrastructure in these two cities may potentially affect the functioning of multiple cables simultaneously.

Further, recognising the importance of cable landing stations to India's push for a digitalised economy, the state of West Bengal has announced an "Internet Cable Landing Station Policy 2023" to bring ten cable landing stations to West Bengal by 2025 with Digha, in the district of Medinipur, being identified as a probable landing site.[42]

Resilience (of infrastructure) has been defined as the *"amount of change a system can undergo without changing state"* and vulnerability as "*the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes*".[43] Since, the amount of change a system can go through without it changing its state will determine its ability to cope with climate extremes, the concepts of resilience and vulnerability are clearly linked, and any assessment of the 'resilience' of infrastructure must begin by identifying the degree and extent of its 'vulnerability'.[44] Vulnerability, in turn, is a function of exposure, sensitivity, and adaptive capacity.[45] 'Exposure' as per the Fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report is "*the nature and degree to which a system is exposed to significant climatic variations"*[46] and hence, understanding the exposure of these cities to natural hazards becomes important as this will affect the exposure of the

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[39] "India secures its burgeoning submarine cables industry", *Communications Today,* February 2024 https://www.communicationstoday.co.in/india-secures-its-burgeoning-submarine-cables-industry/

[40] Ibid

[41] Suvesh Chattopadhyaya, "Cable Landing Stations in India", *Submarine Cable Networks,* last accessed 20 June 2024 https://www.transitchina.com/zh/stations/asia/india

[42] Tanuja K, "Internet Cable Landing Station Policy 2023 Can attract Rs 10000 Crore Investment for Bengal", *Telecom Talk,* 24 November 2023 https://telecomtalk.info/internet-cable-landing-station-policy-2023-can-attract-rs-10000-crore-investment-for-bengal/899147/

[43] https://archive.ipcc.ch/ipccreports/tar/wg2/index.php?idp=689

[44] There has been inconsistent utilisation of the terminology of vulnerability and resilience with the two even used interchangeably. See Nick Brooks, "Vulnerability, risk and adaptation: A conceptual framework", *Tyndall Centre for Climate Change Research,* Working Paper 38 (November 2003)

[45] Shouvik Das et al., "Linking IPCC AR4 & AR5 frameworks for assessing vulnerability and risk to climate change in the Indian Bengal Delta", *Progress in Disaster Science,* Volume 7, (October 2020) https://www.sciencedirect.com/science/article/pii/S2590061720300478. This approach of understanding vulnerability has changed subsequently in the Fifth and Sixth Assessment Reports. It is currently utilised as it provides a useful framework to conceptualise the idea of vulnerability.

[46] James J McCarthy et al., "Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the IPCC", *Cambridge University Press,* (2001). https://www.ipcc.ch/site/assets/uploads/2018/03/WGII_TAR_full_report-2.pdf. There has been variance in the definition of the term "exposure" in the literature related to climate hazard assessment. It has also been defined as "inventory of elements in an area in which hazard events may occur". The present definition has been used as it factors in climatic variations as opposed to an inventory of human assets exposed.

infrastructure located within these cities.[47] Since sensitivity, and adaptive capacity are functions of the infrastructural element, this analysis has been reserved for a future paper. As the exact locations of cable landing stations are usually not public information, hazard-wise susceptibility data for Mumbai, Chennai, Digha, West Bengal; and Andaman & Nicobar Islands(A&N) will be considered.

Tropical Cyclones. "A Vulnerability Atlas of India" has been prepared by the "Building Material Technology Promotion Council" (BMTPC) of the Ministry of Urban Development, which maps the vulnerability of districts of India vis-à-vis a variety of climate hazards.[48] Tropical cyclones are considered a multi-hazard weather system as they are often accompanied with strong wind speeds, high precipitation, coastal flooding, and storm surges.[49] An Indian Meteorological Department (IMD) report has built on the BMTPC classification by undertaking a district-level analysis of these factors, assigned each of them a weighted value, and calculated a "proneness rating" ranging from very high (P1), high (P2), moderate (P3) and low (P4).[50] This data has been compiled for a period from 1891 to 2008.

District	**Flood Zone**	**No. of Severe Cyclones**	**Total No. of Cyclones**	**Wind Speed (mps)** *	**PMSS (m)**	**PMP (cm)**	**Vulnerability**	**Proneness**
Mumbai	Yes	01	1	44	5	95	High	**P3**
Chennai	Yes	0	0	50	3.5	52	Very High	**P2**
Digha	Yes	8	16	47-50	13	56	Very High	**P1**
A&N	Yes	2	2	44	N/A	N/A	High	**P3**

Legend: PMSS – Possible Maximum Storm Surge; PMP – Possible Maximum Precipitation.
* 1 metre per second (mps) = 3.6 kilometres per hour = 1.944 knots

Table 1: Cyclone Proneness
Source: GS Mandal and M Mohapatra, "Cyclone Hazard Prone Districts of India: A Report"

[47] H O Portner et al., "IPCC 2022: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", *Cambridge University Press,* (2022); 3056 doi:10.1017/9781009325844. This report utilises the term 'hazard' to understand the potential occurrence of a natural event that may cause damage. However, for the purposes of this paper, the term hazard is used to refer to the natural event itself.
[48] "*Vulnerability Atlas of India*", Building Materials and Technology Promotion Council, Ministry of Urban and Housing Affairs, Government of India, Third Edition (2019). https://bmtpc.org/topics.aspx?mid=56&Mid1=180
[49] GS Mandal and M Mohapatra, "Cyclone Hazard Prone Districts of India: A Report", *National Disaster Management Authority,* (2010) https://ndma.gov.in/sites/default/files/PDF/cyclone/cyclonepronedistrict.pdf
[50] Ibid

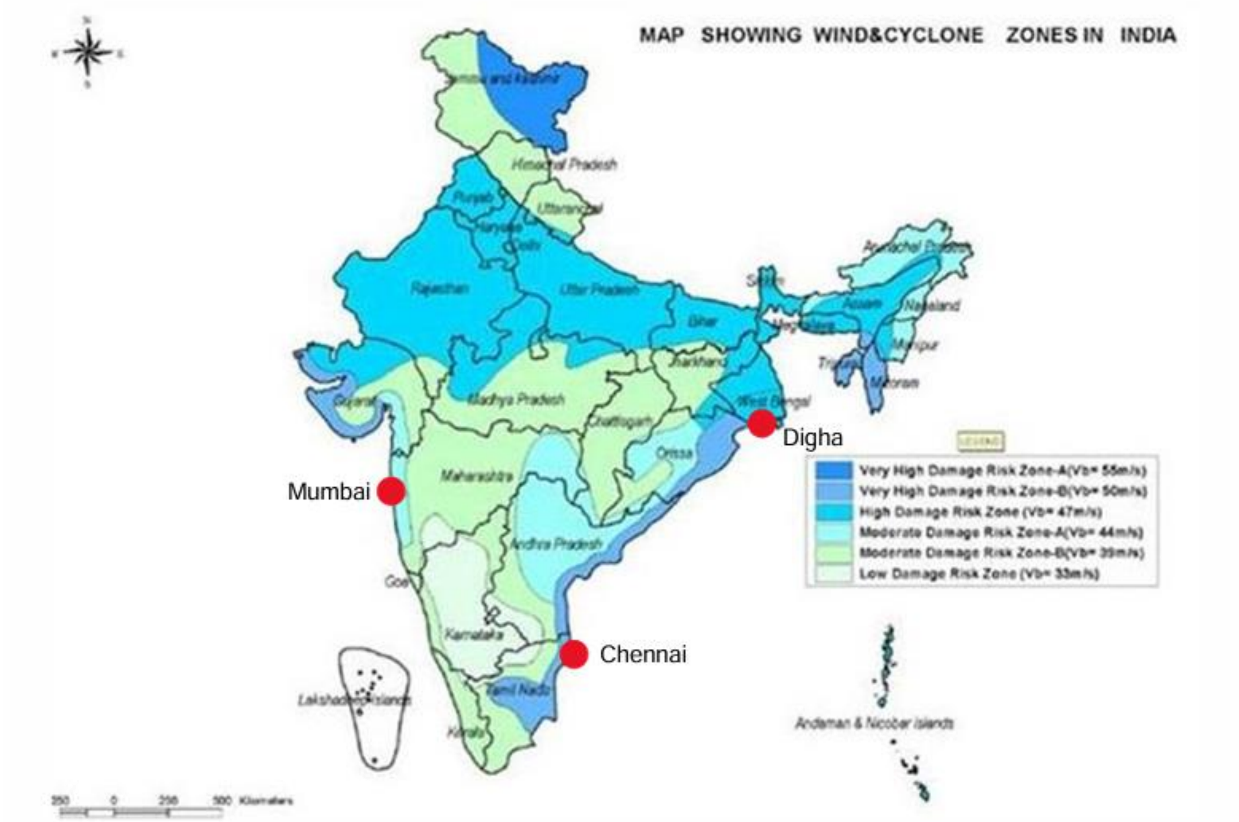

Fig 1: Wind & Cyclone Risk Zones in India

Source: "Cyclone", National Disaster Management Authority, Government of India https://ndma.gov.in/Natural-Hazards/Cyclone

Coastal Erosion. The "National Assessment of Shoreline Changes along the Indian Coast" — a study conducted by the "National Centre for Coastal Research" (NCCR) — indicates that 33.6 per cent of the Indian coast is undergoing erosion.[51] Of this, the shorelines in West Bengal and Tamil Nadu are eroding at a rate of 60.5 per cent and 42.2 per cent, respectively, over the period 1990-2018.[52] 25.5 per cent of the coastline of the state of Maharashtra, too, is suffering erosion.[53] The manner in which shorelines undergo change differs quite widely — even within the same state. The change need not necessarily be wrought by erosion. Accretion, or the seaward development of the shoreline is also a process that does occur. While a greater percentage of the coast of Tamil Nadu is undergoing erosion, the city of Chennai itself is undergoing high levels of accretion and is, in fact, classified as an accretion hot spot.[54] Even within Chennai, the coast near the Adyar River is stable

[51] Dr Sisir K Dash, "National Assessment of Shoreline Changes along Indian Coast – East Coast", *National Centre for Coastal Research, Ministry of Earth Sciences, Government of India*, (March 2022) p7 https://www.nccr.gov.in/?q=technical-report
[52] Ibid
[53] Ibid
[54] Ibid p23

or undergoing low levels of erosion, but the coast between the Adyar and the Coovum River — which corresponds to the area of Marina Beach — varies from "low erosion" to "high accretion".[55] Especially high levels of coastal accretion may also pose challenges to the beach manholes as it may render them more difficult to locate and access by maintenance teams. Further, additional build-up tends to create extra pressure on the beach manholes, weakening their structural integrity and thus necessitating more frequent repair and maintenance. This problem may be exacerbated if frequent repairs need to be carried out in Coastal Regulation Zones which would entail seeking of necessary permissions with the associated procedural requirements. In the above context, it is pertinent to note, that, not very far north of Marina Beach, the coast near Kattupalli is undergoing high levels of erosion.[56] Similarly, while the general coast along West Bengal suffers an alarming rate of erosion, the shoreline around Digha — where the new cable landing stations are proposed — experiences are both low levels of erosion as well as some accretion.[57] Therefore, when it comes to coastal erosion, the precise location of the beach manhole and cable landing station assumes great importance.

Sea Level Rise. Another aspect that will affect the availability of coastal space is the oft-discussed challenge of sea level rise, with India being no exception to the adverse impacts of this phenomenon. Sea-level rise figures, while not appearing to be overly alarming by themselves in the immediate term, are compounded by the annual flooding levels that the region routinely receives. Climate Central — a non-profit organisation that conducts research and reports on climate change and its effects on the lives of people — has developed a climate risk screening tool that identifies the extent of land projected to be below annual flood level by 2050. The following images depict the forecasted water levels at the sites of cable landing infrastructure because of the projected sea level rise and the annual floods based on a medium emission cut scenario factoring in a two degrees Centigrade increase in temperature. These images indicate that Mumbai and Digha are particularly vulnerable to a significant increase in water levels by 2050 (sea level rise combined with annual flood levels). In Chennai, and the Andaman and Nicobar Islands, specific cable landing locations will need to be identified in order to assess the risk as the effects at these places are not uniform. Is emphasised that particular focus needs to be given to this factor as cable projects are generally designed with a 25-year life cycle and, therefore, these sorts of adverse effects are expected to be experienced within the life span of one cable landing project, with 2024 as a base year.

[55] Ibid Map No. NCCR/SCM/359
[56] Ibid Map No. NCCR/SCM/360
[57] Ibid Map No. NCCR/SCM/ 496

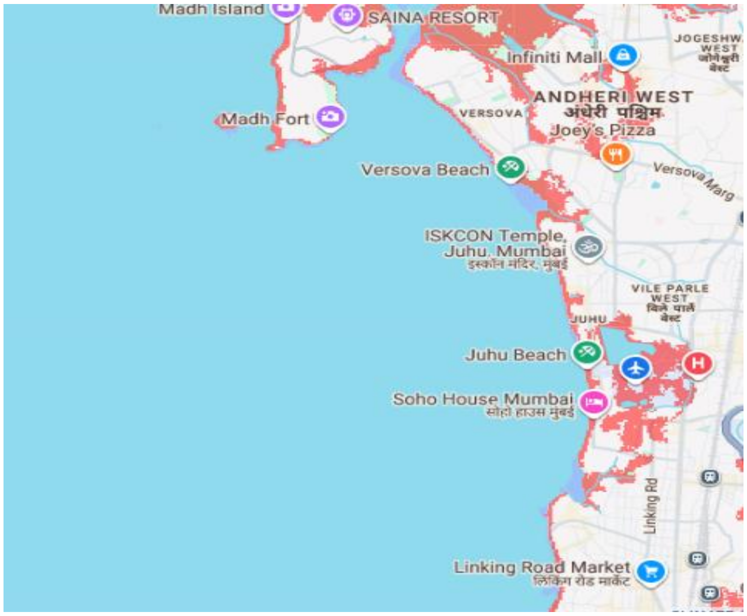

Fig 2: Mumbai

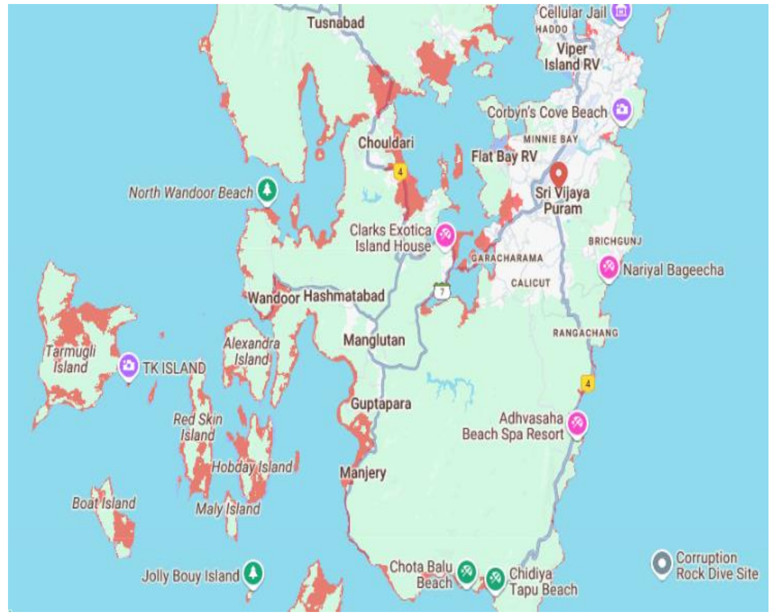

Fig 3: A&N

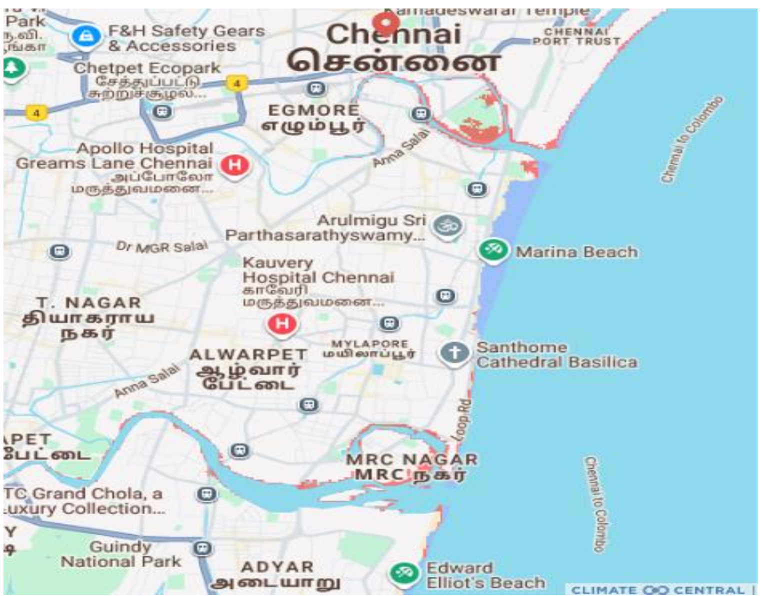

Fig 4: Chennai

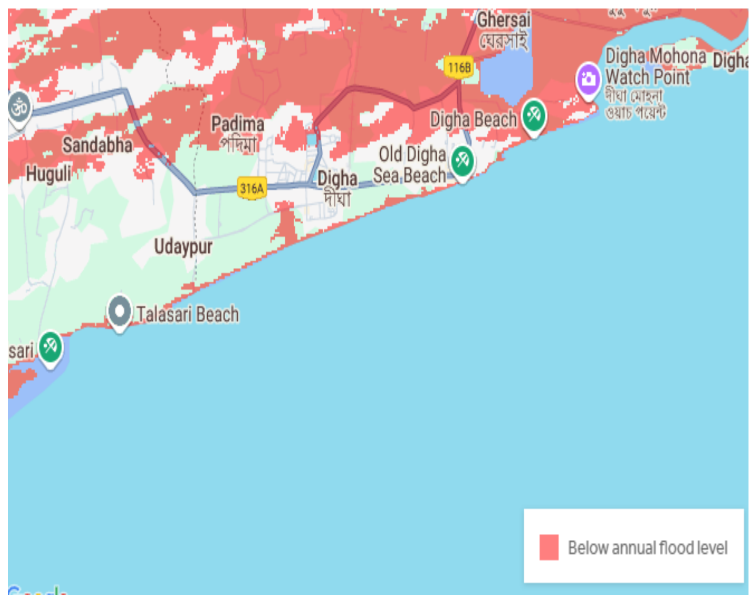

Fig 5: Digha, WB

Source: "Land projected to be below annual flood level in 2050", Coastal Risk Screening Tool, Climate Central
https://coastal.climatecentral.org/map/14/72.8412/19.1334/?theme=sea_level_rise&map_type=year&basemap=roadmap&contiguous=true&elevation_model=best_available&forecast_year=2050&pathway=rcp45&percentile=p50&refresh=true&return_level=return_level_1&rl_model=coast_rp&slr_model=kopp_2014

Multi-hazard Vulnerability. Obviously, it is important to not look at these hazards in isolation, as the effects over a geographic space are likely to be compounded over time. Hence an assessment of multi-hazard vulnerability is very important. The "Indian National Centre for Ocean Information Services" (INCOIS) has prepared a "Coastal Multi-Hazard Vulnerability Atlas" factoring sea-level change rate, shoreline change rate, high-resolution topography, and extreme water level.[58]

District	Area under Multi-Hazard Vulnerability (sq. kms)	Percentage of District under Multi-Hazard Vulnerability
Mumbai City	23.13	37.29
Mumbai Suburban	105.30	25.19
Chennai	195.35	58.67
Purba Medinipur	2829.29	74.27
South Andaman	225.15	36.27

Fig 6: Mumbai

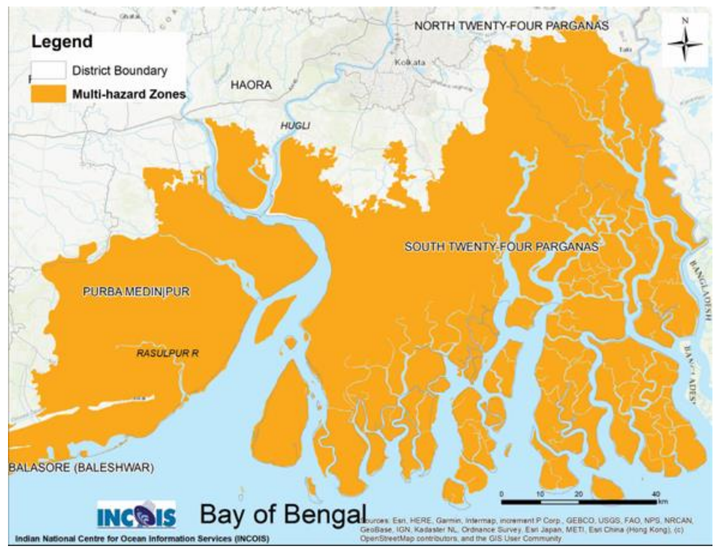

Fig 7: Purba Medinipur, WB

Source: S Nayak et al., "Coastal Multi-Hazard Vulnerability Atlas", *Indian National Centre for Ocean Information Services*

Dynamism of Climate Change

Recently, both Mumbai and Chennai have been bearing the brunt of more frequent and intense natural disasters. Mumbai is particularly vulnerable to flooding and storm surges that may be caused by tropical cyclones, whose frequency of occurrence and intensity are projected to increase with

[58] S Nayak et al., "Coastal Multi-Hazard Vulnerability Atlas", *Indian National Centre for Ocean Information Services, Ministry of Earth Sciences, Government of India,* (2022). https://rsmcnewdelhi.imd.gov.in/download.php?path=uploads/climatology/INCOIS_MHVM_Atlas_Document_HS.pdf

rising surface and upper ocean temperatures in the Arabian Sea.[59] Within the last five years alone, as many as three cyclones, namely, *Nisarga, Tauktae,* and *BiparjoyI*, have impacted Mumbai, a city often cited to be shielded from cyclones.[60] Additionally, the past decade has seen four years of notable flooding in the city.[61] Similarly Chennai is now routinely flooded during the period of November and December, having suffered fourteen cyclonic storms in the past 20 years.[62] Both these cities are particularly vulnerable to flooding and storm surges as their average elevation is less than 15 metres above sea level.[63] A large number of depressions are formed in the Bay of Bengal and hence the coastal districts of West Bengal and Tamil Nadu are in the "high" to "very high" risk of cyclonic storms intensity category.[64] Therefore, not only do existing cable landing stations need to be upgraded for climate resilience but new cable projects must factor climate change risks and impacts in the design and planning stages of each such project especially when incentivised through State policy.

Conclusion

Growing demand for stable and persistent data connectivity is driving the rapid growth of cable infrastructure. While undersea cable infrastructure is designed for a life of 20 to 30 years, the timelines in respect of climate change vary significantly. Moreover, neither the occurrence nor the effects of natural disasters are uniform across the globe. This requires resilience to be a bespoke solution relevant to local vulnerabilities, rather than being a generic 'one-size-fits-all' one. Localised effects of climate disasters require to be factored into the design and building of cable infrastructure, especially the cable landing stations and beach manholes. The mapping of local vulnerabilities associated with cable landing infrastructure in India's coastal cities is critical to the development of policy solutions tailored to Indian conditions. While at a global level, research has been done to identify "climate-change hotspots" vis-à-vis cable landing infrastructure, such research is not available for Indian conditions. For instance, the "Recommendations on the Licensing Framework and Regulatory Mechanism for Submarine Cable Landing in India" released by the Telecom Regulatory Authority of India on 19 June 2023 merely makes a mention of the fact that the cable network may be damaged by natural disasters without any details being provided in respect of mitigating mechanisms.[65] Likewise, while the "Expert Appraisal Committee" recommendations for the Chennai-Andaman Nicobar Islands (CANI) Submarine Cable System under the Coastal Regulation Zone regulations recommends moving the beach manhole and cable landing station at

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[59] Adam H Sobel et al, "Tropical Cyclone Hazard to Mumbai in the Recent Historical Climate", *Monthly Weather Review Vol 147* (2019) 2355- 2366 https://www.ldeo.columbia.edu/~sobel/Papers/sobel_et_al_19_mumbai.pdf
[60] Prabhash K Dutta, "Nisarga, an exception: Why Mumbai does not get cyclones", *India Today,* 03 June 2020 https://www.indiatoday.in/india/story/nisarga-an-exception-why-mumbai-does-not-get-cyclones-1684957-2020-06-03
[61] Dharmappa Hagare, "Climate Change May Worsen Flooding in Mumbai and Chennai", *The Diplomat,* 20 June 2024 https://thediplomat.com/2024/06/climate-change-may-worsen-flooding-in-mumbai-and-chennai/
[62] Ibid
[63] Ibid
[64] GS Mandal and M Mohapatra, "Cyclone Hazard Prone Districts of India: A Report", *National Disaster Management Authority,* (2010) https://ndma.gov.in/sites/default/files/PDF/cyclone/cyclonepronedistrict.pdf
[65] "Recommendations on Licensing Framework and Regulatory Mechanism for Submarine Cable Landing in India", *Telecom Regulatory Authority of India* (June 2023) https://trai.gov.in/sites/default/files/Recommendation_19062023.pdf

the Chennai end some 10-12 metres landward in high erosion areas,[66] a similar specificity is lacking for the Andaman-Nicobar leg of the project. Thus, while there is an acknowledgment of the impact of natural hazards on cable systems, a more detailed analysis of the extent of such impacts is certainly required. In this context, it is a matter of some solace (and considerable anticipation) that the National Maritime Foundation, New Delhi, will be undertaking a research project under the Coalition for Disaster Resilient Infrastructure Fellowship 2024-25. Within this fellowship project a contextualised disaster-risk assessment will be undertaken for cable landing sites in India, and policy solutions will be recommended to increase the disaster-resilience of such cable landing infrastructure.

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[66] Minutes Of The 205th Meeting Of The Expert Appraisal Committee For Projects Related To Coastal Regulation Zone, *Ministry of Environment, Forest and Climate Change* (December 2018) https://environmentclearance.nic.in/writereaddata/Form-1A/Minutes/18122018I40QHOXPFINALMINUTES205CRAEACMEETINGDECEMBER172018.pdf