OR Annual report 2020

Appendices

Release of geothermal water from the Nesjavellir and Hellisheidi geothermal power plants. Groundwater monitoring.

Carbfix LJÓSLEIÐARINN REYKJAVIK FIBRE NETWORK ON POWER VEITUR

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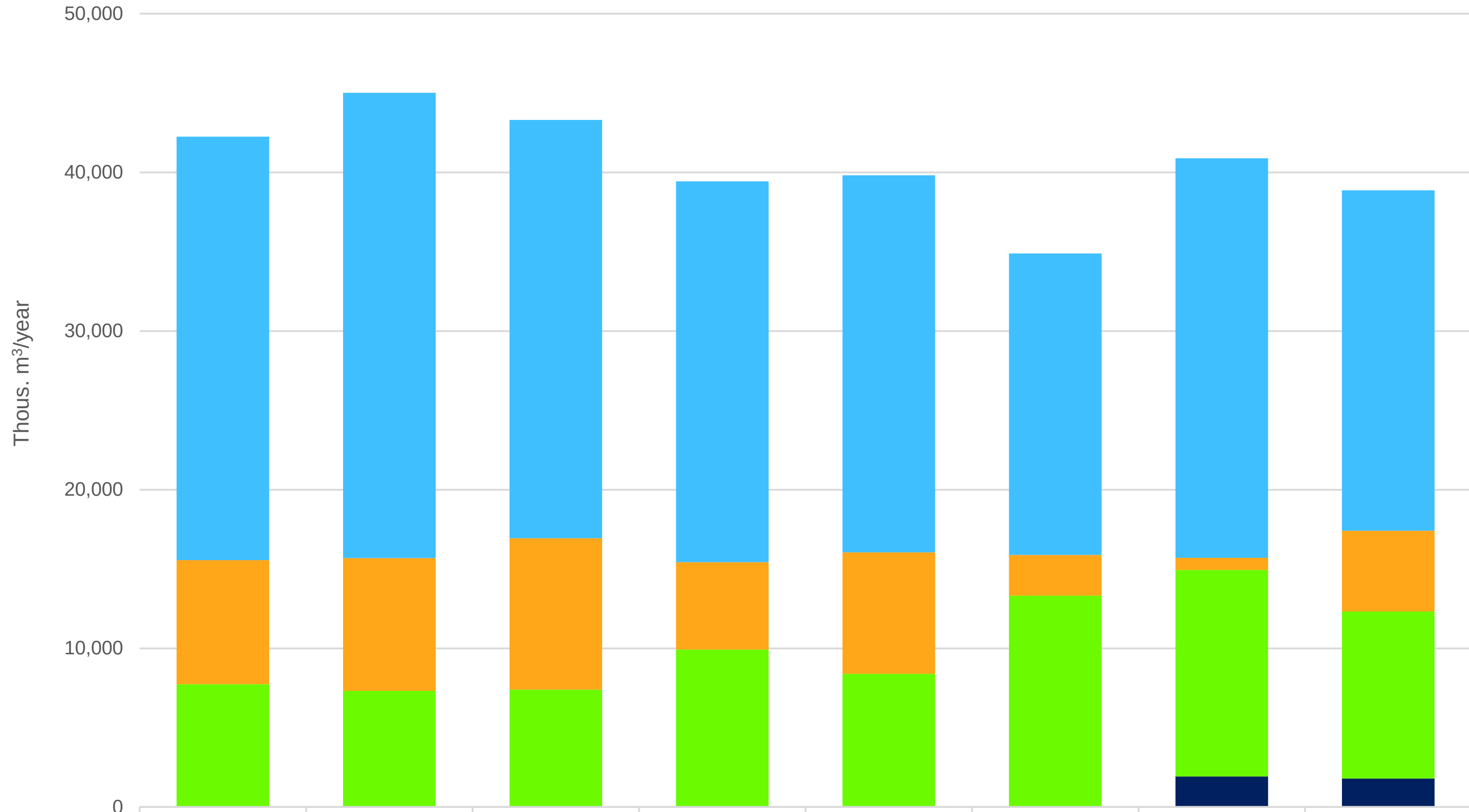
Cover photo: Gretar Ívarsson

Volume of geothermal water from the Nesjavellir Geothermal Power Plant by release route

Geothermal water (thous.m³/year) from Nesjavellir Geothermal Power Plant 2013-2020 by release route.

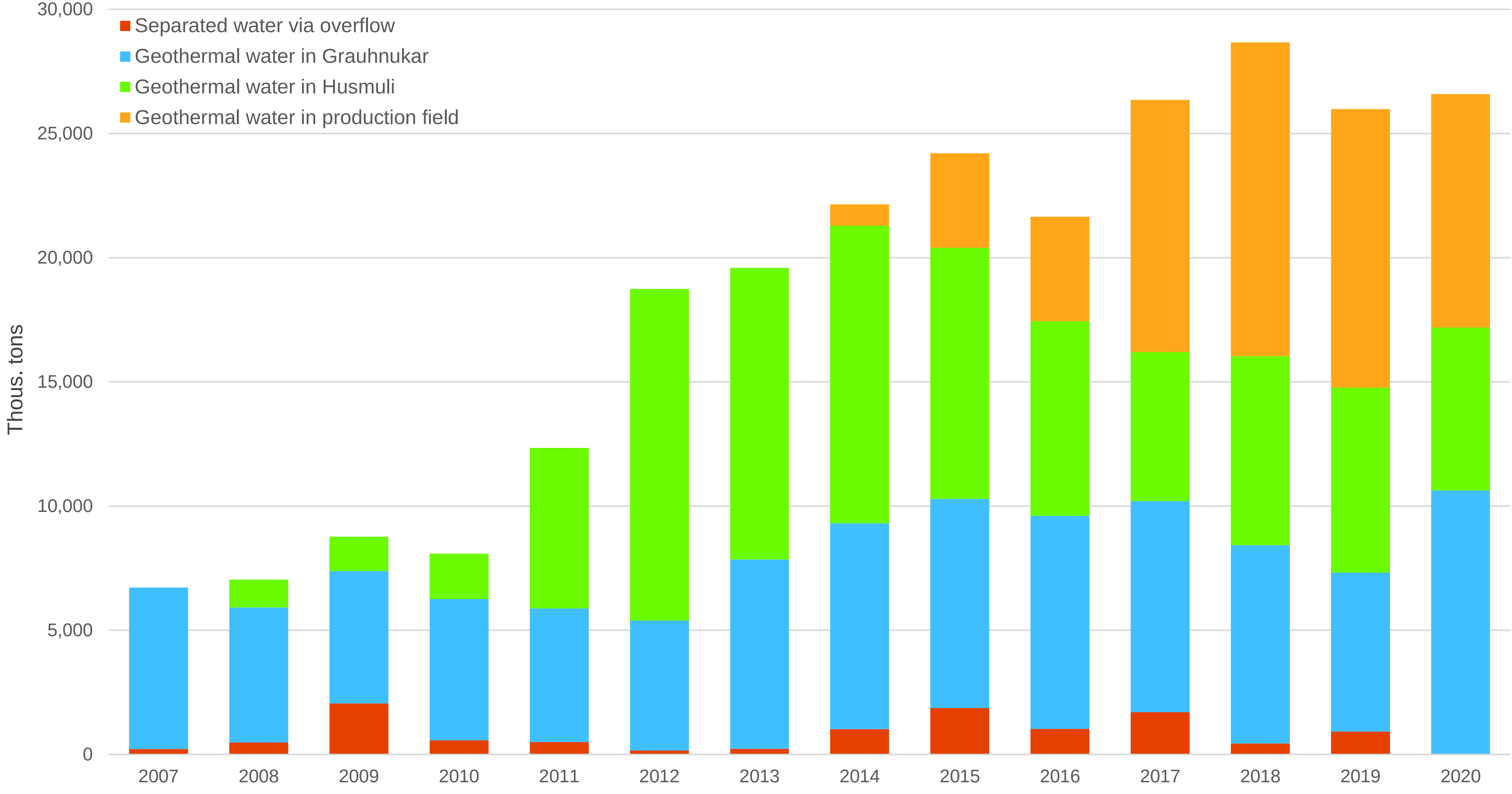
Volumes are rounded to thousands of tonnes.



	2013	2014	2015	2016	2017	2018	2019	2020
Heated groundwater on surface	26,687	29,333	26,371	24,009	23,760	18,993	25,183	21,472
Geothermal water on surface	7,824	8,367	9,545	5,504	7,649	2,556	754	5,083
Geothermal water in shallow injection	7,730	7,317	7,388	9,917	8,395	13,328	13,025	10,528
Geothermal water in deep reinjection							1,915	1,792

Volume of geothermal water from the Hellisheidi Geothermal Power Plant by release route 2007 – 2020

Until September 2011, the largest part of geothermal water was reinjected through wells in Gráuhnúkar. Geothermal water from the plant increased when the Sleggjan plant was launched in autumn 2011, but the reinjection field at Húsmúli was then put into full operation. Since then the geothermal water from the plant has increased. Reinjection in discontinued production wells within the production field started in 2014 and in boreholes in Threngsli in 2016. There was a significant decrease in the release of geothermal water on the surface via overflow in the latter part of 2011 with improvements in the power station's operations, but they increased again around mid-2014 with the diminishing reception of reinjection fields. The situation improved significantly in 2020.



Year	Seperated water via overflow thous. tons/year	Geothermal water in Gráuhnúkar thous. tons/year	Geothermal water in Húsmúli thous. tons/year	Geothermal water in production field thous. tons/year	Total geothermal water thous. tons/year
2007	215	6,502			**6,718**
2008	483	5,439	1,123		**7,045**
2009	2,050	5,335	1,382		**8,767**
2010	572	5,684	1,826		**8,082**
2011	506	5,374	6,461		**12,341**
2012	163	5,224	13,358		**18,745**
2013	233	7,620	11,733		**19,586**
2014	1,024	8,281	11,982	860	**22,147**
2015	1,870	8,422	10,107	3,803	**24,202**
2016	1,025	8,585	7,831	4,213	**21,654**
2017	1,699	8,506	6,001	10,147	**26,353**
2018	447	7,982	7,611	12,625	**28,665**
2019	919	6,409	7,445	11,206	**25,980**
2020	21	10,610	6,558	9,394	**26,583**
Total	**11,227**	**99,973**	**93,418**	**52,248**	**256,866**

Volumes are rounded to thousands of tons

Geothermal fluids discharged via overflows at the Hellisheidi Geothermal Power Plant and in Hverahlid 2020

The reinjection utility is vulnerable to any operational changes and approximately 0.1% of produced geothermal water at Hellisheidi Power Plant was released via overflow. Licensors have been kept informed on the situation, on actions available at any given time and of the ongoing projects to increase the reception of the reinjection utility.

Date	Type of disturbance	24-hour average flow	Total m^3
Hellisheidi power plant			
January 13th & 14th	Maintenance	30	5,900
February 6th & 7th	Malfunction	100	1,500
April 28th – 30th	Maintenance	230	4,400
June 9th – 11th	Malfunction	212	1,000
September 8th – 10th	Malfunction	200	2,500
September 18th – 25th	Construction	314	2,400
Hverahlid			
September 22nd – 24th	Maintenance	75	3,000

Chemical composition of geothermal water and heated groundwater for space heating from geothermal power plants in the Hengill area

Typical concentrations (µg/L) of several trace elements in geothermal water (separated water) and heated groundwater (for space heating) from the Hellisheidi and Nesjavellir geothermal power plants and their maximum permissible concentrations (µg/L) for potable water. When the chemical content of separated water is compared to potable water standards, one can see that the concentration of aluminium is nine times higher and the concentration of arsenic in separated water from Nesjavellir was almost double that of maximum for potable water. The concentration of other substances in separated water and heated groundwater is lower than the given limits for potable water.

Trace element	Unit	Max. recommended value for potable water	HELLISHEIDI		NESJAVELLIR	
			Separated water	Heated groundwater	Separated water	Heated groundwater
Arsenic (As)	µg/L	10	4.96	0.08	18.00	2.09
Barium (Ba)	µg/L	700	0.29	0.58	0.15	0.56
Cadmium (Cd)	µg/L	5	< 0.002	< 0.002	< 0.002	< 0.002
Cobalt (Co)	µg/L	*	< 0.005	< 0.005	< 0.005	< 0.005
Chrome (Cr)	µg/L	50	0.03	0.06	0.13	0.35
Copper (Cu)	µg/L	2,000	< 0.1	0.26	1.59	0.12
Mercury (Hg)	µg/L	1	< 0.002	< 0.002	< 0.002	< 0.002
Manganese (Mn)	µg/L	50	0.32	0.23	0.49	< 0.03
Molybdenum (Mo)	µg/L	*	0.59	0.14	1.99	0.70
Nickel (Ni)	µg/L	20	0.06	0.51	1.19	< 0.05
Phosphorus (P)	µg/L	5,000	< 1	32.3	0.03	42.0
Lead (Pb)	µg/L	10	0.02	< 0.01	0.03	< 0.01
Antimony (Sb)	µg/L	5	0.17	< 0.01	0.39	0.03
Selenium (Se)	µg/L	10	1.43	< 0.5	2.88	1.40
Strontium (Sr)	µg/L	*	4.63	10.90	2.18	18.10
Titanium (Ti)	µg/L	*	0.12	0.07	0.13	0.05
Vanadium (V)	µg/L	*	3.43	7.41	1.98	20.00
Zinc (Zn)	µg/L	3,000	4.06	1.63	4.63	0.35

** Maximum limits not specified in the potable water regulation*

Chemical composition of geothermal water (separated water) and heated groundwater (for space heating) from the Hellisheidi and Nesjavellir Geothermal Power Plants and their maximum permissible concentrations (mg/kg) for potable water

When the chemical content of separated water is compared to potable water standards, one can see that in separated water from the Hellisheidi and Nesjavellir Geothermal Power Plants, the concentration of potassium is almost three times higher than permissible levels for potable water. The concentrations of fluoride in the separated water from Hellisheidi also exceeds the limit. Concentrations of other chemicals in condensate and heated groundwater from both power plants is lower than the given limits for potable water.

Chemical- and physiological factors	Unit	Max. recommended value for potable water	HELLISHEIDI		NESJAVELLIR	
			Separated water	Heated groundwater	Separated water	Heated groundwater
Acidity	pH		9.89	7.69	8.57	8.24
T (pH)	°C		22.5	23.5	22.5	22.7
Carbon dioxide (CO_2)	mg/kg	*	31.1	30.6	23.6	48.9
Hydrogen sulphide (H_2S)	mg/kg	*	24.9	-	81.6	-
Silica (SiO_2)	mg/kg	*	707.1	22.9	709.29	39.64
Sodium (Na)	mg/kg	200	195.0	6.71	163.0	18.5
Potassium (K)	mg/kg	12	33.2	0.98	31.7	2.50
Calcium (Ca)	mg/kg	100	0.49	4.97	< 1.0	9.01
Magnesium (Mg)	mg/kg	50	< 0.09	2.94	< 0.09	4.59
Iron (Fe)	mg/kg	0.2	0.003	0.002	0.003	0.002
Aluminium (Al)	mg/kg	0.2	1.78	0.002	1.80	0.01
Sulphate (SO_4)	mg/kg	200	18.6	4.35	15.02	12.76
Chloride (Cl)	mg/kg	*	170.9	6.78	159.1	14.02
Fluoride (F)	mg/kg	1.5	1.71	0.09	1.36	0.13

** Maximum limits not specified in the potable water regulation*

Chemical composition of groundwater in wells around the Hellisheidi Power Plant in 2020

Well			**HK-24**	**HK-07**	**HK-25**	**HK-12**	**HK-31**	**HK-18**	**KH-50**	**KH-05**	**KH-06**	**HU-1**	**HK-14**
Groundwater flow			**Selvogsstraumur**							**Thingvallastraumur**			
Sample no.			20-5280	20-5173	20-5322	20-5332	20-5331	20-5319	20-5171	20-5334	20-5155	20-5156	20-5170
Date			16.6.2020	25.5.2020	30.6.2020	7.7.2020	8.7.2020	29.6.2020	20.5.2020	9.7.2020	29.5.2020	29.4.2020	19.5.2020
Chemical properties	**Unit**	**Maximum value**											
Acidity	pH		7.79	7.76	8.17	8.16	9.60	7.98	7.15	8.67	8.39	7.81	7.59
T (pH)	°C		23.4	23.4	22.4	22.6	22.7	22.0	23.3	23.2	23.5	23.4	23.3
Conductivity	µS/cm	2,500	131.3	185.8	174.8	138.7	257.0	138.3	181.5	366.0	109.0	68.5	80.6
T (conductivity)	°C		22.7	22.7	22.7	23.0	23.0	22.7	22.7	23.0	22.7	22.7	22.7
CO_2	mg/kg	*	33.2	56.2	57.9	39.0	75.5	42.8	52.4	139.9	35.7	22.8	24.7
F	mg/kg	1,5	0.063	0.091	0.083	0.085	0.885	0.079	0.101	0.626	0.113	0.075	0.093
Cl	mg/kg	*	9.56	8.42	10.60	8.54	8.62	10.57	8.81	8.97	7.97	7.02	7.46
SO_4	mg/kg	200	8.01	15.63	9.36	12.34	10.10	5.06	23.39	11.78	1.26	0.92	2.30
Ca	mg/kg	100	7.31	9.29	10.50	9.88	1.52	7.92	6.76	4.44	6.30	2.94	4.13
Fe	mg/kg	0,2	0.01	0.01	0.01	0.04	0.01	0.02	0.01	0.017	0.02	0.08	0.05
K	mg/kg	12	1.08	0.94	1.37	1.33	1.19	0.84	0.92	4.72	0.79	0.56	0.80
Mg	mg/kg	50	3.92	10.00	7.08	4.86	0.11	4.20	11.80	4.44	3.73	2.52	2.39
Na	mg/kg	200	8.75	10.30	11.60	9.96	59.00	10.50	7.94	67.70	7.28	5.43	6.13
SiO_2	mg/kg	*	20.44	29.14	24.43	21.86	51.86	18.26	36.21	30.64	1.33	0.32	22.71
Al	µg/kg	200	4.07	0.75	4.59	66.30	93.10	3.41	1.03	16.60	0.51	< 0.2	2.24
As	µg/kg	10	0.12	< 0.05	0.06	0.21	0.94	0.10	< 0.05	0.46	< 0.05	< 0.05	< 0.05
Ba	µg/kg	700	0.67	0.26	0.79	1.06	0.39	0.34	0.70	4.77	0.09	0.11	0.55
Cd	µg/kg	5	< 0.002	< 0.002	< 0.002	< 0.002	0.015	< 0.002	< 0.002	0.019	< 0.002	< 0.002	< 0.002
Co	µg/kg	*	0.01	0.12	0.01	0.11	0.015	0.015	0.019	0.039	0.04	0.04	0.012
Cr	µg/kg	50	0.47	0.76	1.08	2.01	0.08	1.49	0.33	0.16	0.10	0.03	0.42
Cu	µg/kg	2,000	1.11	0.61	0.59	0.21	0.38	1.03	1.28	0.41	0.314	< 0.1	0.50
Hg	µg/kg	1	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Mn	µg/kg	50	1.78	3.68	1.54	2.66	0.82	4.55	4.12	11.10	14.90	41.50	0.936
Mo	µg/kg	*	0.30	0.30	0.37	0.36	2.41	0.21	0.15	2.73	0.13	< 0.05	0.14
Ni	µg/kg	20	0.647	1.75	0.723	4.01	0.17	2.99	3.80	0.55	3.61	0.47	0.18
Pb	µg/kg	10	0.09	0.02	0.02	0.03	0.03	0.0	0.0	0.0	< 0.01	< 0.01	0.0
P	µg/kg	5,000	16.2	36.5	22.0	17.7	11.1	30.1	14.9	23.3	1.6	< 1.0	40.2
Sb	µg/kg	5	0.04	0.065	< 0.01	0.083	0.010	0.011	0.127	0.010	< 0.01	< 0.01	< 0.01
Se	µg/kg	10	< 0.5	0.56	< 0.5	1.07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Sr	µg/kg	*	17.7	22.5	20.4	21.5	5.4	14.4	16.7	25.1	8.6	5.8	9.1
Ti	µg/kg	*	0.167	< 0.001	0.406	3.62	0.102	0.069	0.067	0.196	< 0.001	< 0.001	0.092
V	µg/kg	*	15.3	14.4	14.9	20.6	27.5	17.2	3.2	1.2	0.3	< 0.005	7.4
Zn	µg/kg	3,000	24.3	9.9	6.3	9.6	2.5	11.2	14.2	35.5	2.5	0.3	6.3

* *Maximum value not specified in Icelandic regulation*

The impact of the Hellisheidi Power Plant on groundwater is closely monitored in surveillance wells at and around the plant. Samples are collected to analyse overall chemical content and trace elements, in addition to measuring their temperature, conductivity and acidity. The concentration of dissolved solids is far below the limits set for potable water. However, the concentration of sulphate has risen considerably above background limits in well HK-7 (reached maximum at the end of 2014) without any substantial increase in silica, sodium and chlorine, usually associated with separated water. Since reaching their maximum values, the concentrations of sulphate have been falling. The concentrations of sulphate and silica in well KH-50 have been fluctuating and chemical monitoring will be ongoing. Sulphate is created from the oxidation process of hydrogen sulphide which follows the steam released from the plant. Up until 2016, when the gas abatement unit at Hellisheidi was relaunched after its capacity was increased, the bulk of the hydrogen sulphide filtered through the cooling towers, along with condensate water, where the oxidation occurs. Approximately 10 kg of water per second goes into each cooling tower's overflow before it's released into shallow wells at the plant. This release was stopped in 2016 and this water is currently injected back into the geothermal reservoir. Moreover, trace elements, which are mostly in gas form, have been measured in well KH-50 selenium and mercury, although both well below the limits set for potable water), while other substances which mostly follow separated water, e.g. arsenic, have not been detected in the same well. These impacts are likely to be reduced with the ongoing operation of the gas abatement unit and the reinjection of hydrogen sulphide. The chemical composition will continue to be monitored in the surveillance well to gain a better picture of groundwater flows and the release of geothermal water from the Hellisheidi Geothermal Power Plant.