Estimation of volume changes of the coastline between Mt. Reynisfjall and Kúðafljót river, South-Iceland during the 20th and 21st centuries.

Icelandic Road and Coastal Administration Research Fund

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Front page photograph: The photo is taken at the Höfðafjara beach, on the western part of the Kötlutangi protrusion, looking west towards the town of Vík. The photo is taken after an erosion event on the beach, which created about a 2 m high erosional scarp and exposed the upper part of the glacial outburst flood deposit from 1918. Most of the upper part of the deposit is rather fine material and pumice, with interbedded rocks and boulders. Photograph: Jóhannes M. Jóhannesson.

Forsíðumynd: Myndin er tekin í Höfðafjöru, á vesturhluta Kötlutanga, horft til vesturs í átt að Vík. Myndin er tekin í kjölfar rofs í fjörunni, sem myndaði um 2 m hátt rofabarð og afhjúpaði efri hluta setsins úr jökulhlaupinu frá 1918. Stærstur hluti efri hluta setsins er frekar fíngerður sandur og vikur, með stöku grjóti og stórgrýti. Ljósmynd: Jóhannes M. Jóhannesson.

Abstract

The coastline between Reynisfjall mountain and Kúðafljót river in south Iceland has undergone large changes since the beginning of the 20th century. With new data on coastline position, the changes in coastline position and volume between 1904 and 2024 were calculated, including a new calculation of the volume of Kötlutangi protrusion soon after the 1918 glacial outburst flood caused by an eruption in Katla volcano. The new volume is about 325 Mm^3 of material deposited below the 0 meters in chart datum, increasing the total volume by about 25-75 Mm^3 from previous calculations.

To break down the data for more precise results, the research area was split into two and each part into several different smaller parts based on beach names from the area. The five beaches on the western part all show similar evolution over the period, with advancing coastline in the decades following 1918 but then the coastline started to retreat and is still doing so at all beaches. The start of the advancement and retreat differs between beaches, were the closer the beach is to the Kötlutangi protrusion, the quicker the advance and the consequent retreat started. The Víkurfjara beach, which is the most western most beach, started to advance after 1926 at a rate of about 9,1 meters per year until 1969 and 1971. After 1971, the beach started to retreat at a rate of about 5,5 m per year until 2021. The volume of the western part of the research area declined during the period between 1904 and 2024 by about 1,3 million (M) cubic meters (m^3), while the eastern part grew about 160 Mm^3. There are indications that the 1918 glacial outburst flood had large impacts on the volume of the western part at least until 1973, but after 1973 the volume decreased almost to the same as it was in 1904. Although the volume for the western part decreased overall between 1904 and 2024, the three westernmost beaches had an increase in volume over the period, while the other two lost volume, indicating that the suspected volume increase due to the 1918 glacial outburst flood has not completely disappeared on the western part. The Víkurfjara beach has a high number of bathymetric survey data available. There, the volume increase for the 15 profiles on the beach is only 400 m^3/m, and in total about 80 thousand m^3, but surveys in-between show an almost continues decrease since 1971 that would suggest that there was a large increase in volume as some point between 1904 and 1971.

The six beaches on the eastern part do not show a similar evolution, as the two most western ones have a net retreat from 1904 to 2024, while the other four advance during the same period. All six beaches retreated in the first decades following the 1904 coastline but then start to advance around 1930 and onwards with only minor periods of retreat in between. The three easternmost beaches underwent the larges advancement, well over 200 m. The total volume for the eastern part increased from 1904 to 2024, and despite the coastline retreat of the two westernmost beaches, all the beaches increased their volume during the period.

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Ágrip

Strandlengjan milli Reynisfjalls og Kúðafljóts á Suðurlandi hefur tekið miklum breytingum frá upphafi 20. aldar. Með nýjum gögnum um þróun strandlínunnar, voru breytingar á staðsetningu strandlengjunnar og rúmmáli milli 1904 og 2024 reiknaðar, þar á meðal nýr útreikningur á rúmmáli Kötlutanga skömmu eftir jökulhlaupið 1918 sem varð vegna eldgoss í Kötlu. Nýja niðurstaðan er að um 325 Mm^3 af efni hafi borist út í sjó fyrir neðan sjókortanúlli, sem eykur heildarrúmmálið um 25-75 Mm^3 frá fyrri útreikningum.

Til að brjóta niður gögnin fyrir nákvæmari niðurstöður var rannsóknarsvæðinu skipt í tvennt og hvor hluti í nokkur mismunandi smærri svæði út frá fjörumörkum á svæðinu. Fjörurnar fimm á vesturhlutanum sýna allar svipaða þróun á tímabilinu, en strandlengjan fór að ganga fram á fyrstu áratugunum eftir 1918 en hefur síðan verið að hopa nánast samfleytt. Það er mismunandi á milli fjara hvenær fjaran fór að ganga fram og byrjaði síðan að hopa, en því nær sem svæðið er Kötlutanga því fyrr byrjaði fjaran að ganga fram og einnig að hopa. Víkurfjara, sem er vestasta ströndin, fór að vaxa eftir 1926. Vöxturinn var um 9,1 metra á ári fram til áranna 1969 og 1971. Eftir 1971 fór ströndin að hopa um 5,5 m á ári fram til 2021. Rúmmál vesturhluta strandarinnar minnkaði á tímabilinu 1904 til 2024 um 1,4 milljónir (M) rúmmetra (m^3) en austurhlutinn óx um 160 Mm^3. Vísbendingar eru um að jökulhlaupið 1918 hafi haft mikil áhrif á rúmmál vesturhluta strandarinnar að minnsta kosti fram til ársins 1973, en eftir 1973 hefur magnið minnkað og er nú nánast það sama og það var árið 1904. Þrátt fyrir að rúmmál vesturhlutans hafi minnkað í heildina á milli 1904 og 2024, jókst rúmmál á þremur vestustu fjörunum á tímabilinu, en hinar tvær misstu rúmmál. Það bendir til þess að hin líklega rúmmálsaukning vegna jökulhlaupsins 1918 sé ekki alveg horfin á vesturhlutanum. Þar sem fleiri mælingar hafa verið gerðar fyrir framan Víkurfjöru var hægt að skoða breytingar á rúmmáli þar betur. Rúmmálsaukningin fyrir sniðin 15 í fjörunni er aðeins 400 m^3/m, og í heildina 80 þúsund m^3, en mælingar þar á milli sýna nánast stöðuga minnkun á rúmmáli frá 1971 sem bendir til þess að það hafi orðið töluverð rúmmálsaukning einhvern tíma á árunum 1904 til 1971.

Fjörurnar sex á austurhlutanum þróuðust öðruvísi á tímabilinu. Fjörurnar tvær sem eru vestast á austurhlutanum hopuðu á tímabilinu 1904 til 2024, en hinar fjórar gengu fram. Allar sex fjörurnar hopuðu á fyrstu áratugunum eftir 1904, en byrjuðu síðan að ganga fram um 1930 og höfðu aðeins minniháttar tímabil þar sem þær hopuð inn á milli. Þrjár austustu fjörurnar gengu lengst fram, eða vel yfir 200 metra á tímabilinu. Heildar rúmmál fjaranna í austurhluta rannsóknarsvæðisins jókst frá 1904 til 2024 og þrátt fyrir hopið í tveimur fjörum, þá jókst rúmmálið í öllum fjörum á svæðinu yfir tímabilið.

Verkefnið er styrkt af rannsóknasjóði Vegagerðarinnar. Höfundar skýrslunnar bera ábyrgð á innihaldi hennar. Niðurstöður hennar ber ekki að túlka sem yfirlýsta stefnu Vegagerðarinnar eða álit þeirra stofnana eða fyrirtækja sem höfundar starfa hjá.

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Thanks

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Introduction

Objectives

The aim of this project is to calculate both the changes in coastline position and the volume changes of the coast between Mt. Reynisfjall in the West and Kúðafljót river in the East. With the coastline position calculations, the aim is to give rough calculations on the changes of the coastline and to have a closer look at those changes for each beach within the research area. The aim with the volume calculations is to have a rough calculation of the volume and the change in volume within the research area. The position and volume calculations will be set up so that it will be easy to add any future coastline positions and bathymetric survey to the system, making comparisons of future surveys readily available.

With these calculations, it can then be determined whether the coastline has been advancing or retreating, and if so, by how much during each period. The volume calculations will also provide insight into the behavior of the coastline and how it has responded to certain larger events, such as glacial outburst floods. Another objective of this project is to try to calculate the amount of material deposited on the seabed during the glacial outburst floods following the 1918 eruption of Katla volcano. The sediments from that outburst flood are believed to have extended the coastline south of Hjörleifshöfði by several kilometers and forming the sand protrusion of Kötlutangi (Larsen, 2018).

Materials and Methods

A recent project (Jónsdóttir and Sigurðarson, 2023) mapping the coastline changes in the area from aerial photographs and maps has made it possible to calculate both changes in the location and volume of the coastline between Mt. Reynisfjall and Kúðafljót.

Bathymetric surveys have also been made along the coast in front of Vík both by the Icelandic Hydrographic Service now a part of the Icelandic Coast Guard and the Icelandic Road and Coastal Administration (IRCA). The first survey was undertaken in 1953, but the surveys were irregular until the beginning of the 21st century when more frequent surveys were conducted. One bathymetric survey is available from around 1900 and is always referred to 1904 in text to match the 1904 coastline. The two datasets of coastlines and bathymetric surveys can now be combined to calculate the volume changes of the coastline in South Iceland.

Three new coastlines were mapped for this project, 1975, 1986 and 1990, and the methods described in Jónsdóttir and Sigurðarson, 2023, were used for drawing the coastlines from aerial photographs. The photographs used to map the coastlines had been georeferenced by the National Land Survey of Iceland. Most of the coastlines do not extend over the entire research area. The research area was therefore split into two parts, the western and the eastern part, and both parts then split into several smaller parts. The beach along the coastline has several different names, often named after the farm it belongs to, and they were used to split the western and eastern parts further down. Please note that the location of each beach in this project is not the precisely coincide with the geographical division of each beach, as some were extended or shortened to cover specific parts of the beach, for example an outlet of a river.

The coastline changes were then calculated for the mapped coastlines that extended over the entire research area, the western and the eastern part, and then individual beach. This was done to get a more detailed insight into the evolution of each beach.

To calculate the change in coastline positions, profiles were made at a 200-meter interval along the coastline. The western part of the research area has 87 profiles, and the eastern part has 121 profiles. Each profile has a 0-point, on the northern end of the profile, which the distance of every coastline for that profile was calculated from. Intersection point for each mapped coastline and each profile was then found, giving coordinates that the distance between the coastline and the 0-point could be calculated. The distance was then calculated using an application of the Pythagorean Theorem.

The bathymetric surveys used were mostly in shapefile form and ready to be used, whereas others had points with depth. These points were mapped and depth lines drawn in QGIS. All height/depth is in Chart Datum in this project. Intersection points were then found for each profile and each depth line for each survey, giving coordinates and depth to use to create a depth profile for each profile from each survey. On each profile, the 0-point is the starting point, with the next point being the coastline location. Both points are at 0 meters depth. After them, each point is from a different depth from the bathymetric survey. The distance between each point is calculated and the cumulative distance and the different depth of each point are plotted to make a profile. The volume of the profile can then be calculated in m^3/m and the total volume of the profile section in m^3 by multiplying the profile m^3/m with the width of the profile section. Once the m^3 has been found, it can be compared to the results from other bathymetric surveys.

The bathymetric surveys do not always line up with a coastline from the same year. When that occurred, a coastline close in time with the bathymetric survey was selected to be the coastline for that bathymetric survey. Although this does add uncertainty to the volume calculations, as coastline changes could have happened in the time passed between them, it is important to have a coastline position for the volume calculations. The coastline position acts as a second 0 point and without them the volume of that profile would be underestimated, and that underestimation would grow larger the further the first depth line would be away from the 0 point of the profile. This problem only affects calculations for the volume changes of the Víkurfjara and Fagradalsfjara beaches. The alternative would be to have the 0 point at 5 m depth like the first depth line that is common for most of the bathymetric surveys, but that would limit the scope of the volume changes greatly and negate the changes in coastline locations.

Results

Coastline changes

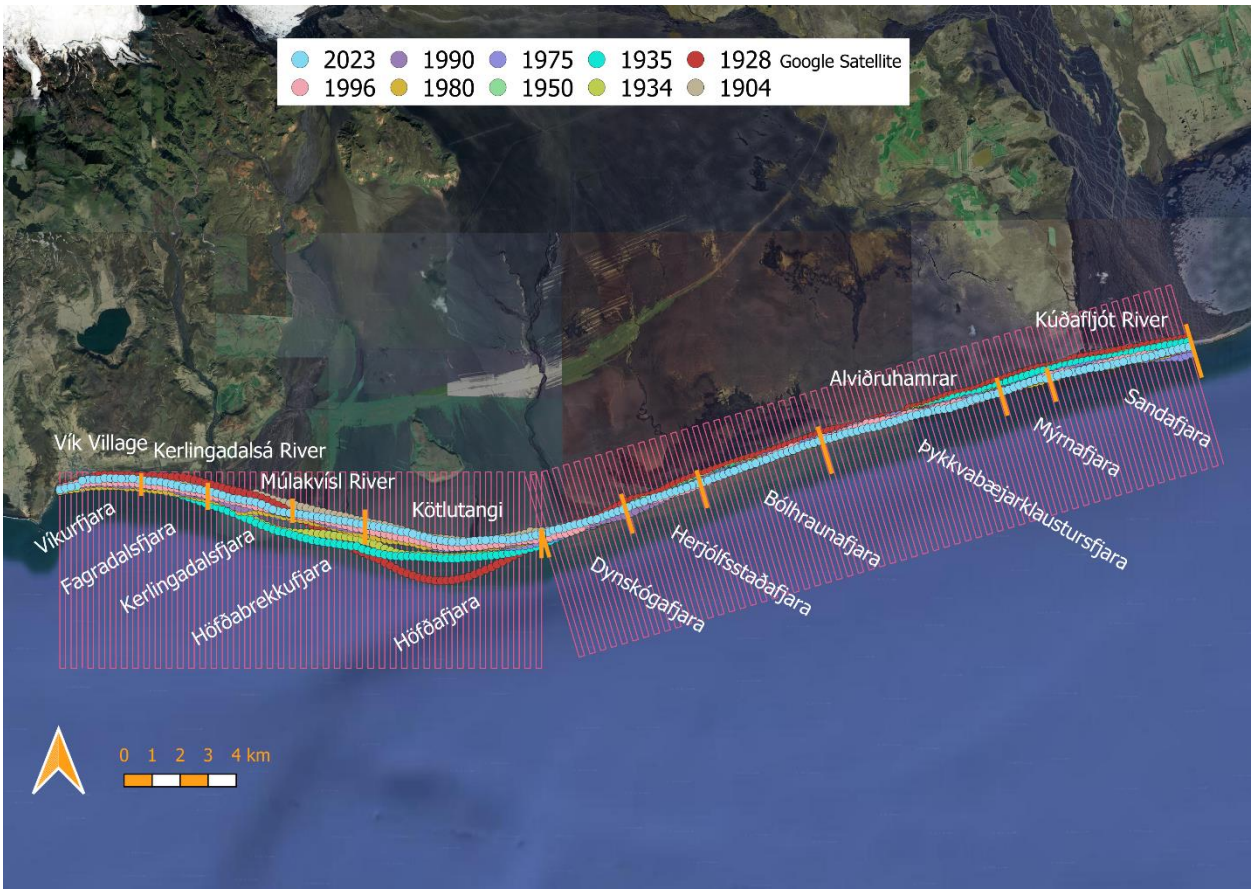

Figure 1. A map that shows all coastlines that extend over the research area along with the profiles set up to calculate changes in coastline location and volume. Each dot on the map is where the profiles intersect the line of each mapped coastline.

The research area is displayed in Figure 1 along with the mapped coastlines that extended over the entire research area. Each dot marks an intersect point between a mapped coastline and the profiles that were made for the research area, with each differently colored point representing a different year of the mapped coastline position. The evolution of the coastline has been different between different parts of the research area, with the largest changes happening in the Höfðafjara beach, but also large changes in the Kerlingadalsfjara- and Höfðabrekkufjara beaches on the western part and in the Mýrnafjara- and Sandafjara beaches on the eastern part of the research area. In Table 1 the total change in the position of the coastline can be seen between different years. The largest change for the coastline happened between 1904 and 1928, when the coastline advanced 158 meters in total over the research area. The coastline then continued to advance, with a short intermission between 1935-1950, until about 1980. After that it started to retreat and has continued to do so until

today. The net changes from 1904 to 2023 are an advancement of about 154 meters. When the research area is divided down into a western and eastern part (Figure 2 and 4), the evolution of the coastline changes somewhat and it becomes evident that the evolution of the coastline is different for either part. The western part follows the same pattern in retreat and advance, but at a larger scale (Table 1 and Figure 3) and has a total advancement of 140 meters over the period. For the eastern part, the changes are smaller, and the coastline seems to have been more stable, apart from 1904 to 1935, when larger changes occurred. The pattern of changes is however different, with retreat happening between 1904 and 1928, and then a long-term advancement until 1980 when it started to retreat again. Over the period the coastline has advanced 16 meters in total.

The coastline changes for the entire research area and after the research area has been broken down into two parts give a good idea of the overall evolution of the changes that have occurred from 1904 to 2023. There have, however, been smaller and more confined changes in the coastline's position, and therefore the data was broken down for each beach to have a closer look at the evolution there. The upside for that is also that more coastlines become available, as not all mapped coastlines extend over the entire research area or over the entire western or eastern part.

Table 1. The calculated changes of each period (in meters) and cumulative changes for the coastline position of the whole research area and the western and eastern part of it.

	Whole area		Western part		Eastern part	
	Period	cumulative	Period	cumulative	Period	cumulative
1904-1928	158	158	533	533	-154	-154
1928-1934	86	244	20	553	136	-18
1934-1935	70	314	115	668	58	39
1935-1950	-86	229	-328	340	11	50
1950-1975	18	247	40	380	3	53
1975-1980	20	267	7	387	27	80
1980-1990	-49	218	-99	288	-1	79
1990-1996	-19	199	-18	270	-32	47
1996-2023	-45	154	-130	140	-31	16
Total	154		140		16	

In Figure 2 the western part of the research area can be seen better, along with the coastline changes over the period. When looking at the coastlines it becomes clear that the largest changes have occurred in Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara, where the 1926 to 1952 coastlines have the largest protrusion to the south. In Table 2 and Figure 3, the changes over the period can be seen for each beach and it becomes clear that the evolution of each beach is different in some ways. All beaches have it in common that there is an advancement for them over the period, but timing of periods of advancement or retreat varies. To examine those changes better, we will have a closer look at each beach in the next sub-chapter.

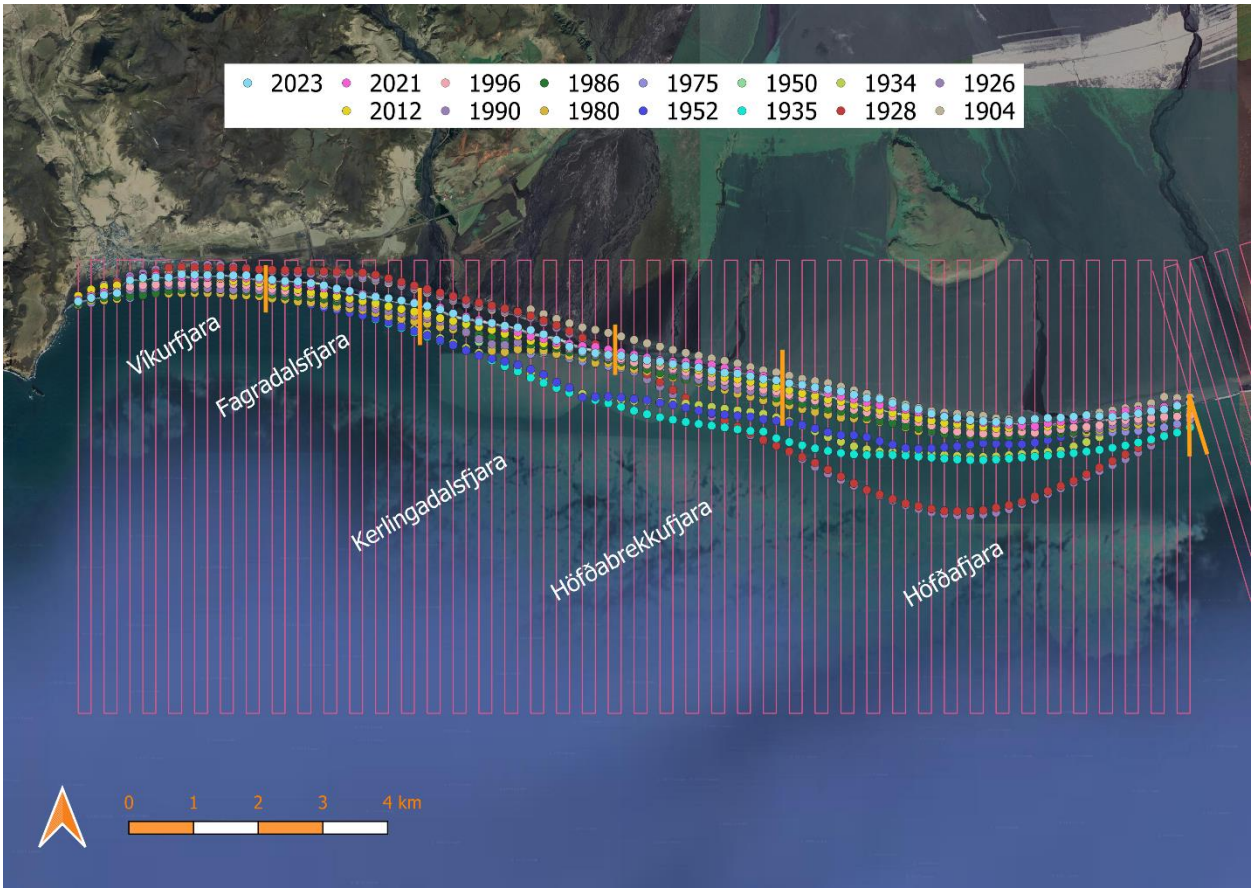

Figure 2. A map that shows all coastlines that extend over the western part of the research area along with the profiles set up to calculate changes in coastline location and volume. Each dot on the map is where the profiles intersect the line of each mapped coastline.

Table 2. The calculated changes of each period (in meters) and cumulative changes for the coastline position at each beach of the western part of the research area.

	Víkurfjara		Fagradalsfjara		Kerlingadalsfjara		Höfðabrekkufjara		Höfðafjara	
	Period	cumulative	Period	cumulative	Period	cumulative	Period	cumulative	Period	cumulative
1904-1928	-24	-24	-53	-53	42	42	-142	-142	1154	1154
1928-1934	154	130	504	452	812	853	170	28	-602	552
1934-1935	12	143	39	490	50	903	32	60	165	717
1935-1950	107	250	-64	426	-416	487	12	72	-453	264
1950-1975	47	297	37	463	7	495	-55	16	62	326
1975-1980	-2	294	13	476	27	521	79	95	-15	311
1980-1990	-95	199	-101	375	-90	431	-22	73	-108	203
1990-1996	-44	155	-37	338	-75	356	-35	38	38	241
1996-2023	-80	76	-139	199	-84	272	54	92	-179	62
Total	76		199		272		92		62	

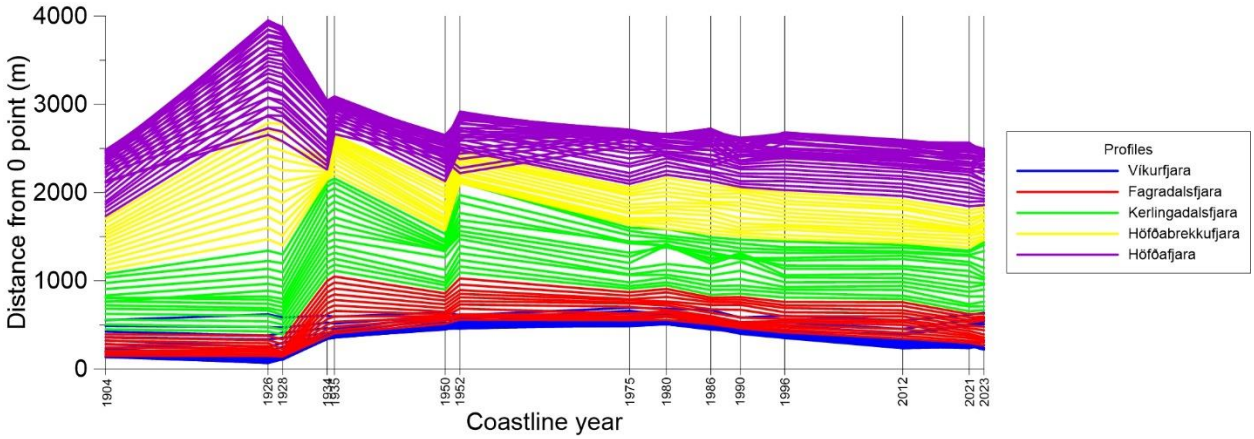

Figure 3. Graph showing the changes in coastline position of the western part. The western part is broken down into five beaches, each depicted by a different color on the graph.

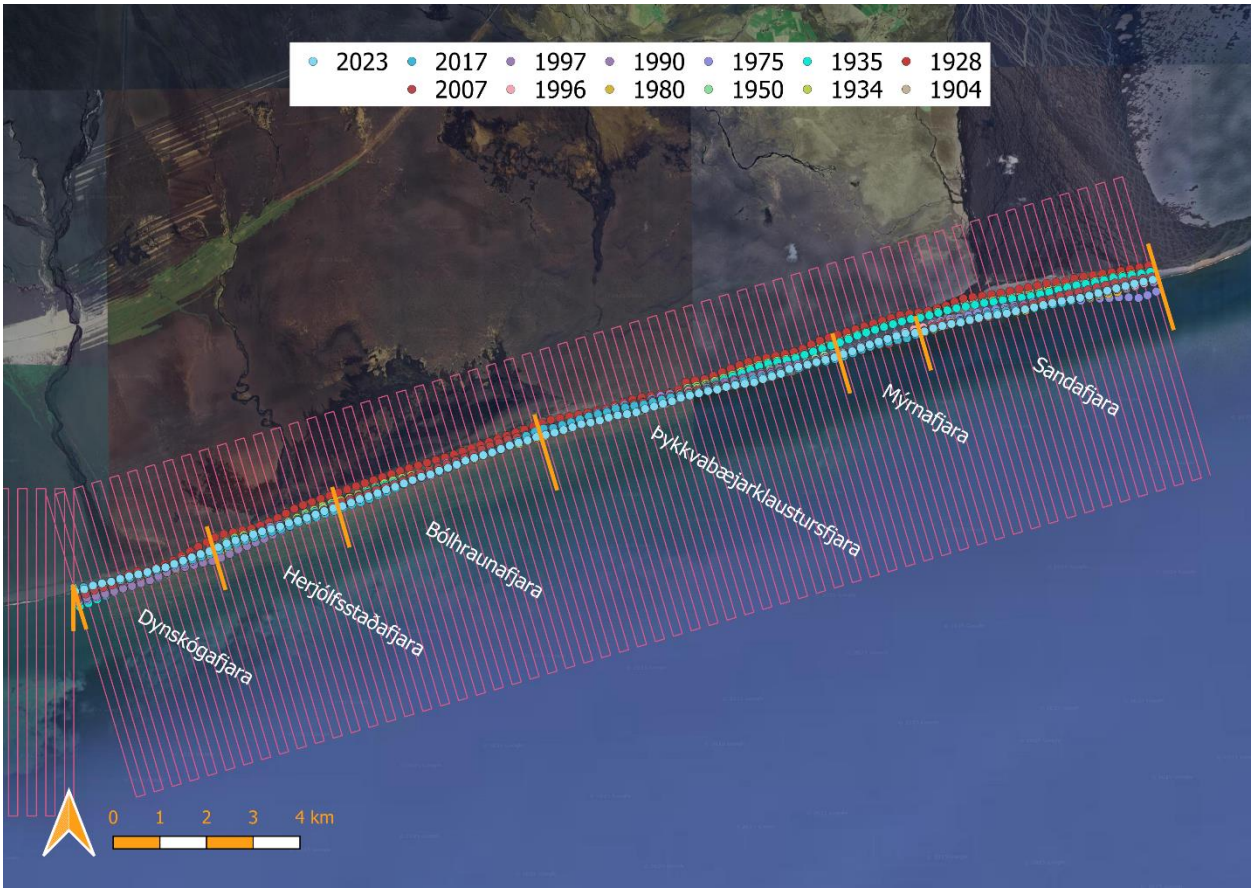

Figure 4. All coastlines that extend over the eastern part of the research area along with the profiles set up to calculate changes in coastline location and volume. Each dot on the map is where the profiles intersect the line of each mapped coastline.

In Figure 4 the eastern part of the research area can be seen better, along with the coastline changes over the period. When looking at the coastlines it becomes clear that there has not been any large-scale advancement such as the advancement in the Höfðafjara beach between 1926-1952. There is however a period with some advancement (Table 3 and Figure 5), between 1928-1934, which in the case of the Mýrnafjara and Sandafjara beaches extends to 1950. The largest retreat happened between 1904 to 1928 for all the beaches, with mostly minor retreat after that apart from the period between 1990-2023 in the Dynskógafjara and Herjólfsstaðafjara beaches, where significant retreat occurred. Those are the two beaches that have retreated during the period, while the other four have advanced significantly from their 1904 position. To examine those changes better, we will have a closer look at each beach in the next sub-chapters.

Table 3. The calculated changes of each period (in meters) and cumulative changes for the coastline position at each beach of the western part of the research area.

	Dynskógafjara		Herjólfsstaðafjara		Bólhraunafjara		Þykkvabæjarklaustursfjara		Mýrnafjara		Sandafjara	
	Period	cumulative	Period	cumulative	Period	cumulative	Period	cumulative	Period	cumulative	Period	cumulative
1904-1928	-136	-136	-229	-229	-141	-141	-86	-86	-71	-71	-72	-72
1928-1934	93	-43	160	-69	164	23	133	47	132	61	133	61
1934-1935	93	50	36	-33	36	59	27	74	14	75	19	80
1935-1950	-54	-4	49	16	41	100	37	111	262	337	251	332
1950-1975	82	78	3	20	-55	45	-1	110	-30	307	19	350
1975-1980	-29	49	37	57	62	107	41	151	67	374	7	357
1980-1990	-12	36	33	89	-12	95	-22	128	-46	328	-17	340
1990-1996	-49	-13	-62	27	-6	89	16	144	8	336	-46	294
1996-2023	-94	-106	-43	-17	23	112	72	216	8	345	47	341
Total	-106		-17		112		216		345		341	

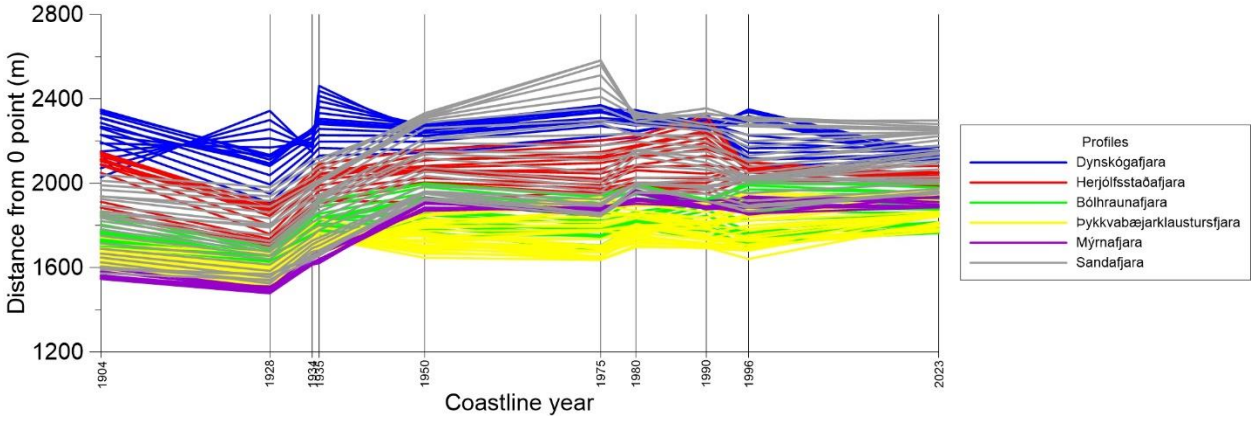

Figure 5. Graph showing the changes in coastline position of the eastern part. The western part is broken down into six beaches, each depicted by a different color on the graph.

Víkurfjara Beach

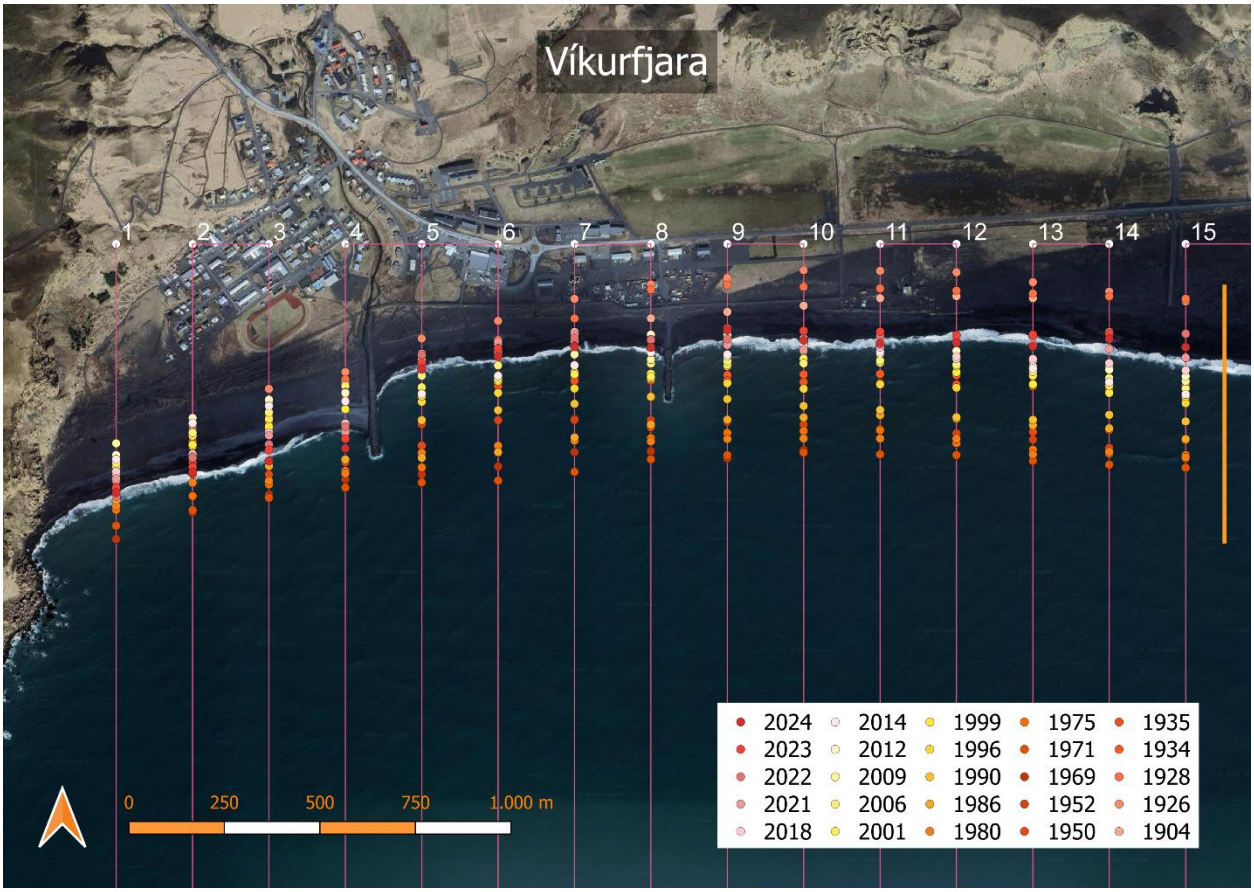

Figure 6. A map showing Víkurfjara beach and coastline locations on the 15 profiles that make up the beach. Please note the two groynes on the beach, one between profiles 4 and 5 and one between 8 and 9.

The Víkurfjara beach consists of 15 profiles all located just south of the village of Vík. Due to the location of the town, the Víkurfjara beach has more coastline position data available than any other beach within the research area, 25 in total. This allows a close examination of the coastline changes at Víkurfjara. In Figure 6 the coastline position can be seen along with the two groynes that were constructed in 2011 and 2017 on the beach to halt the retreat of the coastline there. On the left (west) of profile 1 is the mountain Reynisfjall, a headland that functions as a groyne for the beach as well, limiting movement of sediments from west to east and prevents sediment movement along the coastline from east to west, causing accumulation of sediments (Gíslason, 2011). This is important to keep in mind when looking at the changes of the most western most profiles of Víkurfjara, as the beach there was (until the two groynes were built) more prone to fluctuation in position due to cycles of south-westerly and south-easterly waves which remove and redeposit sediments respectively.

Profiles 1-4 are west of the older groyne, while profiles 5-8 are in between the two groynes. Other profiles are east of the two groynes and largely undefended from the sea. There is a small sea wall

between profiles 10 and 11, which was constructed in 2022, but it should have a limited effect, if any, on this study. In Figure 7 and Table 4, the coastline changes for Víkurfjara from 1904-2024 can be seen. Once the coastline data has been broken down to individual beaches, the pattern of changes become clearer and the Víkurfjara beach shows a clear pattern of retreat and advancement. During the first period, from 1904 to 1926, most profiles retreated well behind the 1904 line. After that, there is almost a continues growth until the 1969 and/or 1971 line, but there is no data available for profiles 12-15 on the 1969 line. After the 1969 and the 1971 lines, the coastline starts to retreat and has mostly continued to do so since. There seems however to be a clear change in profiles 1-4 after 2009, when the profiles start to advance while the others continue to retreat after a small advancement between 2012 and 2014. This advancement of profiles 1-4 is most likely linked to the build of the first groyne at the Víkurfjara beach which has stabilized that part of the beach. It is interesting that there is seemingly a delay of the impact of the 1918 glacial outburst flood to Víkurfjara. This is possibly caused by the lack of coastlines available to us between 1904 and 1926, as the coastline has been described as retreating between 1904 and 1918, whereas afterwards it started to advance (Ísaksson, 1994). It is therefore possible that there was a net advancement of the coastline between 1918 and 1926, but that it was less than the retreat of it between 1904 and 1918. It is also possible that there is an actual delay in sediment transfer, which seems to be the case for the Fagradalsfjara beach for example. All the profiles of Víkurfjara show net advancement from 1904 – 2024 (Table 4), but if the coastline continues to retreat it will eventually retreat behind the 1904 and even the 1926 line. The evolution of the Víkurfjara beach can be split into four periods of alternating retreat and advancement. The first period of retreat is between 1904 and 1926, but after that the coastline advances until 1971 at about 9,1 meter per year. After that there is a retreat of about 5,5 m per year until 2021, and an advancement since then of about 7 meters per year.

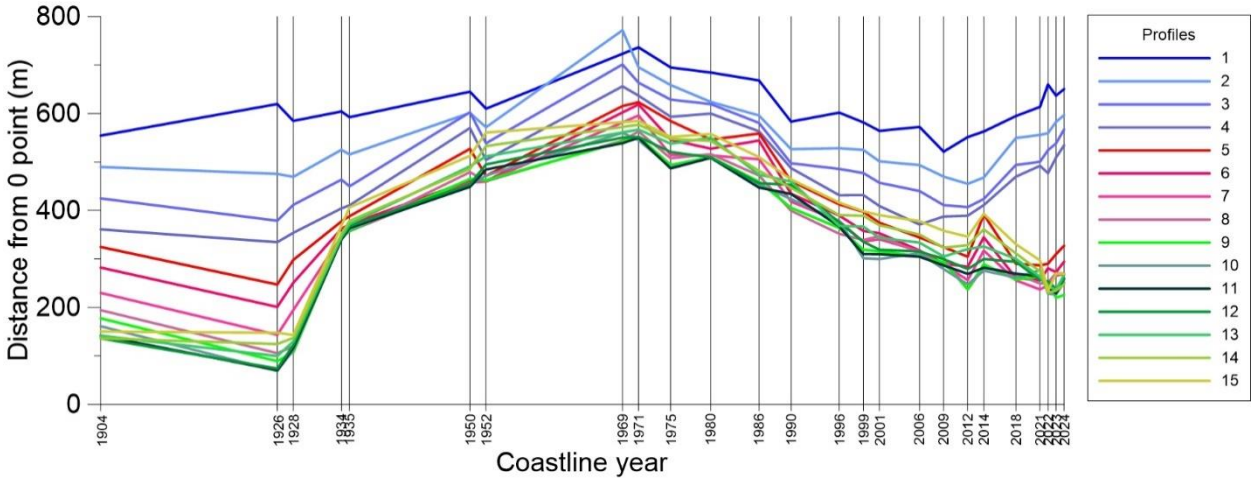

Figure 7. Graph showing the changes in coastline position in the Víkurfjara beach between 1904 and 2024.

Table 4. The change (in meters) in the coastline position between years at the Víkurfjara beach. The change was calculated for each of the profiles of the Víkurfjara beach in the western part of the research area. The middle table is the average change of each period for all profiles and the average change per year of each period. The lowest table shows changes during periods of advancement or retreat and the average per year of each period.

	Víkurfjara profile changes (m)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1904-1926	65	-14	-46	-26	-77	-81	-87	-89	-88	-92	-72	-62	-42	-12	-3
1926-1928	-35	-6	33	19	51	50	51	14	18	43	46	48	30	12	-5
1928-1934	19	56	52	50	80	111	152	225	235	229	223	221	217	215	226
1934-1935	-12	-10	-14	6	10	9	11	12	15	20	24	24	26	27	37
1935-1950	53	86	153	159	139	90	100	122	107	91	85	87	119	107	106
1950-1952	-35	-29	-64	-66	-56	-1	3	-19	-3	20	36	41	20	47	48
1952-1969	162	130	118	111	131	121	84	82	98	67	66				
1969-1971	-35	-6	7	22	21	37	52	21	-8	6	0				
1971-1975	-41	-37	-35	-44	-39	-73	-81	-55	-58	-56	-63	-31	-29	-29	-33
1975-1980	-10	-35	-9	7	-38	-18	-1	9	16	20	22	-11	12	-4	6
1980-1986	-16	-28	-39	-37	13	17	-8	-44	-51	-55	-62	-53	-76	-62	-48
1986-1990	-85	-69	-83	-76	-98	-110	-87	-73	-54	-30	-13	-3	-14	-35	-46
1990-1996	19	2	-12	-56	-48	-45	-40	-48	-42	-45	-67	-77	-92	-56	-48
1996-1999	-20	-4	-9	0	-15	-31	-42	-13	-45	-77	-57	-40	-1	-1	-18
1999-2001	-18	-24	-20	-23	-23	-5	5	8	-3	-2	0	-17	-23	-19	-8
2001-2006	8	-8	-17	-38	-30	-35	-24	-35	-10	12	-5	-3	-10	-19	-12
2006-2009	-51	-24	-29	17	-20	-27	-28	-11	-13	-33	-18	-16	-29	-27	-20
2009-2012	30	-15	-4	2	-20	-6	-32	-65	-56	-32	-17	-20	15	5	-12
2012-2014	11	13	17	22	87	61	61	46	52	28	13	20	5	32	47
2014-2018	32	82	70	59	-101	-83	-61	-14	-31	-14	-12	-6	-25	-49	-63
2018-2021	19	6	7	22	-3	-5	-19	-20	6	15	-6	-37	-38	-37	-33
2021-2022	46	4	24	-15	3	25	9	2	-15	-48	-24	-3	-20	-44	-62
2022-2023	-23	23	14	32	20	-8	20	20	-28	-2	-11	-16	-6	5	35
2023-2024	13	14	29	25	17	21	3	0	5	25	30	20	31	13	0
Total:	97	109	145	177	8	18	46	84	57	100	129	77	83	82	95

	Víkurfjara profile changes (m)	
	average profile change	average change per year
1904-1926	-48	-2
1926-1928	25	12
1928-1934	154	26
1934-1935	12	12
1935-1950	107	7
1950-1952	-4	-2
1952-1969	106	6
1969-1971	11	5
1971-1975	-47	-12
1975-1980	-2	0
1980-1986	-37	-6
1986-1990	-59	-15
1990-1996	-44	-7
1996-1999	-25	-8
1999-2001	-11	-6
2001-2006	-15	-3
2006-2009	-22	-7
2009-2012	-15	-5
2012-2014	34	17
2014-2018	-15	-4
2018-2021	-8	-3
2021-2022	-8	-8
2022-2023	5	5
2023-2024	16	16
Total:	111	0,9

	Víkurfjara	
	period changes (m)	average per year (m)
1904-1926	-48	-2,2
1926-1971	411	9,1
1971-2021	-273	-5,5
2021-2024	22	7,2

Fagradalsfjara Beach

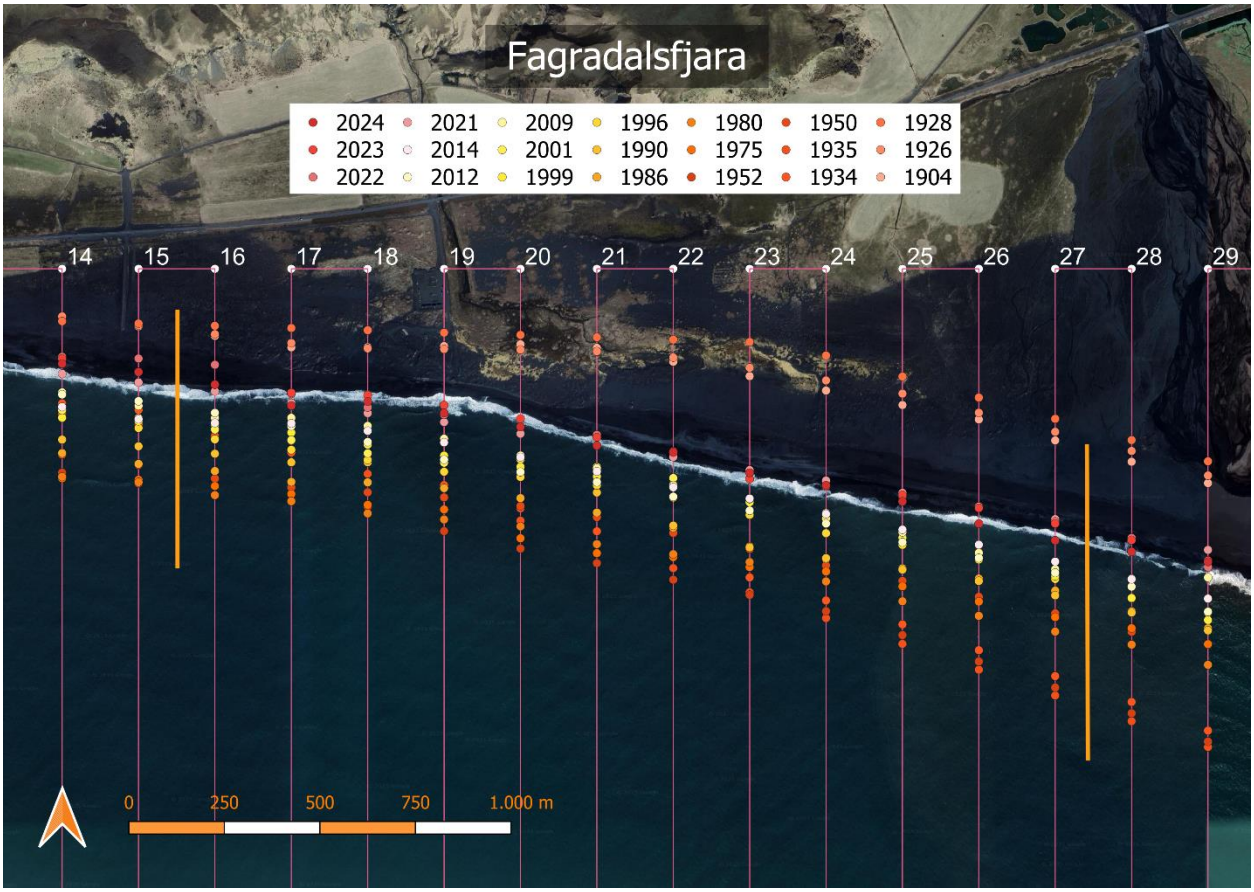

Figure 8. A map showing Fagradalsfjara beach and coastline locations on the 12 profiles that make up the beach.

The Fagradalsfjara beach consists of 12 profiles located east of Víkurfjara and west of the outlet of Kerlingadalsá and Múlakvísl rivers. There are 21 coastlines available for the beach which allows a close examination of the coastline changes at Fagradalsfjara. In Figure 8 the coastline position can be seen and the change in the coastline angle, where it turns further south towards the Kötlutangi protrusion at Höfðafjara.

The Fagradalsfjara shows similar evolution to the Víkurfjara beach, with a distinct advance period followed by a slow retreat period. There was a small retreat for most profiles between 1904 and 1926 (Figure 9 and Table 5) and again between 1926 and 1928, which was then followed by a large advancement to 1934 and 1935. After that, there is an almost continuous retreat of the coastline (apart from 1950 to 1952). Similarly to Víkurfjara, Fagradalsfjara seemingly has a delay of the impact of the 1918 glacial outburst flood to Víkurfjara, and the retreat between 1926 and 1928 could possibly signal that delay. Unlike Víkurfjara however, Fagradalsfjara is only advancing until 1935, or possibly sometime between 1935 and 1950, and the retreat starts around 1950. All the profiles of the Fagradalsfjara beach show considerable net advancement from 1904 – 2024 (Table 5). The evolution

of Fagradalsfjara beach can be split into four periods of alternating retreat and advancement. The first period of retreat is between 1904 and 1928, but after that the coastline advances until 1935 at about 78 meters per year. After that there is a retreat of about 4 m per year until 2023, and an advancement between 2023 and 2024 of about 17 meters.

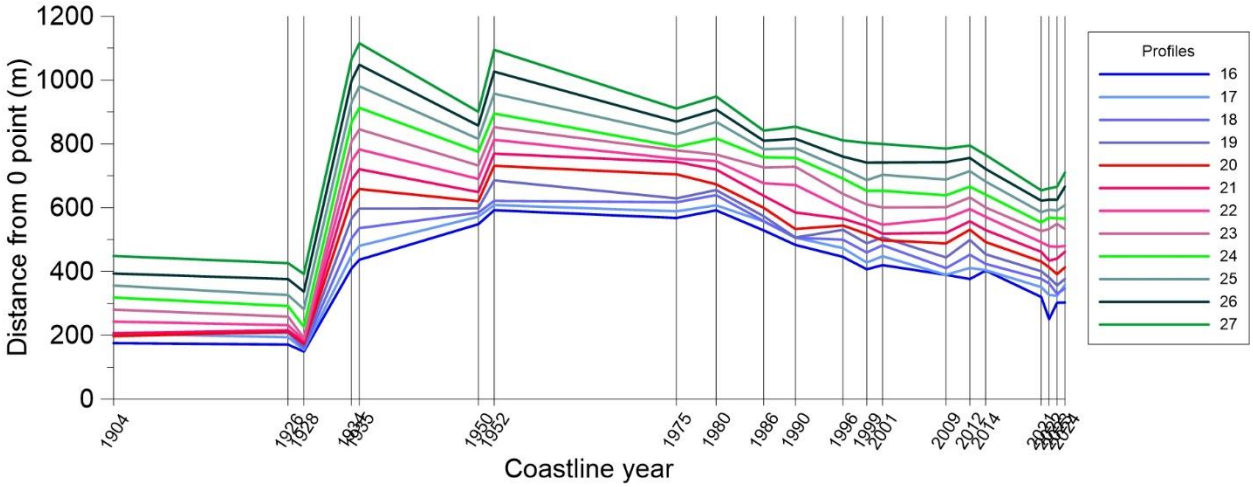

Figure 9. Graph showing the changes in coastline position at Fagradalsfjara beach between 1904 and 2024.

Table 5. The change (in meters) in the coastline position between years at Fagradalsfjara beach. The change was calculated for each of the profiles of the Fagradalsfjara beach in the western part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Fagradalsfjara profile changes (m)													
	16	17	18	19	20	21	22	23	24	25	26	27	average profile change	average change per year
1904-1926	-5	-11	3	8	14	9	-11	-22	-26	-30	-18	-22	-9	0
1926-1928	-22	-39	-47	-43	-39	-37	-47	-67	-65	-45	-39	-34	-44	-22
1928-1934	260	295	342	399	453	507	561	615	640	648	660	672	504	84
1934-1935	28	31	33	31	33	34	36	39	46	51	51	51	39	39
1935-1950	111	91	48	1	-38	-72	-92	-113	-138	-165	-190	-215	-64	-4
1950-1952	44	37	37	88	111	120	122	120	119	142	169	194	109	54
1952-1975	-24	-20	-4	-57	-27	-26	-59	-72	-104	-127	-157	-184	-72	-3
1975-1980	24	19	22	26	-31	-24	-8	-13	26	39	37	38	13	3
1980-1986	-63	-51	-81	-82	-74	-82	-70	-41	-59	-86	-97	-107	-74	-12
1986-1990	-45	-51	-52	-66	-66	-52	-5	2	-2	3	6	12	-26	-7
1990-1996	-38	-33	-6	24	11	-19	-73	-85	-65	-65	-56	-43	-37	-6
1996-1999	-39	-45	-40	-42	-27	-23	-34	-33	-38	-35	-18	-8	-32	-11
1999-2001	13	20	23	19	-20	-24	-17	-10	0	17	-741	-803	-127	-64
2001-2009	-30	-58	-72	-63	-10	3	19	1	-14	-15	743	785	107	13
2009-2012	-13	22	42	55	43	36	30	30	27	26	13	9	27	9
2012-2014	26	-7	-29	-45	-39	-28	-24	-31	-25	-33	-35	-29	-25	-12
2014-2021	-83	-53	-46	-53	-61	-68	-79	-74	-88	-96	-99	-111	-76	-11
2021-2022	-69	-25	-15	-20	-18	-28	-13	7	15	8	3	6	-12	-12
2022-2023	51	-2	-32	-24	-22	6	-2	16	-2	-3	0	5	-1	-1
2023-2024	1	34	17	20	22	21	2	-16	-1	17	41	44	17	17
Total:	127	152	142	175	216	255	237	252	248	252	272	261	216	1.8

	Fagradalsfjara	
	period changes (m)	average per year (m)
1904-1928	-53	-2,2
1928-1935	543	77,6
1935-2023	-291	-4,3
2023-2024	17	16,8

The Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara (Kötlutangi) Beaches

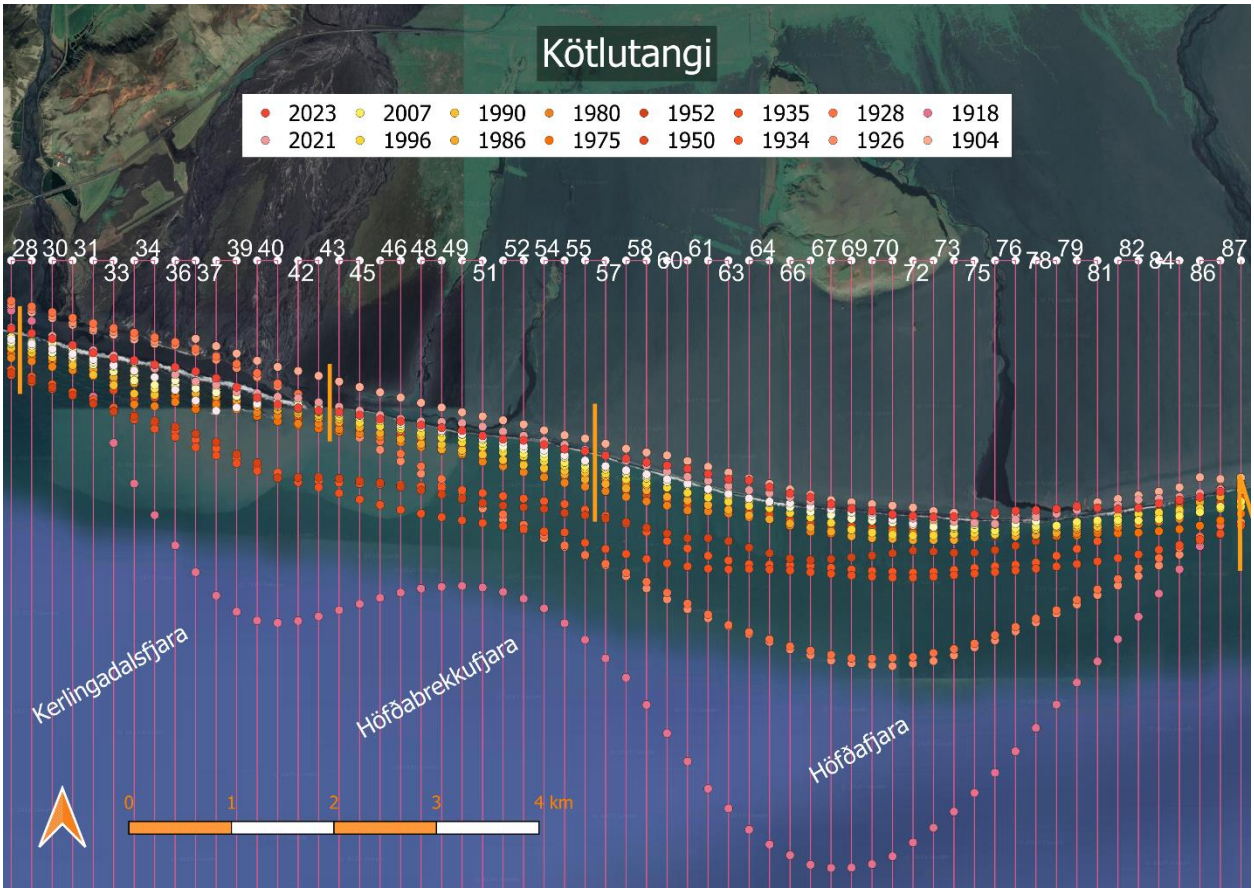

Figure 10. A map showing Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara beaches and coastline locations on the profiles of the three beaches.

The three beaches of Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara consist of 59 profiles, 15, 13 and 31 respectively. They are covered here together due to their similar evolution and due to the impact that the 1918 glacial outburst flood had on the coastline at these three beaches. In Figure 10 the coastline position for the three beaches can be seen and the large advancement that occurred in 1918. The 1918 line is an estimated line, see for further details in (Jónsdóttir and Sigurðarson, 2023 and Larsen, 2018). Kerlingadalsfjara is dominated by the outlet of Múlakvísl rivers, and several other smaller rivers and streams are within the areas of the other two beaches. The coastline itself continues the bend to the south that started at the Fagradalsfjara beach, but on the eastern part of Höfðafjara the coastline starts to turn back north and the angle of the coastline changes completely.

All three beaches show a large advancement between 1904 and 1918 (Figure 11 and Tables 6-8), mostly if not all due to the glacial outburst flood in 1918. There is not an available coastline in the years leading up to 1918 to see if the coastline had retreated further behind the 1904 line or

advanced, but it is likely that just before the 1918 outburst flood the coastline would have been north of the 1904 line (Ísaksson, 1994). After that, however, all the profiles have a long-term retreat, with the biggest retreat coming between 1918 and 1926. Even though the profiles have been retreating since 1926, most profiles still show an advancement since 1904. Only profiles 75-77 at the Höfðafjara beach have retreated behind the 1904 line.

The largest advancement has been for the profiles at the Kerlingadalsfjara beach, which is most likely caused in large parts by the presence of Múlakvísl river. There have been several smaller glacial outburst floods that have entered the ocean from Múlakvísl river since 1918, most notably in 1955 and 2011. These floods do not seem to have had a profound impact on the coastline, and for example the coastline is retreating between 1952 – 1975 and 2007 – 2021. The impact of the floods could of course be more temporary and not picked up due to the length of time between the known coastline position.

The evolution of the three beaches can be split into four periods of alternating retreat and advancement. The first period of advancement is between 1904 and 1918, with well over 100 meters per year that mainly were added in 1918. After 1918 the coastline retreats until 1928 at a similar rate to the previous advancement. Between 1928 and 1935 both the Kerlingadalsfjara and Höfðabrekkufjara beaches advance and then start to retreat slowly from 1935 until 2023. The Höfðafjara beach does however not show this short time of advancement and continues to retreat until 2023.

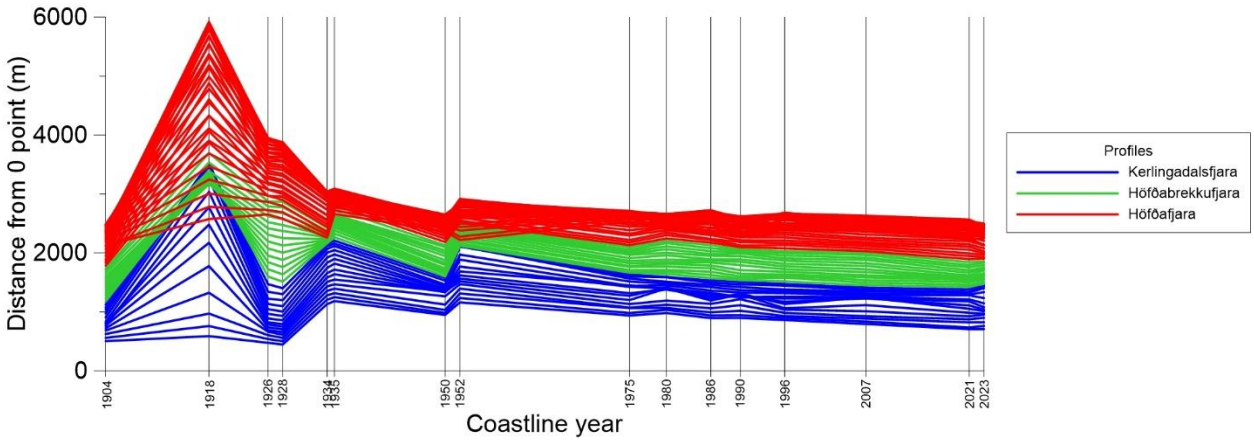

Figure 11. Graph showing the changes in coastline position at the Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara beaches between 1904 and 2023.

Table 6. The change (in meters) in the coastline position between years at Kerlingadalsfjara beach. The change was calculated for each of the profiles of the Kerlingadalsfjara beach in the western part of the research area. The middle table is the average change of each period for all profiles and the average change per year of each period. The lowest table shows changes during periods of advancement or retreat and the average per year of each period.

	Kerlingadalsfjara profile changes (m)														
	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1904-1918	84	200	345	642	1055	1404	1670	1974	2275	2431	2515	2531	2492	2435	2343
1918-1926	-112	-220	-366	-661	-1085	-1433	-1693	-1954	-2148	-2299	-2375	-2372	-2304	-2170	-1996
1926-1928	-29	-37	-46	-52	-35	-37	-38	-28	-30	-33	-39	-39	-27	-42	-69
1928-1934	684	704	724	746	775	805	835	864	887	901	915	907	869	816	745
1934-1935	50	43	35	35	35	41	55	61	73	65	53	45	51	44	63
1935-1950	-234	-269	-285	-268	-205	-202	-304	-368	-470	-522	-579	-616	-655	-629	-634
1950-1952	213	255	279	270	208	172	230	268	339	392	491	539	656	581	535
1952-1975	-222	-254	-248	-322	-339	-317	-292	-303	-240	-343	-445	-457	-554	-513	-474
1975-1980	43	54	4	50	59	200	146	63	-55	-25	9	-35	-53	-11	-44
1980-1986	-87	-95	-75	-62	-55	-209	-192	-122	-95	-78	-88	-61	-54	-95	-59
1986-1990	3	6	27	53	78	104	83	10	-50	-65	-34	-50	-36	-27	-26
1990-1996	-37	-47	-91	-130	-177	-235	-175	-96	-18	2	-12	-18	-41	-21	-33
1996-2007	-67	-61	-42	-57	-26	54	112	57	0	-3	-34	-41	-33	-69	-62
2007-2021	-87	-102	-65	-52	-87	-131	-195	-119	-51	-43	-1	-17	-19	-36	-31
2021-2023	1	28	2	24	29	-14	-37	-72	-98	-67	-47	43	75	95	81
Total:	205	203	199	216	233	202	204	237	318	312	327	360	366	359	338

	Kerlingadalsfjara profile changes (m)	
	average profile change	average change per year
1904-1918	1626	116
1918-1926	-1546	-193
1926-1928	-39	-19
1928-1934	812	135
1934-1935	50	50
1935-1950	-416	-28
1950-1952	362	181
1952-1975	-355	-15
1975-1980	27	5
1980-1986	-95	-16
1986-1990	5	1
1990-1996	-75	-13
1996-2007	-18	-2
2007-2021	-69	-5
2021-2023	3	1
Total:	272	2,3

	Kerlingadalsfjara	
	period changes (m)	average per year (m)
1904-1918	1626	116,2
1918-1928	-1585	-158,5
1928-1935	862	123,1
1935-2023	-631	-7,2

Table 7. The change (in meters) in the coastline position between years at Höfðabrekkufjara beach. The change was calculated for each of the profiles of the Höfðabrekkufjara beach in the western part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Höfðabrekkufjara profile changes (m)														
	43	44	45	46	47	48	49	50	51	52	53	54	55	average profile change	average change per year
1904-1918	2227	2114	2003	1900	1810	1746	1692	1668	1673	1697	1735	1832	1961	1851	132
1918-1926	-1807	-1621	-1442	-1280	-1119	-983	-859	-769	-706	-672	-684	-746	-819	-1039	-130
1926-1928	-87	-89	-85	-73	-71	-67	-59	-45	-49	-48	-30	-12	-7	-56	-28
1928-1934	651	535	420	306	194	86	-14	-106	-179	-255	-330	-404	-441	36	6
1934-1935	103	156	201	240	266	286	293	291	292	295	294	276	323	255	255
1935-1950	-665	-682	-704	-730	-728	-705	-704	-681	-639	-619	-598	-547	-621	-663	-44
1950-1952	522	500	488	507	499	485	496	484	441	407	379	357	351	455	228
1952-1975	-456	-467	-456	-441	-459	-455	-460	-448	-420	-412	-395	-402	-381	-435	-19
1975-1980	-23	8	7	6	39	22	27	48	37	71	86	110	103	42	8
1980-1986	-70	-61	-34	-29	-29	-8	-16	-68	-54	-82	-82	-85	-70	-53	-9
1986-1990	-33	-59	-78	-92	-79	-46	-25	-1	-6	13	-7	-34	-68	-40	-10
1990-1996	-22	14	12	-13	-27	-67	-77	-75	-75	-86	-68	-49	-35	-44	-7
1996-2007	-65	-85	-78	-50	-60	-50	-48	-36	-42	-26	-35	-31	-26	-49	-4
2007-2021	-28	-31	-31	-42	-53	-103	-139	-162	-160	-175	-164	-172	-159	-109	-8
2021-2023	52	42	39	23	37	58	72	89	74	44	39	42	12	48	24
Total:	298	274	262	231	219	197	179	189	184	155	141	134	123	199	1.7

	Höfðabrekkufjara	
	period changes (m)	average per year (m)
1904-1918	1851	132,2
1918-1928	-1095	-109,5
1928-1935	291	41,5
1935-2023	-848	-9,6

Table 8. The change (in meters) in the coastline position between years at Höfðafjara beach. The change was calculated for each of the profiles of Höfðafjara beach in the western part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Höfðafjara profile changes (m)																	
	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
1904-1918	2090	2231	2459	2708	2927	3137	3272	3422	3512	3564	3605	3584	3559	3508	3417	3263	3085
1918-1926	-908	-989	-1134	-1306	-1483	-1661	-1776	-1907	-1974	-2006	-2043	-2020	-1991	-1940	-1853	-1743	-1625
1926-1928	-12	-34	-64	-64	-55	-37	-10	-17	-25	-30	-44	-56	-50	-63	-81	-65	-78
1928-1934	-467	-481	-486	-502	-537	-572	-628	-662	-727	-791	-824	-849	-864	-853	-838	-822	-791
1934-1935	322	299	264	215	174	125	86	47	47	52	59	59	59	55	55	49	49
1935-1950	-625	-618	-619	-617	-594	-598	-590	-558	-537	-493	-476	-475	-482	-476	-482	-482	-492
1950-1952	329	306	314	327	319	301	315	349	379	377	358	331	305	272	246	219	246
1952-1975	-381	-369	-382	-364	-377	-319	-288	-312	-330	-338	-303	-250	-208	-171	-138	-126	-146
1975-1980	113	123	126	93	107	58	19	14	1	17	28	-28	-47	-69	-76	-43	-43
1980-1986	-70	-82	-108	-85	-97	-62	-35	-17	-2	-20	-42	12	50	68	73	67	76
1986-1990	-77	-90	-54	-87	-72	-92	-108	-136	-156	-204	-193	-238	-229	-231	-207	-202	-159
1990-1996	-22	2	-16	-3	-3	19	29	44	48	103	97	151	165	177	167	158	116
1996-2007	-45	-55	-50	-60	-83	-86	-92	-76	-51	-56	-77	-111	-147	-153	-145	-124	-100
2007-2021	-137	-130	-124	-95	-72	-77	-60	-76	-95	-100	-82	-59	-65	-41	-49	-47	-55
2021-2023	7	-20	-30	-61	-79	-68	-68	-96	-59	-36	-39	-14	8	-20	-5	-23	-27
Total:	117	94	95	97	75	70	65	19	32	39	24	37	62	64	84	80.0	56

	Höfðafjara profile changes (m)														
	73	74	75	76	77	78	79	80	81	82	83	84	85	86	average profile change	average change per year
1904-1918	2911	2711	2509	2298	2100	1909	1724	1550	1365	1182	994	799	671	446	2468	176
1918-1926	-1522	-1418	-1289	-1169	-1028	-888	-761	-647	-522	-395	-274	-142	-55	80	-1238	-155
1926-1928	-62	-37	-50	-43	-38	-32	-45	-55	-65	-74	-73	-68	-38	-74	-50	-25
1928-1934	-771	-735	-671	-605	-545	-530	-496	-469	-463	-459	-459	-442	-383	-319	-614	-102
1934-1935	51	54	56	55	59	104	147	196	260	321	379	417	412	403	159	159
1935-1950	-465	-406	-384	-396	-383	-359	-359	-341	-342	-333	-320	-303	-310	-300	-459	-31
1950-1952	248	202	170	155	114	68	56	34	29	-34	-59	-89	-134	-143	191	95
1952-1975	-157	-158	-141	-104	-52	-6	25	32	72	155	197	238	308	311	-132	-6
1975-1980	-35	-24	-17	-11	-17	-20	-21	-30	-63	-82	-96	-101	-132	-124	-12	-2
1980-1986	67	32	7	22	9	-12	-43	-46	-43	-34	-59	-96	-97	-108	-22	-4
1986-1990	-134	-77	-52	-86	-50	-53	-19	15	5	-6	5	43	80	111	-89	-22
1990-1996	75	34	48	45	-11	-12	-20	-44	-63	-59	-31	-28	-17	4	37	6
1996-2007	-58	-41	-35	-36	-21	-2	-27	-21	37	64	65	53	34	-17	-49	-4
2007-2021	-64	-56	-66	-87	-93	-116	-118	-120	-147	-202	-202	-186	-185	-168	-102	-7
2021-2023	-46	-79	-113	-83	-65	-48	-35	-1	38	77	48	30	40	20	-27	-14
Total:	37	1	-29	-45	-21	2	8	55	99	121	116	124	194	122	61	0.5

	Höfðafjara	
	period changes (m)	average per year (m)
1904-1918	2.468	176,3
1918-1928	-1.288	-128,8
1928-1935	-455	-65,0
1935-2023	-664	-7,5

Dynskógafjara, Herjólfsstaðafjara and Bólhraunafjara Beaches

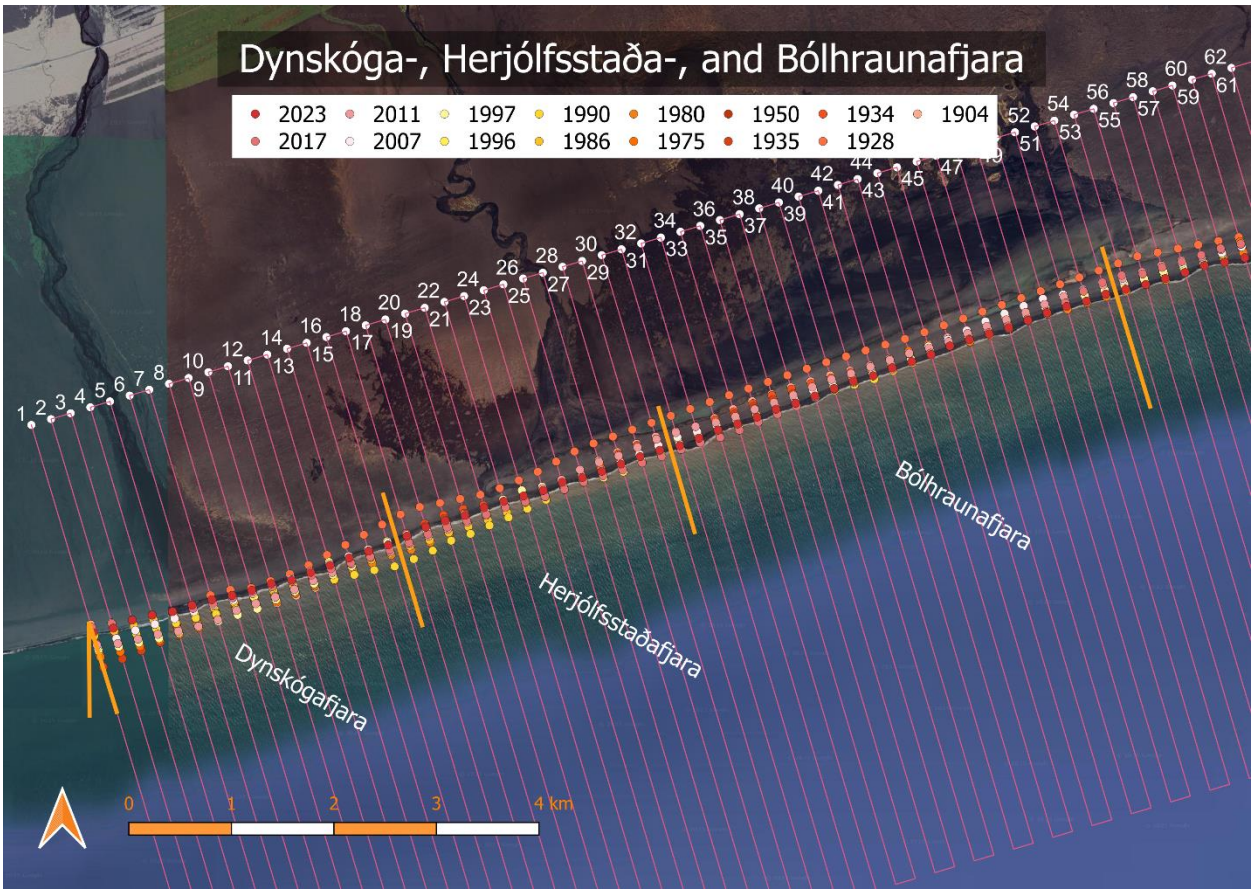

Figure 12. A map showing Dynskógafjara, Herjólfsstaðafjara and Bólhraunafjara beaches and coastline locations on the profiles of the three beaches.

The three beaches of Dynskógafjara, Herjólfsstaðafjara and Bólhraunafjara consist of 53 profiles, 16, 14 and 23 respectively. They are covered here together due to their similar evolution. In Figure 12 the coastline position for the three beaches can be seen and it is evident that the changes have been much less than for the coastline on the western part of the research area. The angle of the coastline has also changed, having a north-east orientation and there are several small rivers and streams the have outlets at the coastline.

Although the changes do not seem as large as for example at the Höfðafjara beach, there are some interesting changes that have happened. Almost all the profiles at Dynskógafjara are advancing from 1904 – 2023 and all profiles at Bólhraunafjara as well, while almost all profiles at Herjólfsstaðafjara are retreating during the same period (Figure 13 and Tables 9-11). The three beaches also do not have as well-defined periods of advancement and retreat but have more of an alternating pattern. Most of the profiles are retreating from 1904 to 1928, apart from the western most profiles close to the Höfðafjara beach and then advance until 1935. After that, the coastline of the Dynskógafjara and the Herjólfsstaðafjara has a long-term retreat while Bólhraunafjara beach advances. The evolution of

the Dynskógafjara beach can be split into three periods, with a short retreat period between 1904 and 1928, an advancement period between 1928 and 1975 and has since then been retreating until 2023 (Table 9). The evolution of the Herjólfsstaðafjara beach can be split into three periods as well, with a short retreat between 1904 and 1928 and then a longer period of advancement between 1928 and 1986. Since 1986 the beach has, however, been retreating (Table 10). The evolution of the Bólhraunafjara beach can be split into four periods, were it retreated between 1904 and 1928 like the other two and then with a period of advancement between 1928 and 1980. From 1980 to 2007 it retreated slightly and since then has been recovering and advancing until 2023 (Table 11).

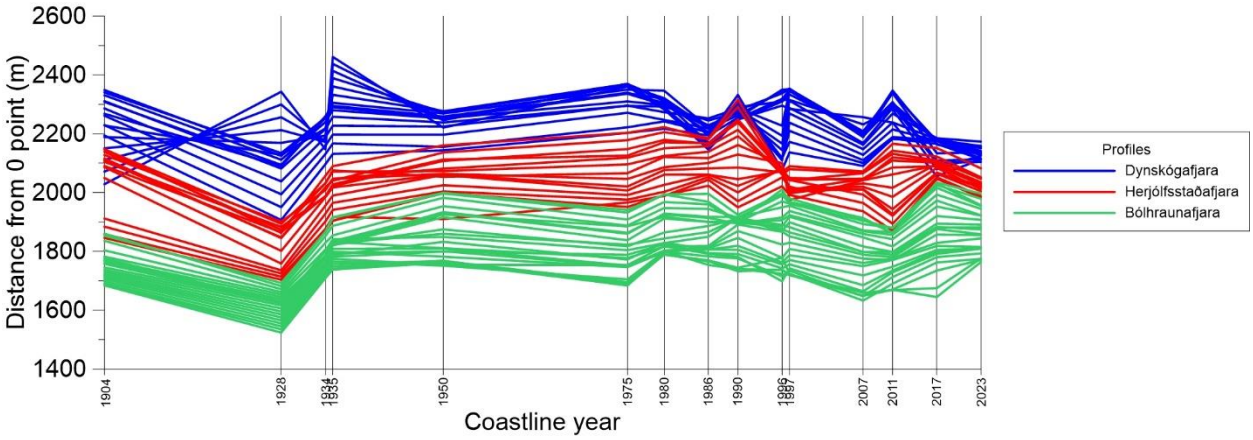

Figure 13. Graph showing the changes in coastline position at the Dynskógafjara, Herjólfsstaðafjara and Bólhraunafjara beaches between 1904 and 2023.

Table 9. The change (in meters) in the coastline position between years at Dynskógafjara beach. The change was calculated for each of the profiles of the Dynskógafjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Dynskógafjara profile changes (m)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	average profile change	average change per year
1904-1928	315	228	145	62	-19	-100	-178	-214	-206	-224	-219	-229	-248	-267	-279	-287	-108	-4
1928-1934	-196	-128	-84	-40	24	90	164	165	121	128	128	134	151	165	180	190	75	12
1934-1935	314	266	242	217	167	114	50	35	36	38	41	42	39	38	36	35	107	107
1935-1950	-240	-187	-168	-116	-85	-57	-36	-36	-36	-38	-28	-19	-3	0	-12	12	-66	-4
1950-1975	139	115	124	96	93	87	81	79	85	83	58	57	71	74	66	60	85	3
1975-1980	-77	-81	-80	-58	-52	-41	-4	-19	-35	-38	-13	-3	-22	-24	20	14	-32	-6
1980-1986	-137	-129	-125	-142	-123	-104	-125	-99	-99	-77	-68	-47	-21	-29	-37	-23	-87	-14
1986-1990	103	92	83	82	61	46	59	71	82	61	42	28	34	81	106	138	73	18
1990-1996	46	68	62	68	95	82	57	18	-60	-89	-104	-129	-176	-183	-193	-255	-43	-7
1996-1997	-11	0	24	30	2	3	16	39	119	119	121	125	128	94	55	60	58	58
1997-2007	-28	-84	-125	-143	-144	-152	-165	-150	-154	-144	-125	-122	-109	-100	-72	-46	-116	-12
2007-2011	-18	51	89	102	130	152	151	105	103	120	106	91	86	79	82	93	95	24
2011-2017	-182	-203	-196	-199	-204	-183	-163	-129	-116	-107	-84	-57	-39	-11	-7	-18	-119	-20
2017-2023	56	46	3	4	3	-33	-41	-23	-20	-30	-12	-27	-34	-51	-59	-52	-17	-3
Total:	84	54	-8	-37	-52	-97	-133	-157	-182	-198	-158	-156	-144	-135	-114	-81	-95	-0.8

	Dynskógafjara	
	period changes (m)	average per year (m)
1904-1928	-108	-4,5
1928-1975	201	4,3
1975-2023	-188	-3,9

Table 10. The change (in meters) in the coastline position between years at Herjólfsstaðafjara beach. The change was calculated for each of the profiles of the Herjólfsstaðafjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Herjólfsstaðafjara profile changes (m)															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	average profile change	average change per year
1904-1928	-285	-260	-225	-221	-227	-253	-265	-271	-285	-291	-176	-159	-144	-142	-229	-10
1928-1934	194	170	123	104	107	138	159	170	182	197	192	177	162	164	160	27
1934-1935	33	23	34	41	38	40	43	31	33	34	37	39	41	37	36	36
1935-1950	70	96	85	84	35	1	-22	17	44	70	60	63	-7	94	49	3
1950-1975	43	42	40	13	37	23	13	-17	-41	-53	-34	-28	56	-47	3	0
1975-1980	19	27	31	46	32	29	55	40	56	54	35	27	23	40	37	7
1980-1986	-39	-24	-13	-4	7	14	-4	14	5	0	35	50	55	33	9	2
1986-1990	132	109	82	70	56	53	45	29	3	-15	-38	-52	-73	-73	23	6
1990-1996	-246	-230	-170	-164	-151	-121	-64	-29	-16	27	59	82	81	72	-62	-10
1996-1997	19	19	-36	-23	-19	-61	-123	-103	-56	-66	-68	-40	-32	-29	-44	-44
1997-2007	-18	-13	24	-8	4	36	68	34	7	5	-3	-50	-55	-56	-2	0
2007-2011	94	76	66	78	62	40	20	-15	-34	-68	-84	-72	-71	-66	2	0
2011-2017	-14	-20	-22	-14	-8	4	31	81	99	124	138	143	158	177	63	10
2017-2023	-69	-70	-63	-55	-70	-63	-61	-62	-72	-45	-46	-60	-64	-64	-62	-10
Total:	-66	-56	-44	-54	-96	-120	-107	-81	-75	-27	106	120	130	137	-17	-0.1

	Herjólfsstaðafjara	
	period changes (m)	average per year (m)
1904-1928	-229	-9,5
1928-1986	318	5,5
1986-2023	-106	-2,9

Table 11. The change (in meters) in the coastline position between years at Bólhraunafjara beach. The change was calculated for each of the profiles of the Bólhraunafjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Bólhraunafjara profile changes (m)												
	31	32	33	34	35	36	37	38	39	40	41	42	43
1904-1928	-161	-178	-165	-142	-129	-126	-123	-130	-133	-145	-152	-143	-121
1928-1934	174	184	180	167	153	138	142	151	159	162	177	163	149
1934-1935	47	50	35	25	28	42	43	40	39	41	41	45	35
1935-1950	83	83	95	99	96	108	103	95	53	33	8	-21	1
1950-1975	-65	-58	-74	-66	-71	-71	-40	-78	-57	-37	-45	-33	-58
1975-1980	62	53	60	60	68	62	33	74	47	21	24	39	50
1980-1986	2	-25	-8	-3	-11	-11	-18	-12	22	22	22	2	13
1986-1990	-72	-68	-61	-30	-1	-19	-1	-3	24	46	64	73	55
1990-1996	73	110	71	75	33	21	7	-12	-40	-22	-38	-24	-46
1996-1997	-17	-42	-8	-24	5	22	17	32	29	-8	-11	-16	7
1997-2007	-71	-54	-58	-72	-84	-69	-63	-70	-82	-85	-67	-62	-55
2007-2011	-46	-52	-25	-14	-7	-13	-18	-31	-19	0	-9	-9	-4
2011-2017	172	164	151	137	128	117	111	104	96	85	92	96	86
2017-2023	-38	-47	-74	-62	-48	-50	-31	-13	-3	-8	2	-18	-2
Total:	142	119	121	151	163	151	161	148	134	106	105	91	110

	Bólhraunafjara profile changes (m)											
	44	45	46	47	48	49	50	51	52	53	average profile change	average change per year
1904-1928	-121	-125	-128	-132	-137	-141	-143	-146	-153	-161	-141	-6
1928-1934	146	151	156	161	165	169	173	176	180	185	164	27
1934-1935	37	36	36	36	34	32	29	27	25	29	36	36
1935-1950	-17	7	45	17	-21	-14	10	20	26	23	41	3
1950-1975	-35	-52	-60	-11	0	-47	-75	-85	-71	-76	-55	-2
1975-1980	52	54	57	36	64	94	97	117	95	105	62	12
1980-1986	12	3	-23	-31	-26	-16	-19	-47	-24	-25	-9	-1
1986-1990	36	13	-1	-4	-11	-7	-25	-14	-34	-25	-3	-1
1990-1996	-68	-56	-49	-49	-83	-61	34	-2	5	-17	-6	-1
1996-1997	31	24	15	14	44	19	-55	-16	-16	-4	2	2
1997-2007	-48	-37	-53	-71	-78	-87	-91	-73	-61	-70	-68	-7
2007-2011	16	21	30	50	65	65	58	21	9	20	5	1
2011-2017	52	48	57	64	63	68	72	64	7	-25	87	15
2017-2023	15	-3	5	14	18	13	12	36	101	119	-3	0
Total:	107	84	86	95	97	87	76	80	88	80	112	0.9

	Bólhraunafjara	
	period changes (m)	average per year (m)
1904-1928	-141	-5,9
1928-1980	247	4,8
1980-2007	-84	-3,1
2007-2023	89	5,6

Þykkvabæjarklaustursfjara (Alviðruhamrar) Beach

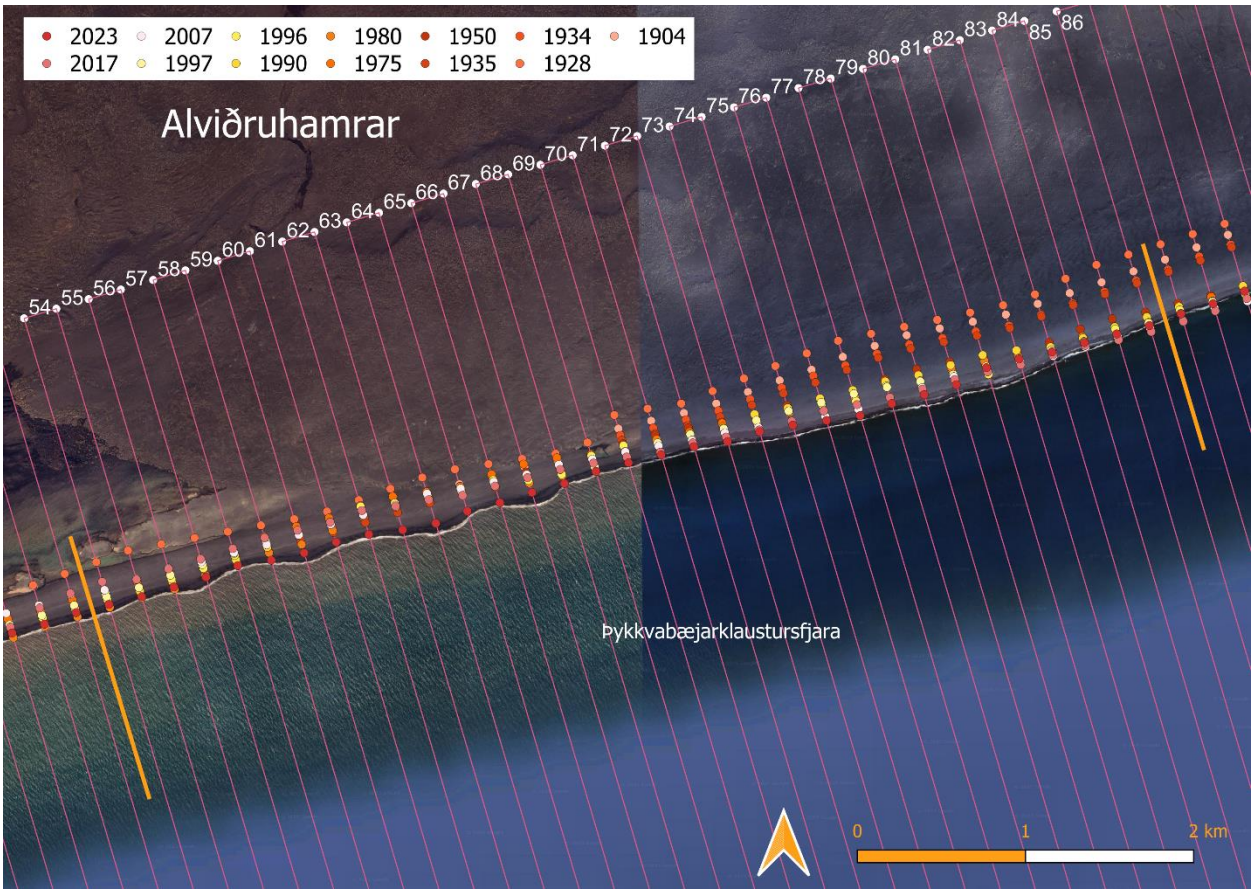

Figure 14. A map showing the Þykkvabæjarklaustursfjara (Alviðruhamrar) beach and coastline locations on the profiles on the beach.

The Þykkvabæjarklaustursfjara beach consists of 33 profiles located in the center of the eastern part of the research area. There are 14 coastlines available for the beach which allows a close examination of the coastline changes at the beach. In Figure 14 the coastline position can be seen, along with the clear change in coastline location from profile 70 and eastward. The coastline shows a similar pattern as the previous three beaches west of the Þykkvabæjarklaustursfjara beach, with a retreat from 1904 – 1928 and then a large advance to 1935. After that, profiles 54-69 tend to have a semi-alternating pattern of retreat and advancement but have a long-term advancement and end up having an advancement of about 100 meters or more between 1904 and 2023. Profiles 70-86 however, have almost continued advancement from 1935 and onwards, with all of them having the 2023 coastline about 200-300 meters further south than that of the 1904 coastline. This advancement of the coastline in the last few decades is a different behavior than of the coastline on the western part of the research area, where a long-term retreat of the coastline has been happening over the last few decades. The beach is bordered by two rivers, the relatively small river of Dýralækir and the much larger river of Kúðafljót to the east. The Dýralækir river does not seem to have had any

profound impact on the beach here, and for comparison there is seemingly no impact on the beach of Bólhraunafjara where the main outlet of the Dýralækir river is. The beaches of Mýrnafjara and Sandafjara east of Þykkvabæjarklaustursfjara have a similar evolution, but the position of the outlet of Kúðafljót river does not seem to have had a long-term effect on them either in terms of steady growth. This advancement could also be caused by the 1918 glacial outburst flood, but it then seems to have had smaller impact on the three beaches in between Þykkvabæjarklaustursfjara beach and Höfðafjara beach. The evolution of the Þykkvabæjarklaustursfjara beach can be split into two periods, with a short retreat period between 1904 and 1928, but since then the beach has been growing at about 3 meters per year, with short and small intermittent periods of retreat (Table 12).

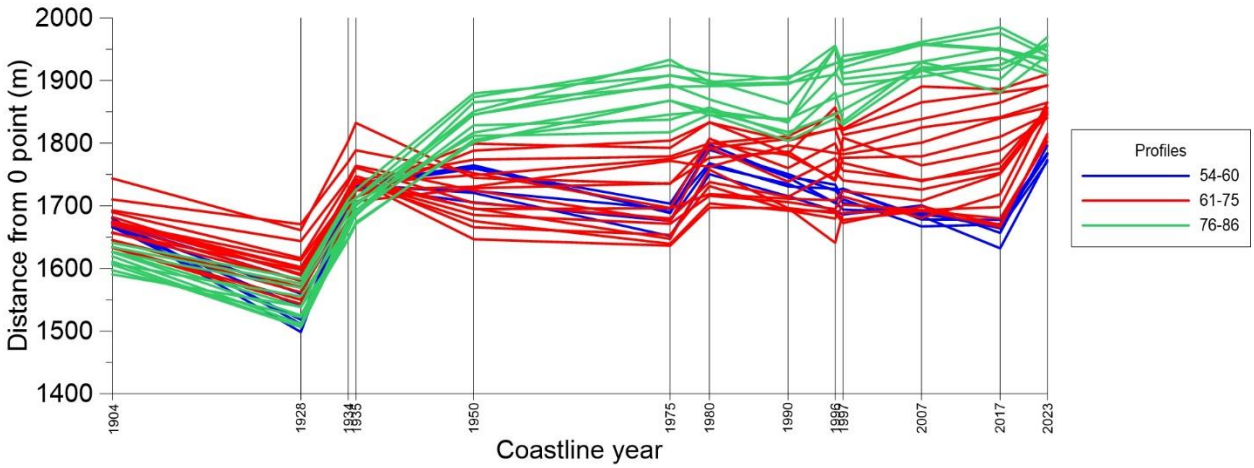

Figure 15. Graph showing the changes in coastline position at Þykkvabæjarklaustursfjara (Alviðruhamrar) beach between 1904 and 2023

Table 12. The change (in meters) in the coastline position between years at Þykkvabæjarklaustursfjara beach. The change was calculated for each of the profiles of the Þykkvabæjarklaustursfjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lowest table shows changes during periods of advancement or retreat and the average per year of each period.

	Þykkvabæjarklaustursfjara (Alviðruhamrar) profile changes (m)											
	54	55	56	57	58	59	60	61	62	63	64	65
1904-1928	-169	-175	-148	-127	-109	-91	-72	-61	-73	-82	-89	-93
1928-1934	194	204	180	157	141	125	109	102	115	123	130	136
1934-1935	31	32	34	35	30	29	28	28	23	23	27	22
1935-1950	24	30	27	-6	-25	-14	-43	-77	-94	-62	-53	-53
1950-1975	-71	-76	-56	-29	-30	-69	-49	-12	-10	-36	-14	1
1975-1980	101	101	94	73	88	99	111	78	61	64	45	23
1980-1990	-46	-39	-51	-37	-29	-35	-62	-38	-1	-11	-10	-7
1990-1996	-41	-26	-12	-4	-29	-23	-8	-2	-55	-13	-11	-2
1996-1997	21	3	-24	-23	-12	-6	-16	-14	48	22	20	15
1997-2007	-42	-49	-43	-18	-5	15	26	14	4	-9	-34	-16
2007-2017	-51	-1	3	-16	-25	-44	-30	-12	-27	5	38	43
2017-2023	141	106	113	111	106	139	140	123	148	147	146	98
Total:	93	111	117	116	102	125	137	129	139	173	195	166

	Þykkvabæjarklaustursfjara (Alviðruhamrar) profile changes (m)											
	66	67	68	69	70	71	72	73	74	75	76	77
1904-1928	-73	-49	-40	-83	-84	-75	-58	-77	-83	-90	-101	-100
1928-1934	120	98	99	141	126	119	100	122	128	135	140	153
1934-1935	25	22	19	30	31	35	37	38	36	35	40	28
1935-1950	-56	-39	-37	-88	21	6	14	34	73	75	106	141
1950-1975	-25	-49	-56	-9	8	41	25	5	-7	16	6	9
1975-1980	58	117	111	65	41	-10	18	21	41	29	28	19
1980-1990	-24	-55	-47	-20	10	34	15	11	-50	-29	-42	-45
1990-1996	40	38	39	-38	-46	-12	16	36	74	19	36	69
1996-1997	-14	-20	-31	66	37	-2	-34	-34	-36	0	-10	-46
1997-2007	-15	-15	-29	-44	2	19	37	25	44	68	87	95
2007-2017	27	18	29	24	31	39	17	26	16	-4	-35	-27
2017-2023	103	92	87	51	36	17	23	28	10	24	59	67
Total:	166	159	145	96	211	211	208	235	246	277	314	363

	Þykkvabæjarklaustursfjara (Alviðruhamrar) profile changes (m)										
	78	79	80	81	82	83	84	85	86	average profile change	average change per year
1904-1928	-75	-52	-53	-57	-58	-58	-89	-108	-104	-86	-4
1928-1934	124	109	112	117	127	127	152	167	162	133	22
1934-1935	25	26	25	26	16	9	10	14	15	27	27
1935-1950	134	128	124	134	154	161	151	153	181	37	2
1950-1975	40	67	51	48	28	51	83	63	25	-1	0
1975-1980	5	-24	-16	-24	-8	-13	-36	-15	1	41	8
1980-1990	-33	-6	-17	-37	-37	-9	9	2	3	-22	-2
1990-1996	28	34	78	119	89	54	21	13	33	16	3
1996-1997	7	4	-20	-49	-40	-35	3	30	4	-6	-6
1997-2007	68	39	13	14	18	36	29	17	31	12	1
2007-2017	-5	9	19	19	22	-9	-9	20	23	4	0
2017-2023	38	34	31	-26	-36	-17	-17	-36	-38	62	10
Total:	358	368	348	284	275	297	307	320	336	216	1.8

	Þykkvabæjarklaustursfjara	
	period changes (m)	average per year (m)
1904-1928	-86	-3,6
1928-2023	303	3,2

Mýrna og Sandafjara Beach

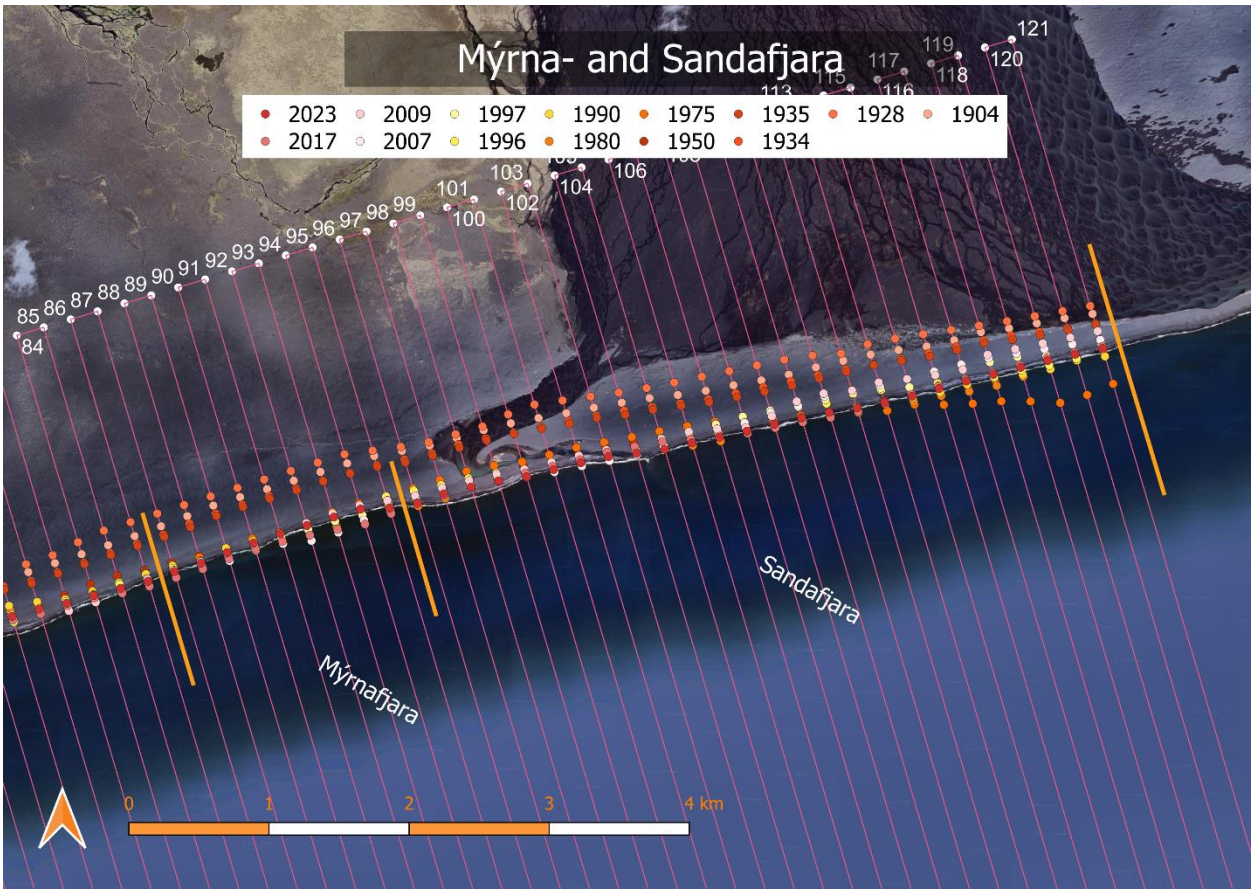

Figure 16. A map showing Mýrnafjara and Sandafjara beaches and coastline locations on the profiles of the two beaches. The outlet of Kúðafljót river makes up most of Sandafjara.

The two beaches of Mýrnafjara and Sandafjara beaches consist of 35 profiles, 9 and 26 respectively. They are covered here together due to their similar evolution. In Figure 16 the coastline position for the two beaches can be seen along with the large outlet of Kúðafljót river which takes up most of the Sandafjara beach. From the location of the coastlines, it can be seen that the two beaches have a very similar evolution as the Þykkvabæjarklaustursfjara beach, with a major period of advancements between 1928 and 1950.Prior to that, the two beaches had a mild retreat between 1904 and 1928, and after 1950 the profiles have a small long term advancement or retreat (few meters to a few dozens) to 2023 and seem to have remained relatively stable. The Mýrnafjara beach has had retreat from 2017-2023, about 40-100 meters per profile, but each profile is still more than 300 meters wider than it was in 1904. Similarly, the profiles for Sandafjara are about 200-300 meters wider than they were in 1904.

The evolution of the Mýrnafjara beach can be split into five periods. The first one is between 1904 and 1928 when the beach retreated, followed by a period of high growth until 1950, at about 18 meters per year. Between 1950 and 1990 the beach was quite stable, with a slight retreat of about 0,2 meters

per year. After the stable period, advancement started again from 1990 to 2007 and then retreat started again that lasted until 2023 (Table 13). The evolution of the Sandafjara beach can be split into four periods. The first one is between 1904 and 1928 when the beach retreated, followed by a period of growth until 1980. From 1980 to 2009 is a period of retreat, followed by an advancement until 2023 (Table 14).

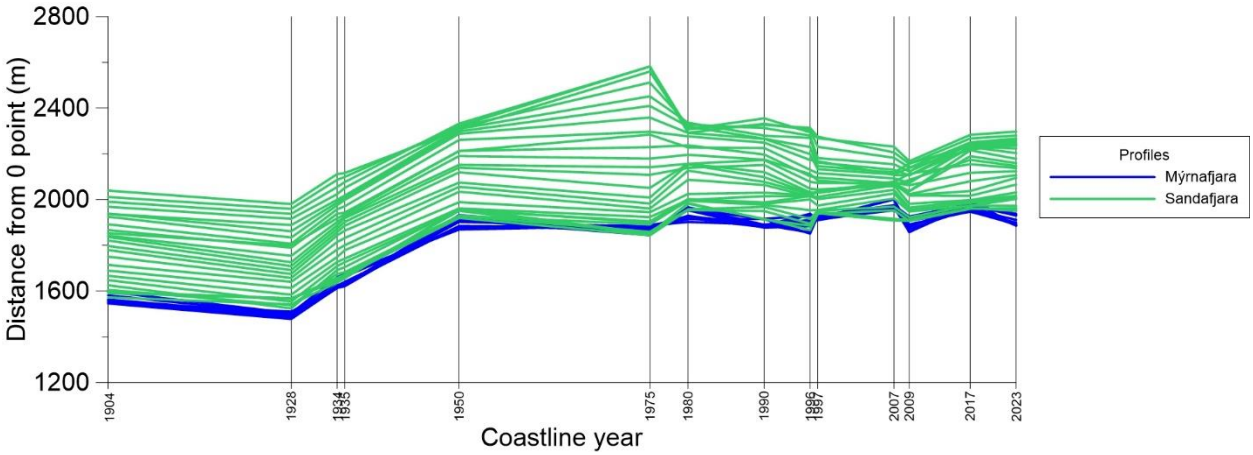

Figure 17. Graph showing the changes in coastline position at Mýrnafjara and Sandafjara between 1904 and 2023.

Table 13. The change (in meters) in the coastline position between years at Mýrnafjara beach. The change was calculated for each of the profiles of the Mýrnafjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Mýrnafjara profile changes (m)										
	87	88	89	90	91	92	93	94	95	average profile change	average change per year
1904-1928	-94	-82	-68	-68	-72	-73	-70	-68	-40	-71	-3
1928-1934	156	139	128	125	126	130	134	137	107	132	22
1934-1935	15	25	16	16	17	13	7	7	11	14	14
1935-1950	195	216	245	251	273	292	290	289	303	262	17
1950-1975	17	9	-6	-15	-21	-49	-65	-66	-72	-30	-1
1975-1980	16	26	42	57	48	83	111	122	101	67	13
1980-1990	-12	1	-41	-39	-43	-77	-78	-77	-47	-46	-5
1990-1996	20	14	54	52	15	7	7	-33	-62	8	1
1996-1997	21	-10	-16	-25	10	34	29	75	77	22	22
1997-2007	44	41	56	40	56	84	84	37	33	53	5
2007-2009	-50	-38	-54	-45	-75	-131	-143	-110	-80	-81	-40
2009-2017	55	53	38	38	57	89	120	140	97	76	10
2017-2023	-47	-45	-46	-47	-56	-72	-92	-112	-41	-62	-10
Total:	336	349	349	340	332	332	336	340	387	345	2.9

	Mýrnafjara	
	period changes (m)	average per year (m)
1904-1928	-71	-2,9
1928-1950	407	18,5
1950-1990	-8	-0,2
1990-2007	83	4,9
2007-2023	-66	-4,1

Table 14. The change (in meters) in the coastline position between years at Sandafjara beach. The change was calculated for each of the profiles of the Sandafjara beach in the eastern part of the research area, along with the average profile change and the average change per year. The lower table shows changes during periods of advancement or retreat and the average per year of each period.

	Sandafjara profile changes (m)													
	96	97	98	99	100	101	102	103	104	105	106	107	108	109
1904-1928	-30	-24	-28	-27	-67	-101	-94	-83	-75	-74	-93	-104	-105	-112
1928-1934	95	83	76	89	136	167	155	143	135	141	157	168	166	163
1934-1935	19	17	24	14	8	13	17	15	30	19	18	21	28	30
1935-1950	304	283	252	257	247	253	227	219	210	234	224	210	233	237
1950-1975	-107	-102	-76	-70	-38	-59	-49	-38	-43	-73	-73	-66	-68	-31
1975-1980	130	136	111	98	104	100	98	75	80	126	143	144	106	31
1980-1990	-67	-71	-5	11	-19	-17	-15	16	6	-23	-49	-56	-37	12
1990-1996	-48	-28	-55	-53	-23	18	28	1	-11	-50	-54	-71	-88	-104
1996-1997	71	54	52	36	1	-26	-13	-4	15	26	13	3	-1	-3
1997-2007	16	-32	-31	18	50	53	40	51	40	30	42	44	46	16
2007-2009	-47	-2	-4	-46	-57	-72	-77	-81	-58	-51	-55	-10	37	27
2009-2017	53	56	49	51	26	31	30	16	-1	18	57	54	42	87
2017-2023	3	-12	-1	-1	29	23	22	33	49	57	27	7	-17	-27
Total:	390	359	364	377	397	382	369	364	376	380	357	344	341	326

	Sandafjara profile changes (m)													
	110	111	112	113	114	115	116	117	118	119	120	121	average profile change	average change per year
1904-1928	-111	-88	-53	-77	-85	-91	-77	-48	-53	-53	-52	-59	-72	-3
1928-1934	161	147	118	148	150	141	126	110	108	117	127	130	133	22
1934-1935	32	23	17	6	13	23	22	18	27	21	13	5	19	19
1935-1950	233	266	278	269	290	290	289	292	267	256	222	190	251	17
1950-1975	-10	-12	17	72	36	71	111	142	194	250	261	254	19	1
1975-1980	15	17	8	-56	-20	-67	-90	-115	-184	-290	-273	-252	7	1
1980-1990	16	-21	-40	-3	-28	-26	-54	-57	-15	39	17	48	-17	-2
1990-1996	-95	-63	-95	-95	-76	-67	-36	-10	-33	-28	-13	-61	-46	-8
1996-1997	-5	-28	-6	-15	-5	-66	-83	-108	-98	-73	-39	-25	-13	-13
1997-2007	-1	-26	-25	-22	-60	-22	-28	-31	-27	-48	-68	-37	0	0
2007-2009	-35	-21	2	-20	0	28	39	-25	-32	-43	-50	-64	-28	-14
2009-2017	154	179	156	160	115	81	78	137	122	110	111	115	80	10
2017-2023	-31	-38	-26	-10	15	20	7	7	14	17	13	14	7	1
Total:	322	336	350	356	344	313	304	313	290	276	269	258	341	2.9

	Sandafjara	
	period changes (m)	average per year (m)
1904-1928	-72	-3,0
1928-1980	429	8,2
1980-2009	-104	-3,6
2009-2023	88	6,3

Volume changes of the Western Part

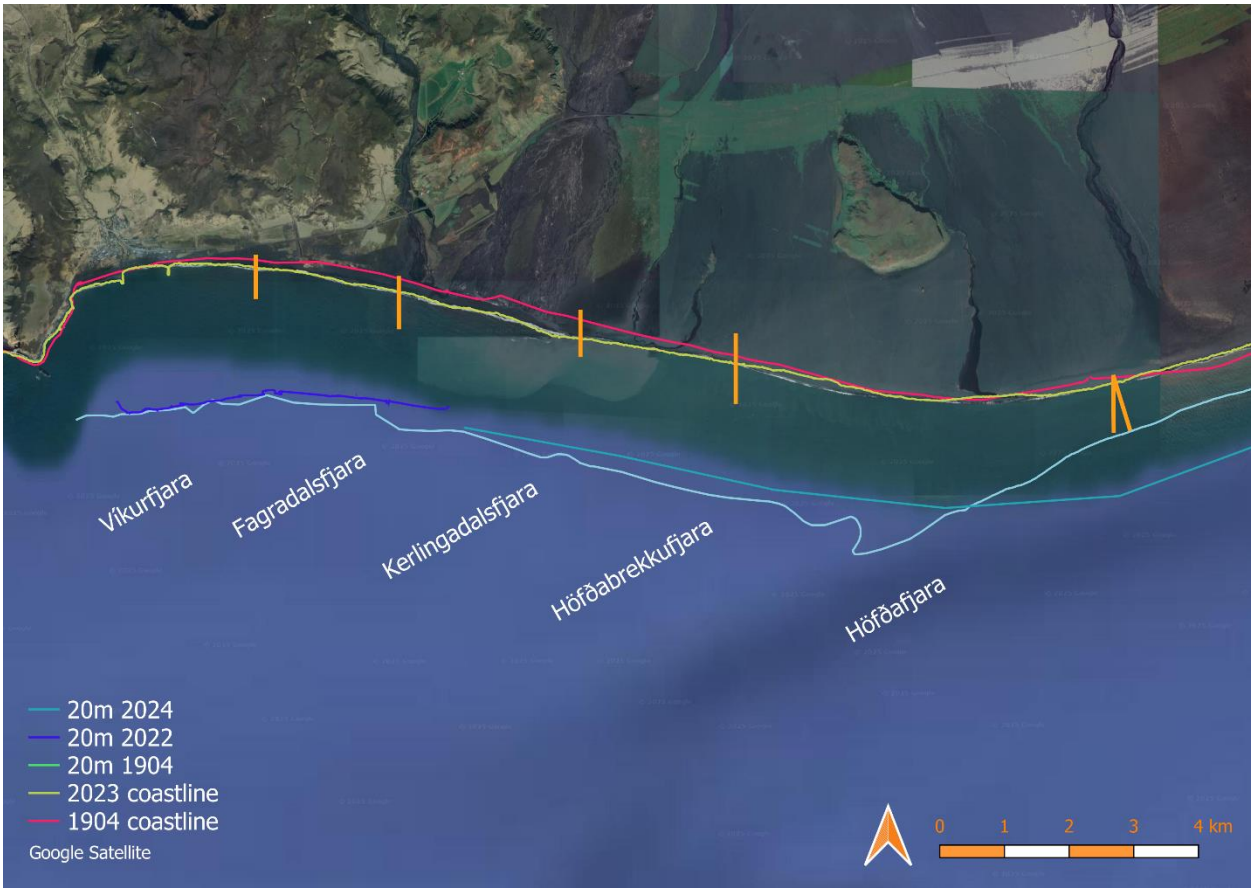

Figure 18. A map showing the western part of the research area along with the two coastlines used for the volume calculations and the depth lines from 1904, 2022 and 2024.

The same approach was taken for the volume change calculations, that is dividing the research area into two parts and then individual beaches. Several bathymetric surveys have been taken of the seabed but most of them only cover the offshore area of the Víkurfjara beach. However, surveys from 1904 and 2024 are available for large parts of the research area, which were used for the calculation of the volume changes. Sadly, the 2024 survey does not extend all the way west to the Víkurfjara and Fagradalsfjara beaches, and therefore a 2022 bathymetric survey was used for profile nr. 4 at Víkurfjara beach to profile nr. 31 at Kerlingadalsfjara beach. No available bathymetric surveys are for profiles 1-3 in Víkurfjara and profiles 32-35 in Kerlingadalsfjara from 2022 or 2024, and they were not used when the volume change was calculated. The coastline used for the calculation is from 2023, as there is not a coastline available that extends over the entire area for 2024. The depth line used for the calculations was the 20 m depth line for all three surveys. Once the volume of each profile had been calculated, the section volume change was found by multiplying the profile volume with the section width, which is 200 meters for all the profiles. Figure 18 shows the map of the area, along with the coastline and depth line's locations used for the volume change calculations.

In Table 15 the results from the volume calculation for the western part of the research area can be seen, and in Table 16 the results from the calculation are broken down to individual beaches and profiles. As evident from the tables, there has been a large decrease in the total volume of the western part between 1904 and 2024, but only Höfðafjara and Höfðabrekkufjara volume is decreasing while the volume of the other three has increased. Both the large total volume decrease and the largest average volume decrease is at the Höfðabrekkufjara beach, followed by Höfðafjara. The Kerlingadalsfjara beach and especially the Fagradalsfjara beach have increased their volume considerably and Víkurfjara has also a small increase in volume. The average distance between the coastline and the 20 m has decreased on all the five beaches during the period, both due to the 20 m depth line moving closer to the shoreline and the advancement of the coastline itself. On the eastern part of the Höfðafjara beach, the 20 m depth line has moved further away from the shoreline, the only area to do so. The volume increase between the two surveys was however not enough to upset the decrease on the western part of Höfðafjara.

These results would suggest that the positive impact of the flood in 1918 on the volume of the area is still present at the Víkurfjara, Fagradalsfjara and Kerlingadalsfjara beaches, but is decreasing and will eventually go lower than the 1904 volume if the retreat continues. For the Höfðabrekkufjara and Höfðafjara beaches, the total volume has already gone past what it was in 1904, although the western part of Höfðafjara still has higher volume than it did in 1904. Unfortunately, there are no available bathymetric surveys in the decades following the 1918 glacial outburst flood, so the impact of it on the volume of the area cannot be calculated but is likely to have increased considerably.

Table 15. The total difference of changes in volume on the western part of the research area between 1904 and 2022/2024. The changes are also broken down into individual beaches and the section average change of each profile of that beach, along with the distance of the coastline to the 20 m depth line.

	Total volume change (m^3)	Section average change (m^3)	Average distance to 20 depth (m) in 1904	Average distance to 20 depth (m) in 2024
Western part	-1.339.991	-15.402	2.219	1.936
Víkurfjara	80.033	6.669	2.394	2.287
Fagradalsfjara	824.043	68.670	2.318	1.955
Kerlingadalsfjara	484.867	32.324	2.380	1.850
Höfðabekkufjara	-2.387.354	-183.643	2.387	1.897
Höfðafjara	-341.580	-10.674	1.955	1.843

Table 16. The volume from 1904 and 2022/2024 surveys, the difference in volume of each profile, the width of the section between profiles and the total volume (m^3/m) of each section, broken down for individual beaches.

	Víkurfjara															
Profiles / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1904 volume (m^3/m)	33.355	32.355	31.771	31.069	30.497	29.949	29.008	28.533	28.105	28.277	27.378	26.353	26.978	27.018	26.574	437.221
2022 volume (m^3/m)	NA	NA	NA	30.370	30.113	29.570	29.161	29.030	28.133	27.931	27.747	27.454	27.069	26.734	26.828	340.139
Difference between years (m^3/m)				-700	-385	-379	153	498	28	-347	368	1.101	92	-284	254	400
Section width (m)	100	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
total volume of section (m^3)	0	0	0	-139.955	-76.952	-75.812	30.627	99.545	5.585	-69.308	73.668	220.281	18.336	-56.746	50.763	80.033

	Fagradalsfjara												
Profiles / years	16	17	18	19	20	21	22	23	24	25	26	27	Total
1904 volume (m^3/m)	26.146	26.493	27.042	27.417	27.509	27.730	28.135	28.554	28.935	29.308	31.892	33.690	342.850
2022 volume (m^3/m)	27.073	26.518	26.848	27.296	27.828	28.516	29.029	29.824	30.268	30.611	31.254	31.905	346.971
Difference between years (m^3/m)	928	25	-194	-121	319	786	894	1.270	1.333	1.303	-638	-1.785	4.120
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	
total volume of section (m^3)	185.539	5.024	-38.755	-24.178	63.762	157.255	178.828	253.985	266.581	260.617	-127.547	-357.068	824.043

	Kerlingadalsfjara															
Profiles / years	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	Total
1904 volume (m^3/m)	34.934	35.587	36.324	36.824	37.235	37.994	39.039	39.603	39.872	41.266	42.702	44.057	44.686	44.704	45.941	600.765
2022 volume (m^3/m)	32.701	33.574	34.464	35.434	NA	NA	NA	NA	41.451	42.471	43.714	45.104	46.133	46.820	47.455	449.319
Difference between years (m^3/m)	-2.232	-2.013	-1.860	-1.390					1.579	1.205	1.012	1.047	1.447	2.117	1.514	2.424
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
total volume of section (m^3)	-446.481	-402.664	-371.953	-278.042	0	0	0	0	315.816	241.058	202.328	209.321	289.353	423.310	302.820	484.867

	Höfðabrekkufjara													
Profiles / years	43	44	45	46	47	48	49	50	51	52	53	54	55	Total
1904 volume (m^3/m)	47.483	48.417	49.323	50.235	51.358	52.431	53.464	54.372	55.236	56.100	57.110	57.939	58.545	692.013
2022 volume (m^3/m)	47.962	48.622	49.384	49.952	50.784	51.468	52.175	53.119	53.885	54.439	55.310	56.167	56.809	680.076
Difference between years (m^3/m)	479	206	61	-283	-574	-963	-1.289	-1.254	-1.351	-1.661	-1.800	-1.772	-1.736	-11.937
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	
total volume of section (m^3)	95.824	41.140	12.182	-56.548	-114.818	-192.649	-257.794	-250.712	-270.249	-332.200	-360.027	-354.381	-347.121	-2.387.354

	Höfðafjara															
Profiles / years	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
1904 volume (m^3/m)	59.238	59.911	60.444	61.102	62.703	64.933	66.388	66.884	66.770	66.654	73.320	73.402	73.036	72.479	71.878	70.803
2022 volume (m^3/m)	57.699	58.381	59.199	59.878	60.416	61.137	61.863	62.184	63.069	63.883	64.466	65.331	66.011	66.411	66.984	67.336
Difference between years (m^3/m)	-1.539	-1.530	-1.245	-1.224	-2.287	-3.795	-4.525	-4.700	-3.701	-2.771	-8.854	-8.071	-7.025	-6.068	-4.894	-3.466
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
total volume of section (m^3)	-307.711	-306.000	-249.001	-244.843	-457.340	-759.045	-905.099	-939.996	-740.267	-554.181	-1.770.771	-1.614.199	-1.404.941	-1.213.647	-978.865	-693.274

	Höfðafjara															
Profiles / years	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	Total
1904 volume (m^3/m)	69.743	68.573	68.106	67.370	66.523	65.227	63.913	63.033	61.984	60.435	58.720	56.924	55.593	53.624	52.980	52.169	2.054.861
2022 volume (m^3/m)	67.652	67.823	67.492	67.119	66.839	66.643	66.373	65.991	66.012	65.986	65.714	65.157	64.681	64.272	63.580	62.970	2.058.554
Difference between years (m^3/m)	-2.091	-750	-614	-251	316	1.416	2.460	2.958	4.028	5.551	6.994	8.233	9.089	10.648	10.601	10.801	3.693
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	100	
total volume of section (m^3)	-418.240	-150.076	-122.878	-50.171	63.276	283.287	491.988	591.613	805.675	1.110.132	1.398.846	1.646.614	1.817.711	2.129.589	2.120.133	1.080.099	-341.580

Víkurfjara volume changes

More numerous bathymetric surveys are available for the Víkurfjara beach, so the evolution of the volume there can be studied in greater detail. Three different approaches for the calculations were taken, (1) Only calculating the volume changes between years with known coastline position and bathymetric survey from the same year down to 10m depth. (2) Calculating volume changes of all the bathymetric surveys and all depth lines down to 10m depth but assigning each bathymetric survey a coastline position close in time, so for example a bathymetric survey from 2016 could have a coastline position from 2018. (3) Calculating the changes using only the 1904 and the 2022 surveys down to 20 m depth, as was done for the entire area.

In Figure 19 and Table 17 the results from the first approach can be seen. There are five years that have both a known coastline location and a bathymetric survey, 1971, 2012, 2014 and 2022. Unfortunately, the 1971 bathymetric survey only covers the first 6 profiles, the 2014 survey does not cover profiles 11-15, and the 2022 survey does not cover profiles 1 and 2.

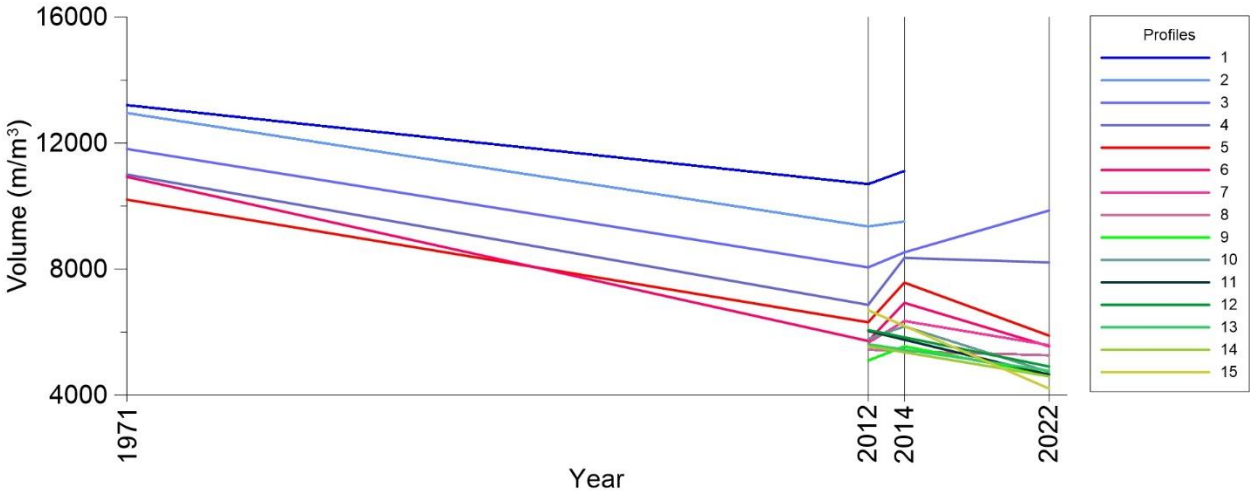

Figure 19. Graph showing volume changes on the profiles at the Víkurfjara beach during the years when a coastline and a bathymetric survey were taken the same year. The calculation for the volume extends down to 10 m depth.

Table 17. The profile volume (m^3/m) at the Víkurfjara beach when both depth- and coastline surveys are available from the same year. The volume calculation goes down to 10-meter depth.

Profiles / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1904	13.884	12.621	11.303	9.985	9.777	9.348	8.851	8.678	8.380	7.865	7.752	7.887	7.982	7.975	8.066
1971	13.202	12.952	11.813	11.000	10.205	10.928									
2012	10.696	9.349	8.055	6.867	6.311	5.717	5.658	5.444	5.092	5.778	6.036	6.067	5.614	5.551	6.693
2014	11.111	9.511	8.532	8.354	7.570	6.928	6.348	5.385	5.546	6.178					
2022			9.860	8.212	5.889	5.549	5.585	5.265	4.652	4.727	4.648	4.909	4.770	4.597	4.206

After 1971 the volume starts to decrease significantly and continues to do so until 2022 for the most profiles, after a short increase between 2012 and 2014. The only profile that shows a volume increase between 2014 and 2022 is a profile that is west of the first groyne (profiles 1-4) that was made in 2011. Profile 4, which is also west of the groyne but closer to it, shows a slight decrease between 2014 and 2000, but much less than the other profiles. This would indicate, granted only over a short period, that the first groyne is causing volume increase in front of the beach.

In Figure 20 and Table 18 the results from the second approach can be seen, where volume changes of all the bathymetric surveys and all depth lines down to 10m depth were calculated and each bathymetric survey was assigned a coastline position close in time. With this approach, all fifteen bathymetric surveys that have been made for Víkurfjara are available, and the results can be seen in Figure 20 and Table 18. In Figure 21 each bathymetric survey has been plotted up on the profile and has the year of both the bathymetric survey and the coastline which is used. The first seven profiles have data back to 1957 and most of them show a slight growth until 1963 and or until 1971. After that, the seven profiles are decreasing long term. Once data becomes available for all fifteen profiles, the long-term evolution is that the volume decreases until about 2012 when most profiles start to grow again. By 2019, all profiles except the first four start to decrease and continue to do so until 2022, but the first four indicate a long-term growth but 2022 data is not available for the first two profiles.

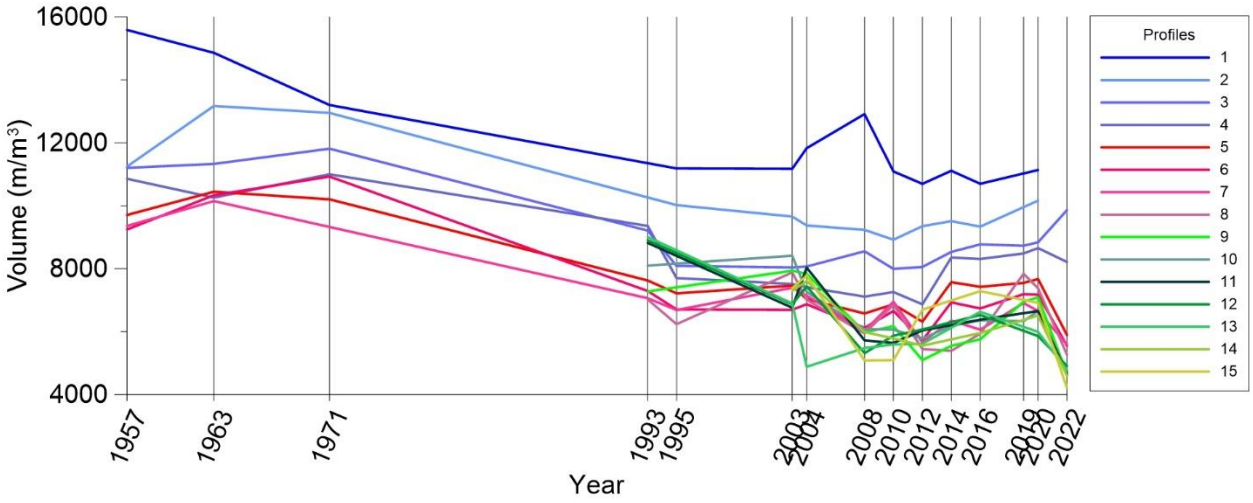

Figure 20. Graph showing volume changes down to 10 m depth on the profiles at the Víkurfjara beach between 1957 and 2022. This graph contains all bathymetric surveys that have been made in front of the Víkurfjara beach.

Table 18. The profile volume (m^3/m) at the Víkurfjara beach for all bathymetric surveys that have been made. The volume calculation goes down to 10 meters.

Profiles / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1904	13.884	12.621	11.303	9.985	9.777	9.348	8.851	8.678	8.380	7.865	7.752	7.887	7.982	7.975	8.066
1957	15.587	11.248	11.204	10.856	9.705	9.246	9.359								
1963	14.863	13.172	11.331	10.259	10.447	10.332	10.148								
1971	13.202	12.952	11.813	11.000	10.205	10.928									
1993			9.210	9.357	7.624	7.290	7.059	7.023	7.274	8.096	8.821	8.904	9.004		
1995	11.187	10.019	8.086	7.700	7.214	6.705	6.685	6.235							
2003	11.175	9.655	8.041	7.513	7.460	6.692	7.392	7.881	7.935	8.410	6.759	6.866	6.897	7.295	7.377
2004	11.831	9.371	8.068	7.409	7.028	6.869	7.140	7.012	7.837	7.258	8.033	7.433	4.879	7.603	7.779
2008	12.914	9.232	8.551	7.111	6.574	6.117	6.020	5.942	5.972	6.073	5.720	5.314	5.476	5.984	5.080
2010	11.090	8.921	7.992	7.256	6.866	6.655	6.949	6.846	6.172	6.062	5.636	5.869	5.590	5.782	5.091
2012	10.696	9.349	8.055	6.867	6.311	5.717	5.658	5.444	5.092	5.778	6.036	6.067	5.614	5.551	6.693
2014	11.111	9.511	8.532	8.354	7.570	6.928	6.348	5.385	5.546	6.178					
2016	10.698	9.337	8.773	8.306	7.423	6.734	6.060	5.935	5.754	6.356	6.378	6.526	6.628	5.955	7.284
2019			8.728	8.485	7.547	7.188	6.908	7.836	6.949	6.329					
2020	11.137	10.164	8.837	8.654	7.669	7.173	6.650	7.377	7.090	6.652	6.652	5.856	5.989	6.508	6.914
2022			9.860	8.212	5.889	5.549	5.585	5.265	4.652	4.727	4.648	4.909	4.770	4.597	4.206

With approach 3, where the volume changes are calculated between the bathymetric surveys in 1904 and 2022 down to 20 m depth. The coastline position and depth lines for those two surveys can be seen in Figure 22 and in Figure 23 and Table 19 the results from the third approach can be seen. Five of the fifteen profiles lost volume over the period, while the other 10 have increased in volume. The total increase over the profiles is only 400 m^3/m, indicating a relatively stable coastline if data from other bathymetric surveys and coastline position were not available. As the volume for Víkurfjara has increased between 1904 and 2022 bathymetric surveys, but surveys in between show an almost continues decrease since 1971, would suggest that there was a large volume increase as some point between 1904 and 1971. That volume increase is most likely caused by the 1918 glacial outburst flood, but due to lack of available surveys between 1918 and 1971, the exact timing of the volume increase at the Víkurfjara beach cannot be found.

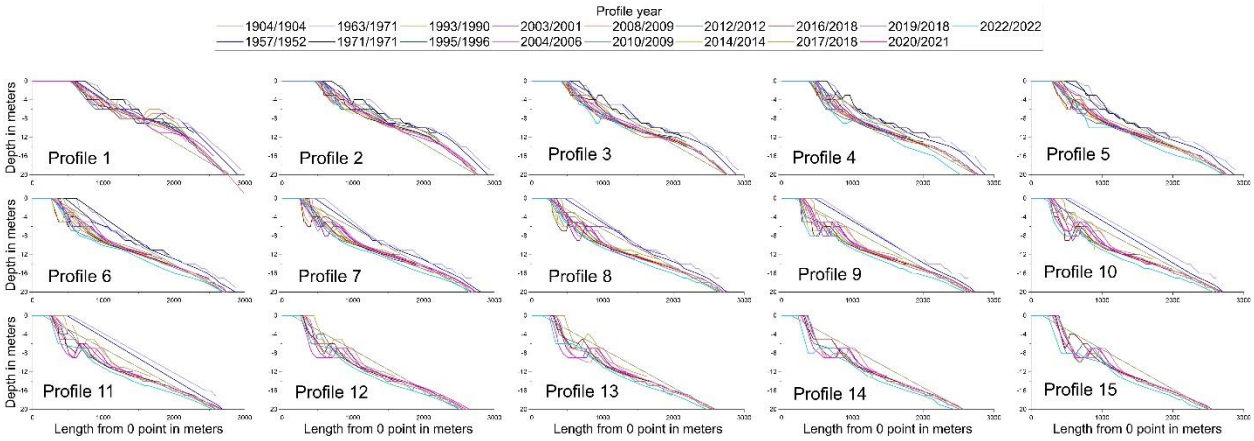

Figure 21. Graph showing the changes of the profiles volume of the Víkurfjara beach. The years on the left mark the year of the bathymetric survey while the years on the right mark the year of the coastline.

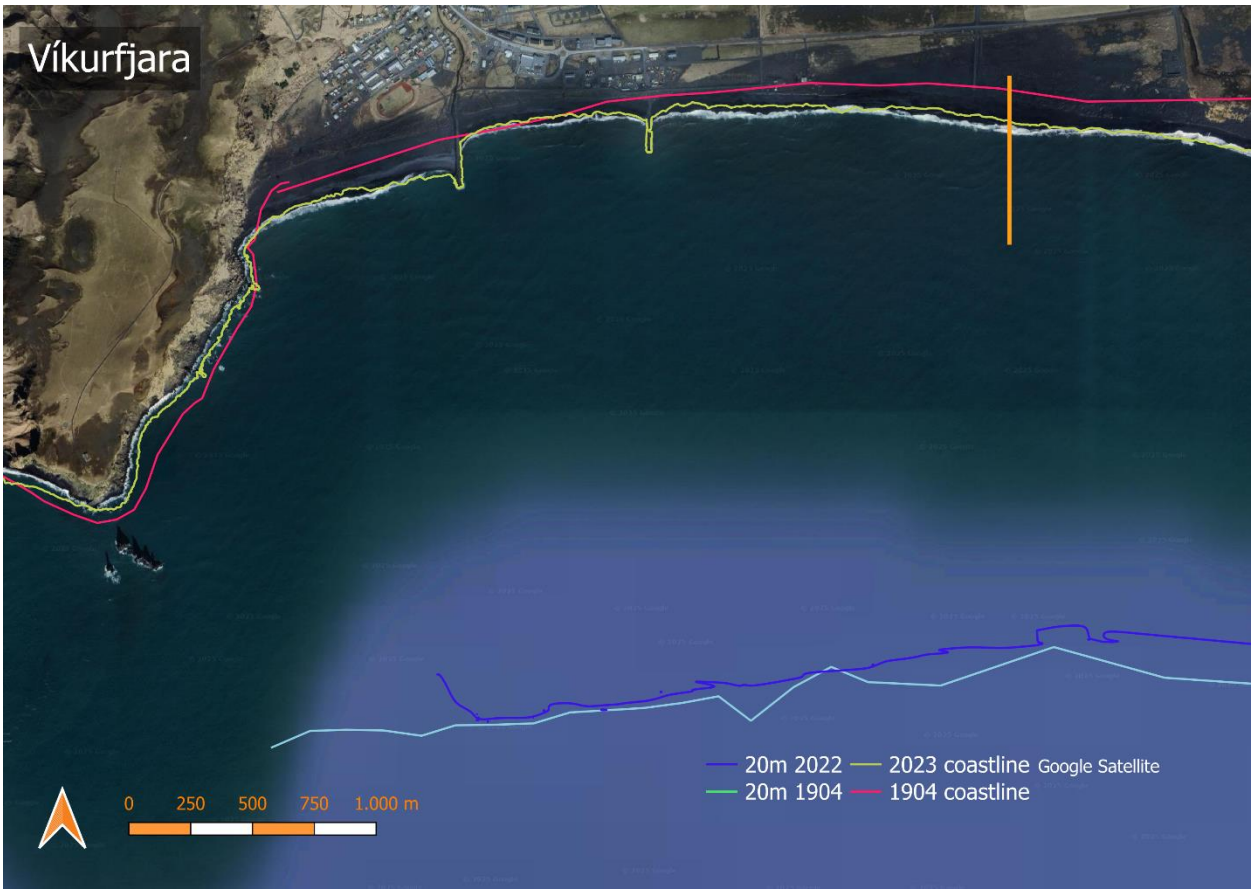

Figure 22. A map showing the Víkurfjara beach, along with the two coastlines used for the volume calculations and the depth lines from 1904 and 2022.

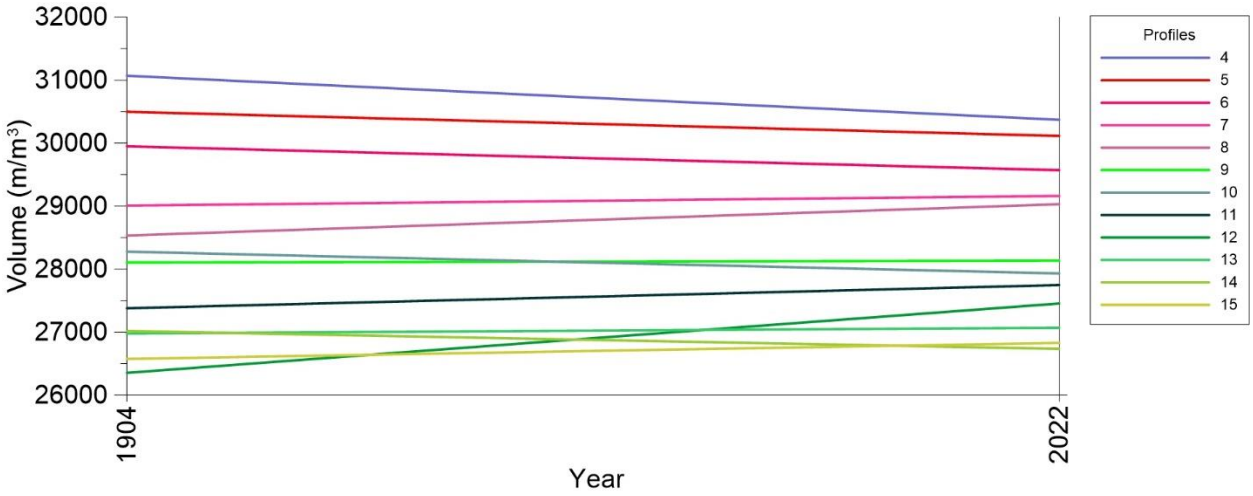

Figure 23. Graph showing volume changes on the profiles at the Víkurfjara beach between 1090 and 2022. The calculation for the volume extends down to 20 m depth for profiles 4-15. No bathymetric survey data from 2022 is available for profiles 1-3.

Table 19. The profile volume (m^3/m) at the Víkurfjara beach from 1904 and 2022. The volume calculation goes down to 20 meters. There is no depth data available for profiles 1-3 for 2022.

	Víkurfjara															
Profiles / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1904 volume (m^3/m)	33.355	32.355	31.771	31.069	30.497	29.949	29.008	28.533	28.105	28.277	27.378	26.353	26.978	27.018	26.574	437.221
2022 volume (m^3/m)	NA	NA	NA	30.370	30.113	29.570	29.161	29.030	28.133	27.931	27.747	27.454	27.069	26.734	26.828	340.139
Difference between years (m^3/m)				-700	-385	-379	153	498	28	-347	368	1.101	92	-284	254	400

The Kötlutangi protrusion volume change between 1904 and 1918

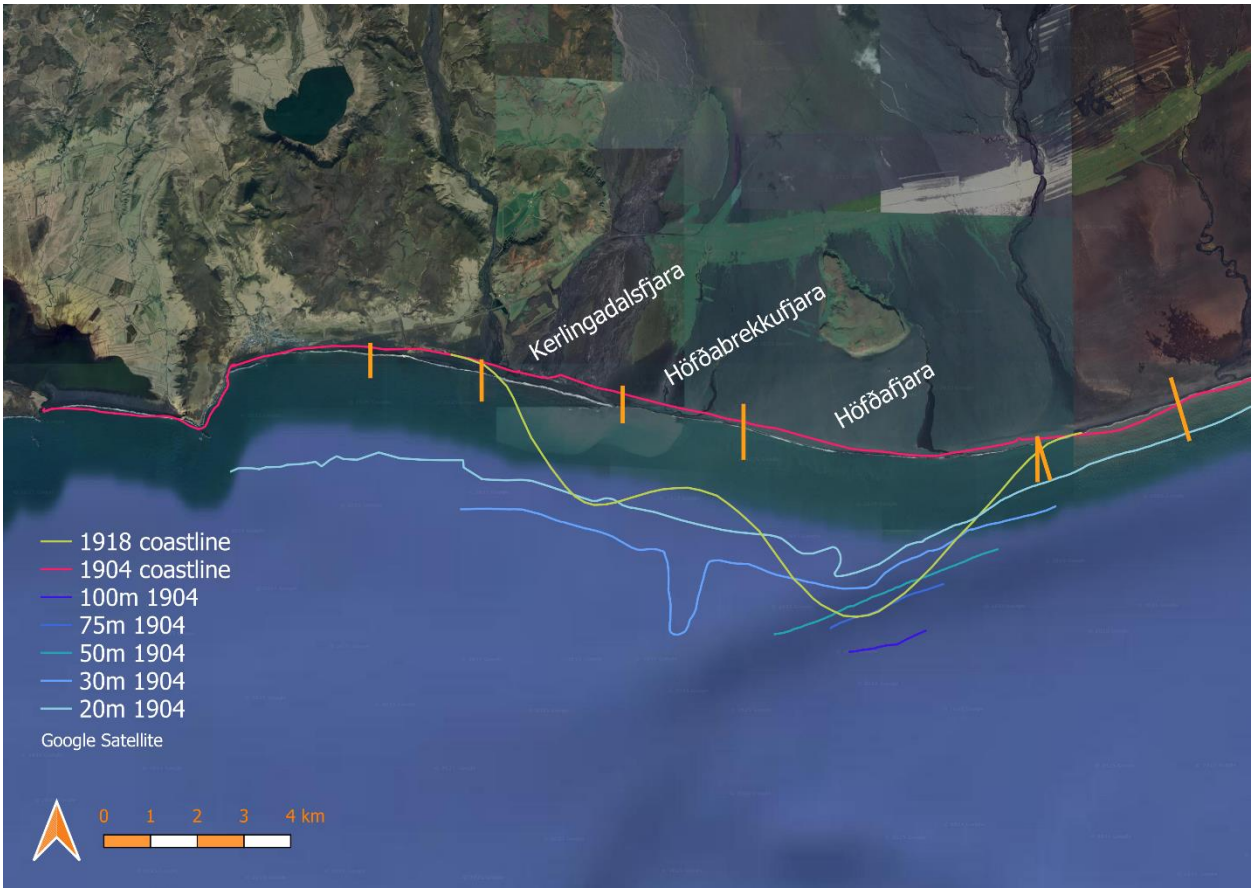

Figure 24. A map showing the area of the Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara beaches, along with the 1904 and 1918 coastlines and the 5 m, 10 m, 20 m, 50 m, 75 m and 100 m depth lines from 1904 used in the calculation for the volume changes for Kötlutangi in 1918.

On the 12th of October 1918, an eruption started in Katla Volcanic system. The eruption site was within the caldera of Katla volcano, underneath the Mýrdalsjökull Ice cap. The eruption lasted for 24 days and caused numerous glacial outburst floods, with the first flood being the largest. The initial outburst flood lasted for about 5-6 hours and has been estimated to have a volume of about 300.000 m^3s^{-1}. The glacial outburst flood consisted of meltwater from the glacier due to the subglacial eruption, cooled solidified lava in the form of tephra, rock fragments of various sizes from previous eruptions, uprooted soil and ice and icebergs. The flood expanded over the Mýrdalssandur outwash plain and entered the ocean, depositing high volumes of sediments on the seabed and extended the coastline in front of the outlet of Múlakvísl river and the coastline south of the mountain of Hjörleifshöfði, at the three beaches of Kerlingadalsfjara, Höfðabrekkufjara and Höfðafjara (Figure 24). This protrusion continued to grow until the 17th of October at least. The western part of the protrusion, the one in front of Múlakvísl river outlet, largely disappeared before the 4th of November

1918, but the eastern part extended about 4 km further than it had before the eruption but started to be eroded soon after as well. (Larsen, 2018, Tómasson, 1996).

With the new coastline positions and bathymetric survey there is an opportunity to calculate the volume derived from the 1918 glacial outburst flood. The glacial outburst flood deposit would have included grain size of all sizes, along with pieces of ice and other debris. A 40° incline on the deposit, similar to the incline of large grain sized deltas, was chosen to represent the front of the flood deposit, but a 25° or a 30° incline are likely to work as well but would give a larger volume than the 40° incline. The coastline and bathymetric survey from 1904 were used to represent the volume before the glacial outburst flood, as it is the only available data before the flood, while the 1918 coastline was used for the post-flood coastline. To compare the two, the intersection point between the line with 40° incline from the coastline position of 1918 and the line between the two depth lines from 1904 that the coastline point from 1918 fell in between, was calculated. The intersection point becomes the end point of each profile, that is the one from 1904 and the one from 1918, and the volume changes of the profiles calculated to find the volume that was deposited in the 1918 glacial outburst flood. This approach takes into the account the different angle between depth lines from the 1904 bathymetric survey and the different depth for different profiles, giving a more accurate calculation of the volume from the outburst flood. In Figure 24 the coastline location and depth lines that were used in the calculations can be seen. Only the most southerly part of the Kötlutangi protrusion extended beyond the 50 m and the 75 m depth lines from 1904, while most of the protrusion did not extend beyond the 20 m and 30 m depth lines. Table 20 shows the result of the volume change calculations, where the addition of the Kötlutangi protrusion is estimated to be about 325 Mm^3. In Tables 20 and 21 the result is broken down to each of the three beaches, where the Höfðafjara beach had both the most total volume increase and the profile section average, while Kerlingadalsfjara and Höfðabrekkufjara have similar values.

Table 20. The total difference of changes in volume from 1904 to after the glacial outburst flood in 1918. The changes are also broken down into individual beach and the average change of each profile section of that beach.

	Total volume change (m^3)	Section average change (m^3)
Kötlutangi	324.728.420	5.412.140
Kerlingadalsfjara	43.772.162	2.918.144
Höfðabrekkufjara	37.924.996	2.917.307
Höfðafjara	243.031.263	7.594.727

Table 21. The profile volume (m^3/m) at Kerlingadalsfjara, Höfðabrekkufjara, and Höfðafjara beaches from 1904 and 1918. The volume calculation goes down to 20 meters.

	Kerlingadalsfjara															
Profiles / years	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	Total
1904 volume (m^3/m)	373	1.093	2.334	5.622	11.683	18.461	24.332	30.314	35.456	40.971	58.157	61.022	60.670	57.777	46.351	454.616
1918 volume (m^3/m)	402	1.258	2.838	7.416	16.600	27.244	36.633	46.968	56.601	65.167	84.210	87.511	86.994	83.717	69.916	673.477
Difference between years (m^3/m)	29	165	504	1.794	4.918	8.782	12.301	16.654	21.145	24.196	26.053	26.489	26.323	25.941	23.565	218.861
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	5.750	33.097	100.851	358.839	983.547	1.756.452	2.460.264	3.330.746	4.229.052	4.839.243	5.210.684	5.297.848	5.264.653	5.188.137	4.712.999	43.772.162

	Höfðabrekkufjara													
Profiles / years	43	44	45	46	47	48	49	50	51	52	53	54	55	Total
1904 volume (m^3/m)	43.182	41.147	39.108	37.277	35.425	34.169	33.199	32.970	33.491	34.680	36.760	40.536	45.050	486.993
1918 volume (m^3/m)	64.083	60.079	56.194	52.731	49.377	47.074	45.258	44.631	45.170	46.687	49.377	54.681	61.275	676.618
Difference between years (m^3/m)	20.901	18.932	17.086	15.455	13.952	12.905	12.060	11.660	11.679	12.006	12.618	14.145	16.226	189.625
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	4.180.274	3.786.436	3.417.133	3.090.948	2.790.411	2.580.972	2.411.910	2.332.093	2.335.862	2.401.268	2.523.502	2.829.041	3.245.145	37.924.996

	Höfðafjara															
Profiles / years	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
1904 volume (m^3/m)	50.775	57.139	77.831	88.332	101.221	153.963	172.203	191.565	207.688	222.661	371.753	382.816	435.445	428.950	416.319	368.189
1918 volume (m^3/m)	69.475	78.696	104.466	120.784	138.696	196.027	218.737	245.147	267.046	286.702	432.636	447.832	503.908	499.017	486.735	435.265
Difference between years (m^3/m)	18.700	21.558	26.636	32.452	37.475	42.064	46.534	53.581	59.358	64.041	60.883	65.015	68.464	70.067	70.416	67.075
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total volume of section (m^3)	3.739.914	4.311.524	5.327.168	6.490.317	7.495.038	8.412.766	9.306.833	10.716.220	11.871.628	12.808.118	12.176.560	13.003.072	13.692.763	14.013.491	14.083.281	13.415.064

	Höfðafjara															
Profiles / years	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	Total
1904 volume (m^3/m)	354.389	340.380	319.074	203.959	187.436	168.409	149.445	90.599	82.944	59.613	53.324	46.660	37.143	29.345	20.498	13.383	5.883.452
1918 volume (m^3/m)	417.755	399.039	369.456	247.158	223.964	198.866	174.666	122.600	108.659	73.114	64.241	55.076	42.816	33.361	22.438	14.230	7.098.609
Difference between years (m^3/m)	63.366	58.659	50.382	43.199	36.528	30.457	25.221	32.001	25.715	13.500	10.918	8.416	5.673	4.016	1.939	847	1.215.156
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	12.673.107	11.731.871	10.076.414	8.639.722	7.305.693	6.091.437	5.044.213	6.400.282	5.142.951	2.700.037	2.183.570	1.683.201	1.134.541	803.201	387.811	169.453	243.031.263

Volume changes of the Eastern Part

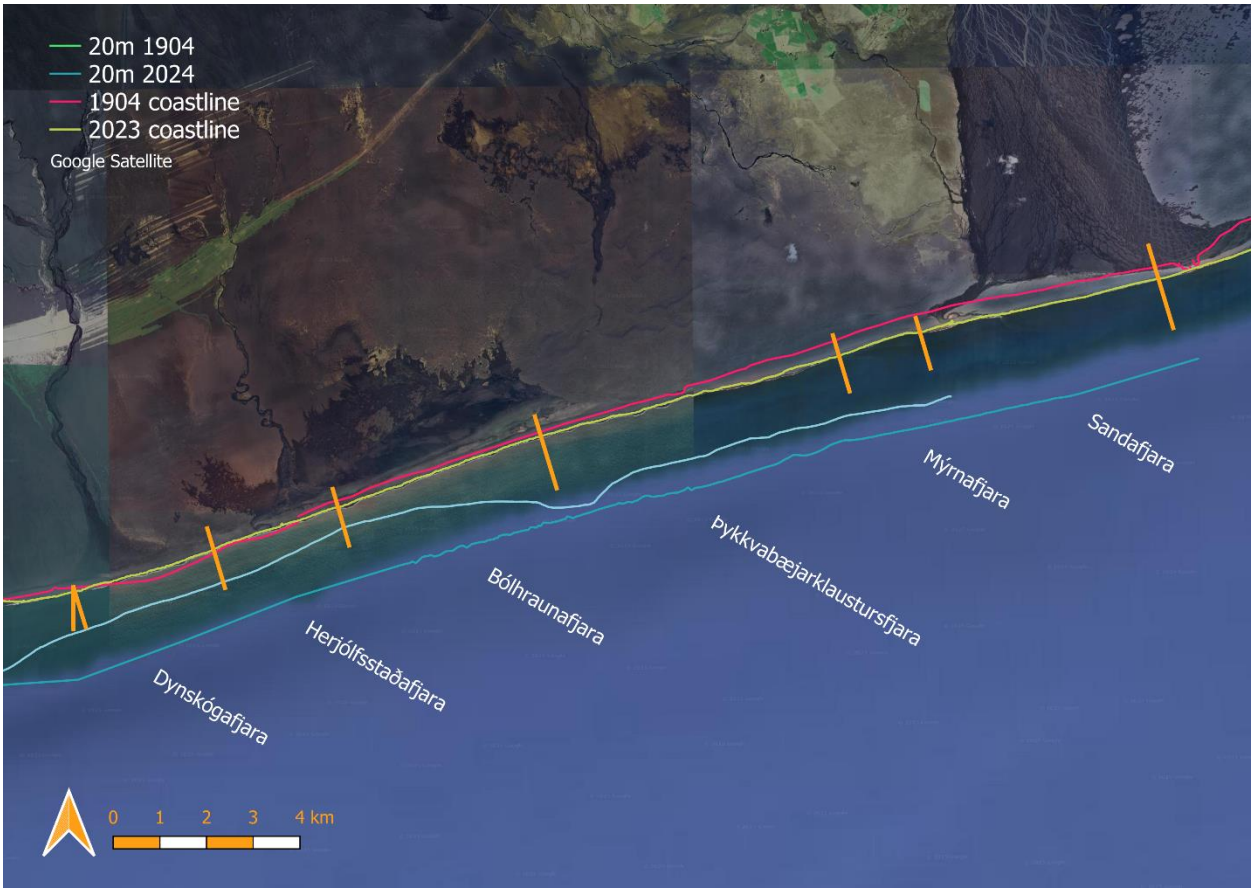

Figure 25. A map showing the eastern part of the research area along with the 1904 and 2023 coastlines and the 20 m depth line from 1904 and 2024 used in the calculation for the volume changes.

There are only two bathymetric surveys available for the eastern part, in 1904 and 2024. The coastline used for the calculation is from 2023, as there is not a coastline available that extends over the entire area for 2024. The depth line used for the calculations was the 20 m depth line for both the surveys. Once the volume of each profile had been calculated, the section volume change was found by multiplying the profile volume with the section width, which is 200 meters for all the profiles. Figure 25 shows the map of the area, along with the coastline and depth line's locations used for the volume change calculations. In Table 22 the results from the volume calculation for the eastern part of the research area can be seen, and in Table 23 the results from the calculation are broken down for individual beaches. The total volume increase for the eastern part between 1904 and 2024 is about 160 Mm^3 and each beach increases in volume over the period. The Þykkvabæjarklaustursfjara beach increased its volume the most over the period, while the Bólhraunafjara beach increased its section average the most. The 20 m depth migrated further from the shoreline during the period, especially at the three most western beaches of the eastern part.

Table 22. The total difference of changes in volume on the western part of the research area between 1904 and 2024. The changes are also broken down into individual beaches and the section average change of each profile of that beach, along with the distance of the coastline to the 20 m depth line.

	Total volume change (m^3)	Section average change (m^3)	Average distance to 20 depth (m) in 1904	Average distance to 20 depth (m) in 2024
Eastern part	160.186.226	1.686.171	1.149	1.764
Dynskógarfjara	25.837.968	1.614.873	652	1.681
Herjólfsstaðarfjara	25.553.755	1.825.268	629	1.575
Bólhraunafjara	44.835.486	1.949.369	962	1.712
Þykkvabæjarklaustursfjara	49.535.844	1.501.086	1.538	1.857
Mýrnafjara	14.423.172	1.602.575	1.813	1.969

Table 23. The volume from 1904 and 2024 surveys, the difference in volume of each profile, the width of the section between profiles and the total volume (m^3/m) of each section, broken down for individual beaches.

	Dynskógafjara																
Profiles / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1904 volume (m^3/m)	49.929	50.242	50.640	50.797	50.764	50.943	51.266	51.598	51.901	52.049	51.993	51.747	51.412	51.138	50.749	50.261	817.429
2024 volume (m^3/m)	60.257	60.265	59.924	59.890	60.007	59.818	59.730	59.765	59.707	59.507	59.599	59.246	58.946	58.623	58.347	58.152	951.782
Difference between years (m^3/m)	10.327	10.023	9.284	9.094	9.243	8.875	8.463	8.167	7.806	7.459	7.606	7.499	7.534	7.485	7.599	7.891	134.354
Section width (m)	100	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	1.032.735	2.004.625	1.856.711	1.818.740	1.848.604	1.774.938	1.692.670	1.633.401	1.561.169	1.491.732	1.521.234	1.499.701	1.506.846	1.497.010	1.519.723	1.578.130	25.837.968

	Herjólfsstaðafjara														
Profiles / years	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
1904 volume (m^3/m)	49.691	49.268	49.009	48.992	48.946	48.819	48.383	47.830	47.283	46.545	44.776	44.208	43.601	43.063	660.412
2024 volume (m^3/m)	57.672	57.199	56.974	56.845	56.484	56.265	56.147	56.087	55.848	55.943	55.889	55.744	55.573	55.510	788.181
Difference between years (m^3/m)	7.981	7.930	7.966	7.854	7.538	7.447	7.764	8.257	8.565	9.399	11.113	11.536	11.972	12.448	127.769
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	1.596.190	1.586.091	1.593.139	1.570.754	1.507.680	1.489.317	1.552.801	1.651.428	1.713.025	1.879.716	2.222.573	2.307.122	2.394.400	2.489.518	25.553.755

	Bólhraunafjara											
Profiles / years	31	32	33	34	35	36	37	38	39	40	41	42
1904 volume (m^3/m)	42.953	43.034	42.882	42.737	42.614	42.606	42.590	42.536	42.680	43.174	43.796	44.183
2024 volume (m^3/m)	55.635	55.451	55.224	55.189	55.082	54.932	55.145	54.404	54.811	54.400	54.604	53.941
Difference between years (m^3/m)	12.682	12.417	12.342	12.452	12.468	12.326	12.554	11.869	12.131	11.226	10.808	9.758
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200
Total volume of section (m^3)	2.536.314	2.483.401	2.468.332	2.490.402	2.493.544	2.465.267	2.510.872	2.373.717	2.426.172	2.245.198	2.161.592	1.951.581

	Bólhraunafjara											
Profiles / years	43	44	45	46	47	48	49	50	51	52	53	Total
1904 volume (m^3/m)	44.282	44.615	44.812	45.170	45.619	46.165	46.751	47.237	47.887	49.409	50.236	1.027.966
2024 volume (m^3/m)	54.275	54.189	54.017	54.003	53.941	54.032	53.986	53.748	53.484	53.851	53.799	1.252.144
Difference between years (m^3/m)	9.993	9.574	9.205	8.833	8.322	7.868	7.235	6.511	5.598	4.442	3.564	224.177
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	1.998.659	1.914.768	1.840.974	1.766.629	1.664.448	1.573.562	1.447.076	1.302.287	1.119.510	888.478	712.705	44.835.486

	Þykkvabæjarklaustursfjara																
Profiles / years	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
1904 volume (m^3/m)	50.664	50.993	51.170	51.149	49.918	48.883	48.332	47.902	47.505	47.434	47.540	47.916	48.074	48.274	48.603	49.001	48.081
2024 volume (m^3/m)	53.803	54.211	54.187	54.077	53.968	54.253	54.674	54.833	54.556	55.287	55.923	55.811	56.160	55.736	56.366	56.412	56.476
Difference between years (m^3/m)	3.139	3.218	3.017	2.928	4.050	5.371	6.342	6.931	7.051	7.853	8.383	7.896	8.087	7.462	7.764	7.411	8.395
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total volume of section (m^3)	627.891	643.626	603.436	585.541	810.081	1.074.146	1.268.335	1.386.189	1.410.100	1.570.680	1.676.603	1.579.186	1.617.327	1.492.342	1.552.749	1.482.175	1.679.018

	Þykkvabæjarklaustursfjara																
Profiles / years	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	Total
1904 volume (m^3/m)	47.760	47.744	47.667	47.481	47.326	47.732	47.864	47.486	47.561	47.818	48.369	48.728	48.760	48.551	48.350	48.392	1.599.027
2024 volume (m^3/m)	56.633	56.635	56.883	56.772	56.929	57.215	57.433	56.866	56.658	57.332	56.969	56.788	56.495	56.405	56.755	57.203	1.846.707
Difference between years (m^3/m)	8.874	8.891	9.215	9.291	9.604	9.482	9.570	9.380	9.097	9.514	8.600	8.060	7.735	7.854	8.404	8.811	247.679
Section width (m)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	1.774.700	1.778.181	1.843.091	1.858.191	1.920.759	1.896.425	1.913.961	1.876.023	1.819.453	1.902.815	1.719.986	1.612.094	1.546.966	1.570.770	1.680.893	1.762.109	49.535.844

	Mýrnafjara									
Profiles / years	87	88	89	90	91	92	93	94	95	Total
1904 volume (m^3/m)	48.560	48.664	48.763	48.942	49.117	49.453	49.851	50.267	50.155	443.773
2024 volume (m^3/m)	57.322	57.467	57.440	57.514	57.649	57.826	58.018	58.162	58.826	520.224
Difference between years (m^3/m)	8.762	8.803	8.678	8.571	8.532	8.373	8.166	7.895	8.672	76.452
Section width (m)	200	200	200	200	200	200	200	200	200	
Total volume of section (m^3)	1.752.467	1.760.561	1.735.546	1.714.262	1.706.372	1.674.611	1.633.254	1.578.934	1.734.332	15.290.338

The bathymetric survey for 2024 is much more extensive than just the one depth line that is available for 1904. Figure 26 shows the location of the two coastlines and the two 20 m depth lines that were used for the volume change calculations at Þykkvabæjarklaustursfjara. Both the coastline and the 20 m depth line have moved further south than the 1904 lines, and the volume has increased by about 50 Mm^3. Figure 27 shows the 2024 bathymetric survey down to 20-meter depth at a 1-meter interval.

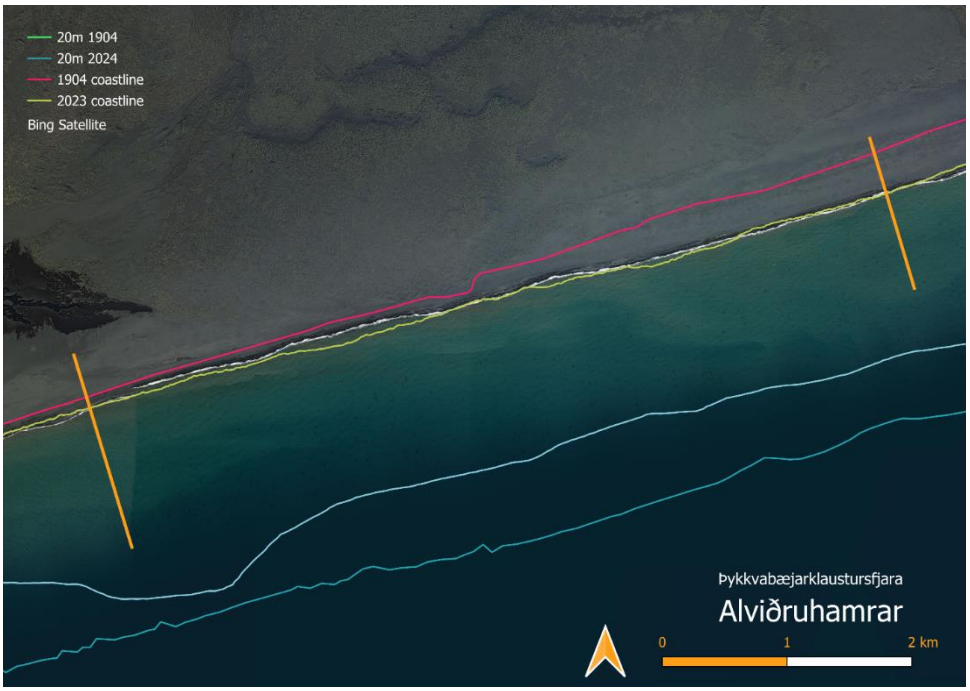

Figure 26. A map showing the Þykkvabæjarklaustursfjara (Alviðruhamrar) beach, along with the 1904 and 2023 coastlines and the 20 m depth line from 1904 and 2024 used in the calculation for the volume changes.

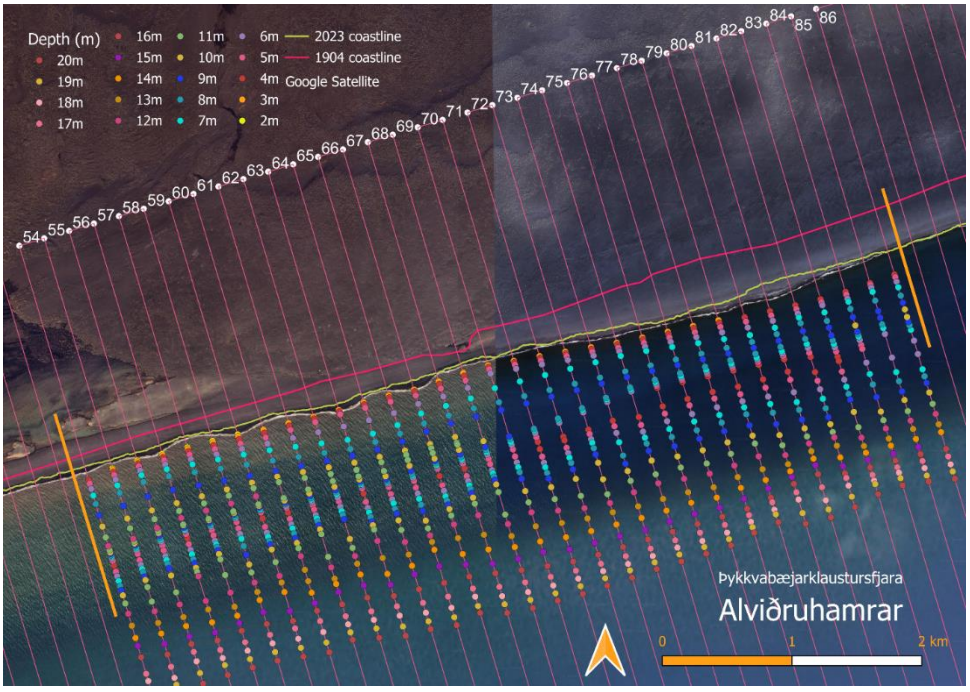

Figure 27. A map showing the Þykkvabæjarklaustursfjara (Alviðruhamrar) beach, along with the 1904 and 2023 coastlines and the depth lines from the 2024 survey. The profiles derived from this survey and the profiles created to calculate volume change can be seen in Figure 28.

In Figure 28, the profiles that were used to calculate the volume change, along with the profile of the 1-meter interval survey, are plotted against each other. This reveals a large sandbar that is in between the coastline and the 20 m depth line in the 2024 survey. This demonstrates the difficulty with only using the 20 m depth line in volume calculations, as the topography of the seabed is lost in between the coastline and the 20 m depth. However, the 20 m depth line is only available for the 1904 survey, and using the 1-meter interval profile would skew the results. The 2024 survey does bring the possibility for the future comparison with other new surveys.

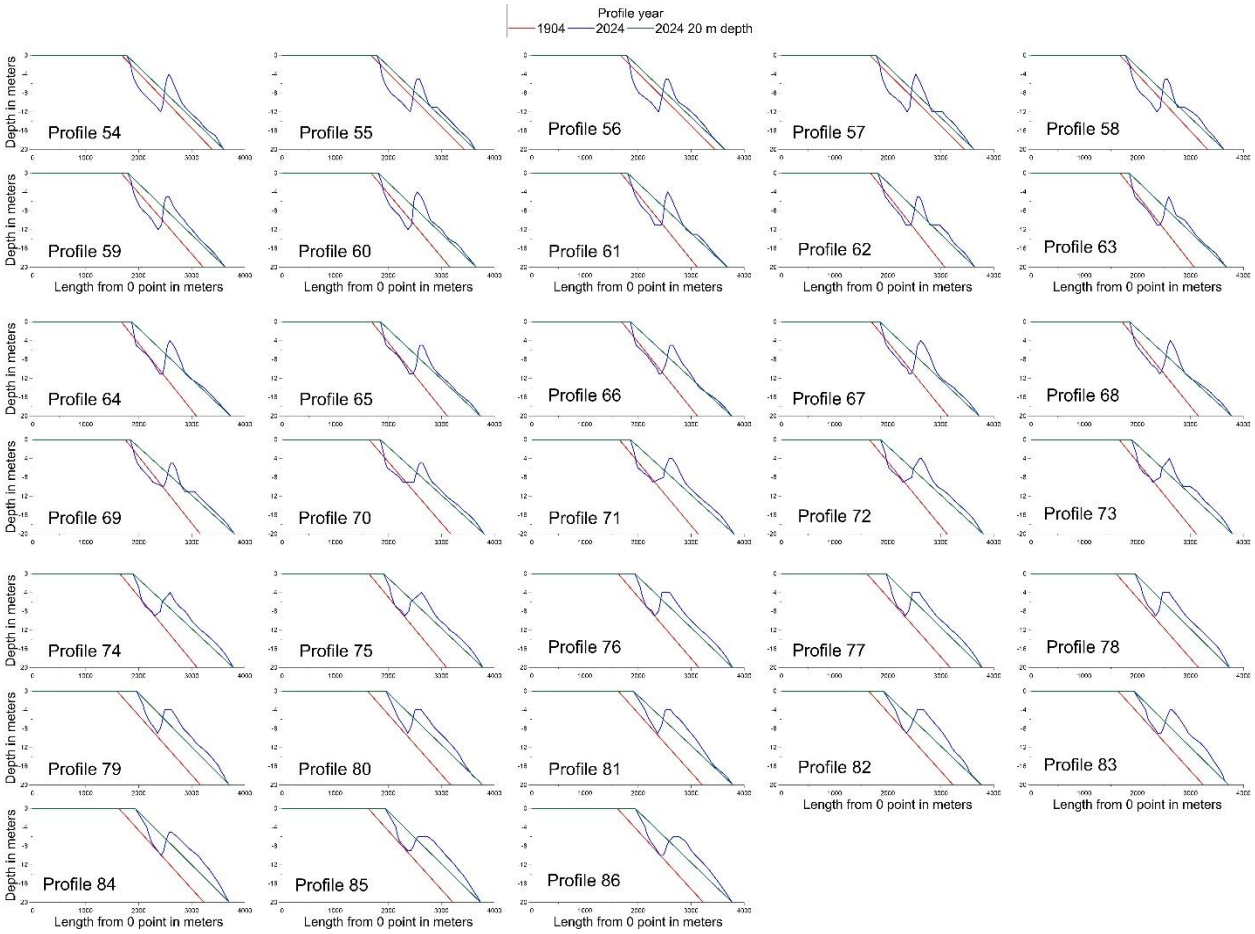

Figure 28. Graph showing the profiles of the Þykkvabæjarklaustursfjara (Alviðruhamrar) beach with the bathymetric surveys from 1904 and 2024. The 2024 survey is shown both only with the coastline position from 2023 and the 20 m depth line and with the complete survey along with the 2023 coastline position.

Discussion

This is not the first attempt to calculate the volume for Kötlutangi protrusion, as the volume had previously been estimated to be between 200-300 Mm^3 (Tómasson, 1996) and 250 Mm^3, assuming an unchanged 50 m depth line (Larsen, 2018). We however argue that the 50 m depth line changed over the distance of a number of profiles, increasing the overall volume of the flood deposit, and that the protrusion extended past the 75 m depth line on the most southern end. Using other depth lines to calculate also increases the accuracy of the calculations for every part of the area.

The calculated total volume of Kötlutangi presented in this report, about 325 Mm^3, is probably still an underestimation of the total volume brought by the glacial outburst flood. A 40° angle of the front slope was used to prevent overestimation of the volume, but realistically the angle of the front slope was probably less than that. Tómasson, 1996 and Jónsson, 1982, have also pointed out, that it is likely that the volume is even greater as gravity currents would likely have carried the finest material beyond the protrusion. Tómasson argued that the finest material could have been up to 26% of the volume of the flood deposit, which would add an additional 84,4 Mm^3 to the total volume of the deposition below 0 m at Chart Datum, bringing the total volume up to about 409 Mm^3. The area of the Kötlutangi protrusion, mapped out using the 1904 coastline as the back area, is about 25 km^2, which would add an additional 100 Mm^3 to the total volume of the protrusion, if an average height of 4 meters above CD is used. That would mean that the Kötlutangi protrusion had about 509 Mm^3 of total volume, both above and below the CD, shortly after its formation in 1918.

Due to limited bathymetric surveys for the whole research area, it is difficult to say when the impact of the 1918 glacial outburst flood occurred at each beach, and when the impact of it started to erode. The sea charts available today are largely based on surveys done in 1973 and 1904. The 20 m depth line from 1973 seems to be based on the 1904 line in some areas in the western part of the research area, while there is no data from 1973 available for the eastern part. If the 20 m depth line from 1973 is used in volume calculations for the western part, and compared with the results from 1904 and 2024, the result (Table 24) gives an increase in volume from 1904 to 1973 of about 82 Mm^3 on the western part, indicating a period of growth between 1904 and 1973. Between 1973 and 2024, the volume decreases about 83 Mm^3, which gives the total change of decreased volume of about 1,4 Mm^3 from 1904. This would indicate that the volume increase derived from the 1918 eruption has largely been eroded away, as it did with the comparison of 1904 and the 2024 surveys only, but that it only has done so in about the last 50 years and before that the volume was still being distributed away from the Kötlutangi protrusion and to the nearby areas of the coastline. One thing to keep in mind though, as the 20 m depth lines are almost identical between 1904 and 1973, it is the advancement of the coastline (1975 line used for calculations for the 1973 survey) that results in most of the increase and not a change in the location of the 20 m depth line.

The direct impact of the 1918 glacial outburst flow is less evident on the eastern part. A trend in coastline advancement after 1928 and until 1950, and in some cases until 1975, is an indication that the coastline extended after the glacial outburst flow, and the overall increase in volume between 1904 and 2023 supports that. The volume and coastline advancement in the eastern part seem to be more stable than in the western part and there is little to no indication that a period of long-term

coastline erosion is happening there, suggesting that the eastern and western parts will evolve differently in the future.

Table 24. The total volume change and the section average change between the 1904 and 1973 surveys and the 1973 and 2024 surveys for the western part of the research area.

	Total volume change (m^3)	Section average change (m^3)
1904-1973	81.739.761	1.021.747
1973-2024	-83.079.753	-1.038.497
total change:	-1.339.991	-16.750

The authors of the report are responsible for its contents. Its findings should not be interpreted as the stated policy of the Icelandic Road and Coastal Administration or the opinions of the institutions or companies for which the authors work.

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