

**RioTinto**

KMP SO<sub>2</sub> EEM Program – Technical Memo P04

**Atmospheric Sulphur Dioxide**  
Passive Diffusive Sampler Network: 2016 Results

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## 1 Overview

A network of sulphur dioxide (SO<sub>2</sub>) passive diffusive samplers for was established in the Kitimat Valley during June 2016 following recommendations from a pilot study that evaluated the performance of passive SO<sub>2</sub> samplers (see Technical Memo P03: Passive Diffusive Sampler Network: Pilot Study Results, April 2016).

A second network was established during July 2016, following public consultation during the Kitimat Ambient Air Quality Monitoring Workshop, 23–24 June 2016 (Tamburello and Alexander 2016). The second network was established in urban and residential areas of Kitimat; site selection was informed by public input obtained during the workshop, and also included sites from the 2011–2012 network, e.g., sited close to schools.

This memo describes the establishment of both networks and the results of the SO<sub>2</sub> passive diffusive sampler network during 2016.

## 2 Study Design

The Kitimat Valley network was established 22–23 June 2016 at 16 monitoring sites primarily located along the Wedeene and Bish roads to capture the plume path, and also included co-location with three ambient stations (Haul Road, Riverlodge and Whitesail). On July 18, an additional site at Highway 37 and the Onion Lake Ski Trail was added to the network. The Kitimat Urban network was established on July 18, with 15 stations located in urban and residential areas of Kitimat (see Appendix Table A1 for exact location of all monitoring sites). Where possible sites were established in close proximity to previous passive sampler monitoring sites, which were operated during 2011–2012 (see Technical Memo P01: Passive Diffusive Sampler Network: 2011–2012) or schools, hospitals, etc. in the urban network.

As recommended under the pilot study, the network employed IVL passive SO<sub>2</sub> samplers (URL: [diffusivesampling.ivl.se](http://diffusivesampling.ivl.se)) with an exposure period of one month (see Technical Memo P03: Passive Diffusive Sampler Network: Pilot Study Results). Both networks operated until 13 October 2016, providing four one-month exposures under the valley network, and three one-month exposures under the urban network. In total, during 2016, there were 32 monitoring sites with 110 sample exposures across both networks, with replicate samplers deployed during 30% of the time (to assess variation in measurements).

Following deployment all samplers were returned to IVL for analysis.

## 3 Results

The observed data showed elevated atmospheric SO<sub>2</sub> along the plume path (a transect of approximately 45 km; Figure 1 and Appendix Table A2 and Figure A1); notably during June–August plume concentrations were high north of Rio Tinto (concentrations > 10 µg m<sup>-3</sup> were observed at the Rife Range monitoring site during June and July, 2016), and during August–October higher concentrations were observed south of Rio Tinto (concentrations > 20 µg m<sup>-3</sup> were observed at Bish Road during September, 2016).

In contrast, all monthly exposures under the urban network were consistently < 1 µg m<sup>-3</sup> (Figure 1). The lower concentrations observed in the urban areas were explained by the dominant wind directions during the 2016 exposures, which generally directed emissions from the Rio Tinto facilities to west of the Kitimat urban area along the Kitimat Valley (see Figure 2).

The concentration of SO<sub>2</sub> measured by passive samplers was also compared to the active observations at three ambient stations to evaluate sampler performance (Haul Road, Riverlodge and Whitesail; summarised to coincide with the monthly passive sampler exposure periods). In general, there was good correspondence between passive and active (R<sup>2</sup> = 0.98); however, the one-to-one regression slope suggests that passive samplers represented about 80% of the SO<sub>2</sub> concentrations reported by the active samplers (see Figure 3). This difference is similar to the variation between duplicate sampler exposures, i.e., on average there was ~15% variation between duplicate samplers (see Appendix Table A3). Moreover, the comparison against the active stations suggests a larger deviation at stations with low atmospheric SO<sub>2</sub> concentrations (see Whitesail in Figure 3).

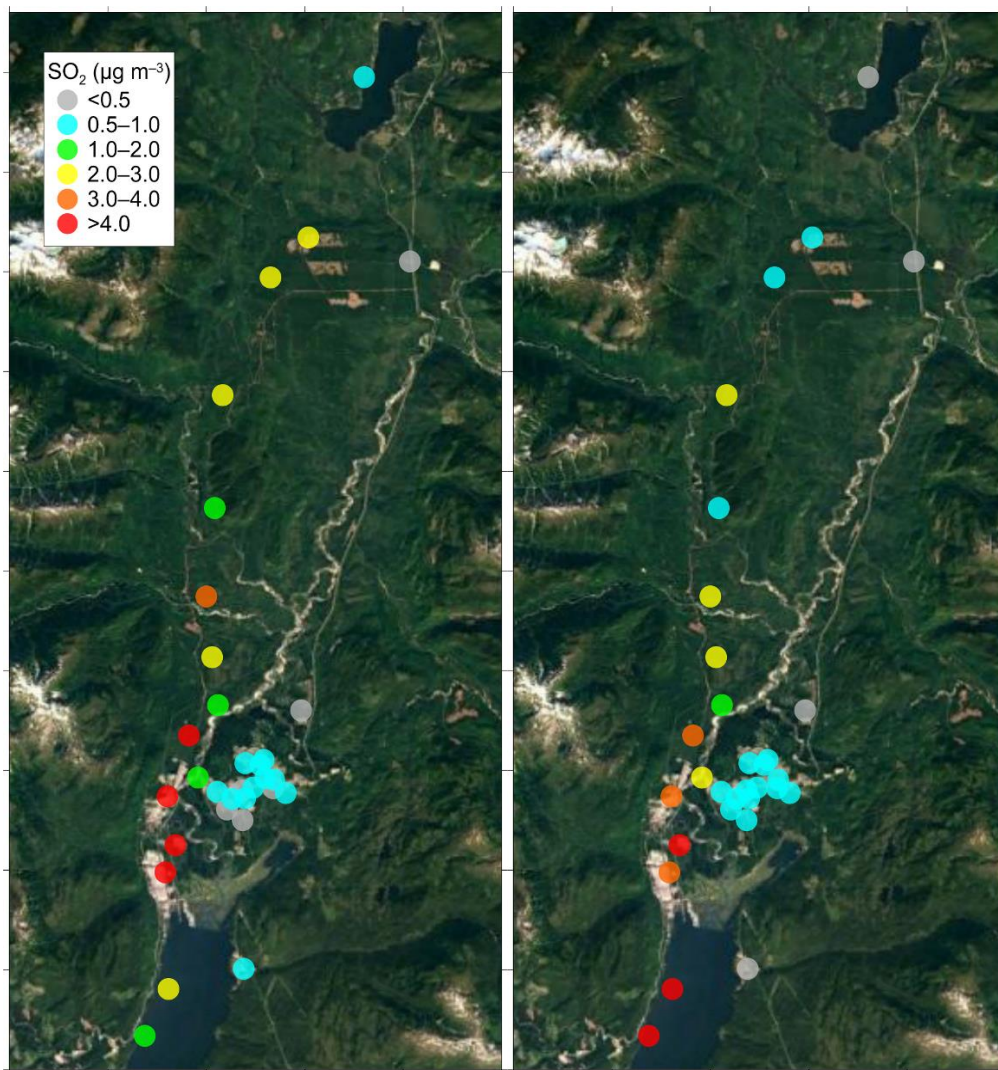
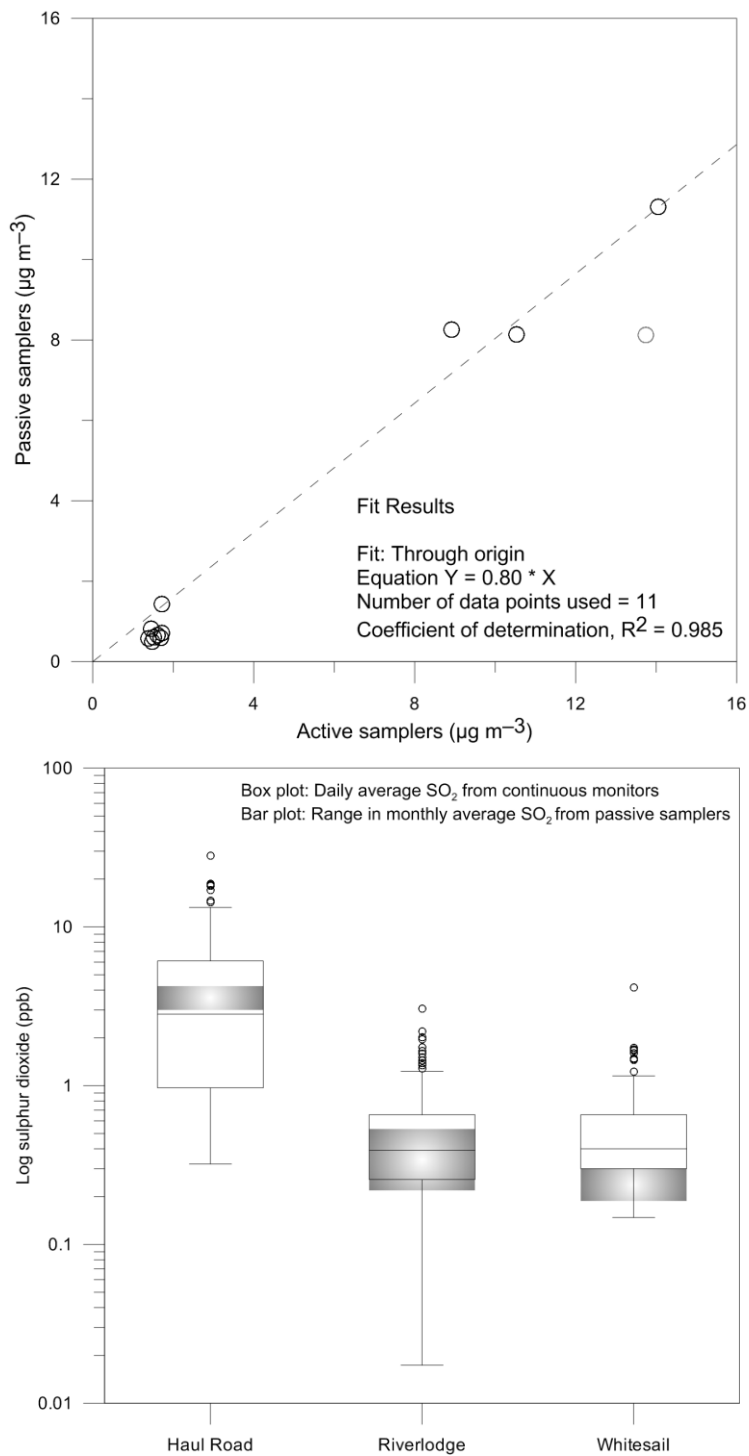


Figure 1. Average atmospheric sulphur dioxide (SO<sub>2</sub>) concentration (µg m<sup>-3</sup> [= ppb × 2.62]) during June–August (left) and August–October (right) 2016 in the Kitimat Valley and urban passive

diffusive monitoring networks. Note: monthly exposures under the Kitimat urban network started mid-July 2016. For further details on passive samplers see: IVL: [www.diffusivesampling.ivl.se](http://www.diffusivesampling.ivl.se).



**Figure 2. Average atmospheric sulphur dioxide (SO<sub>2</sub>) concentration during June–October 2016 (average of three to four monthly exposures) in the Kitimat valley and urban passive diffusive monitoring networks. The image is zoomed-in and centered on the Kitimat urban network; in addition, wind rose plots during the same period are shown for Haul Road (latitude: 54.02919, longitude: -128.70269), Riverlodge (latitude: 54.05389, longitude: -128.67144) and Whitesail (latitude: 54.06691, longitude: -128.63913) meteorological stations. Note: the dominant wind direction explains the low atmospheric SO<sub>2</sub> measured in the urban area.**



**Figure 3. Comparison of IVL passive diffusive samplers for sulphur dioxide (SO<sub>2</sub>) against continuous measurements (µg m<sup>-3</sup>) at Haul Road, Riverlodge and Whitesail during 22 June–13 October 2016. Passive samplers were exposed at each station for four weeks (see Appendix A for exposure dates). The scatter plot (upper) includes a linear regression of active against passive (R<sup>2</sup> = 0.98). However, passive SO<sub>2</sub> observations are lower than active, notably at Riverlodge and Whitesail (as show in the scatter [upper] and bar [lower] plots).**

## 4 Conclusion

The 2016 results demonstrate the ability of the passive samplers to map out the plume path along the Kitimat Valley; as such, it is recommended that deployments during 2017 attempt to further define the width and extent of the SO<sub>2</sub> plume.

The low atmospheric SO<sub>2</sub> concentrations at Riverlodge and Whitesail were a challenge for the IVL samplers. As such, it is recommended that a larger number of replicates are deployed at the ambient stations to allow for a more thorough assessment / calibration of passive samplers against the active measurements.

In summary, the results from the 2016 network confirm that passive samplers can be used to provide empirical observations of atmospheric SO<sub>2</sub> concentrations to (a) assess spatial and temporal changes, (b) evaluate modelled concentration fields, and (c) estimate dry deposition of SO<sub>2</sub>.

## 5 Literature Cited

Tamburello, N. and C.A.D. Alexander. 2016. Kitimat Air Quality Monitoring Workshop: Optimization of the Ambient Air Quality Monitoring Network. Report to Rio Tinto. Kitimat, B.C. 214 pp. + appendices.

Technical Memo P01: Passive Diffusive Sampler Network: 2011–2012 March 2015. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2013 and 2014 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

Technical Memo P03: Passive Diffusive Sampler Network: 2015 Pilot Study Results, April 2016. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2015 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

## Appendix A.

**Table A1. Location of passive diffusive sampler monitoring sites established and deployed during June–October (V and A sites) and July–October (U sites) 2016. Note: V denotes Valley, A denotes Ambient stations, and U denotes Urban sites. See Figures A1 and A2 for mapped site locations.**

ID	Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)
V00	HWY37 at Onion Lake Ski Trail	54.29532	-128.53650	241
V01	Onion Lake Ski Trail North	54.30437	-128.61655	223
V02	Wedene Road West km 9	54.28593	-128.64471	197
V03	Mound TKTP92	54.23226	-128.67892	127
V04	ENSO	54.18131	-128.68178	112
V05	LNG Muster Station	54.14140	-128.68559	114
V06	Sand Pit	54.11443	-128.67961	70
V07	Wedene at Powerline	54.09294	-128.67343	26
V08	Claque Mountain Trail at Powerline	54.07872	-128.69531	68
V09	Sand Hill at Powerline	54.05111	-128.71008	170
V10	Rifle Range	54.01693	-128.70958	43
V11	Bish Road 4.1 km	53.96473	-128.70387	35
V12	Bish Road Pullout 4	53.94320	-128.72061	114
A01	Haul Road station	54.02919	-128.70269	11
A02	Riverlodge station	54.05389	-128.67144	18
A03	Whitesail station	54.06691	-128.63913	94
A04	Lakelse Lake NADP station	54.37721	-128.57734	111
U01	Low Channel	54.04629	-128.66356	11
U02	Kitimat City Centre MAML	54.05507	-128.65199	30
U03	Nechako Elementary	54.05655	-128.62810	94
U04	Mount Elizabeth School	54.06028	-128.62775	94
U05	Cable Car residential area	54.09192	-128.60854	50
U06	Kitimat General Hospital	54.05146	-128.64951	19
U07	Blueberry Street	54.04179	-128.65115	12
U08	Anderson Street	54.06731	-128.65057	92
U09	Fulmar Street	54.06102	-128.63463	88
U10	Kitimat Valley Institute	54.06897	-128.63620	98
U11	Kitimat City High	54.05635	-128.64391	86
U12	Industrial area Kitimat Hotel	54.05997	-128.68704	2
U13	St. Anthony's Elementary	54.05471	-128.61835	92
U14	Kildala Elementary	54.05101	-128.65961	16
U15	Haisla Nation Council	53.97498	-128.64581	5

**Table A2. Results of the passive diffusive sampler monitoring network for June–October 2016. Atmospheric sulphur dioxide concentrations ( $\mu\text{g m}^{-3}$ ) are presented for each exposure (E01–E04), the average (AVE) and relative standard deviation (COV) between the four exposures is presented; in addition the average for the first two (JJA: June–July–August) and second two (ASO: August–September–October) exposures is also shown. See Table A1 for site locations and Figure A1 for map of average concentrations over the four exposures.**

ID	E01	E02	E03	E04	AVE	COV	JJA	ASO
	$(\mu\text{g m}^{-3})$					(%)	$(\mu\text{g m}^{-3})$	
V00		0.366	0.299	0.368	0.34	11.4	0.366	0.334
V01	3.197	1.995	0.896	1.095	1.80	58.4	2.596	0.996
V02	2.316	1.890	1.089	0.590	1.47	52.8	2.103	0.840
V03		4.698	2.342	1.920	2.99	50.1	2.374	2.131
V04	1.310	1.297	0.466	0.597	0.92	48.9	1.304	0.532
V05	4.618	3.316	2.428	2.322	3.17	33.5	3.967	2.375
V06	2.141	2.662	1.742	2.543	2.27	18.4	2.402	2.142
V07	1.406	1.098	1.455	1.459	1.35	12.7	1.252	1.457
V08	4.308	3.850	3.842	3.763	3.94	6.3	4.079	3.803
V09	5.907	5.569	2.729	4.532	4.68	30.5	5.738	3.630
V10	10.009	10.814	3.812	3.875	7.13	53.4	10.411	3.844
V11	1.424	2.888	5.526	20.300	7.53	115.2	2.156	12.913
V12	0.965	2.304	4.683	11.894	4.96	98.2	1.635	8.289
A01	8.006	11.179	7.981	7.957	8.78	18.2	9.593	7.969
A02	0.576	0.650	1.406	0.590	0.81	49.9	0.613	0.998
A03	0.497	0.586	0.700	0.791	0.64	20.0	0.542	0.745
A04	0.844	0.674	0.399	0.535	0.61	31.1	0.759	0.467
U01		0.422	0.785	0.649	0.62	29.7	0.422	0.717
U02		0.484	0.633	0.693	0.60	17.8	0.484	0.663
U03		0.471	0.602	0.685	0.59	18.4	0.471	0.644
U04		0.535	0.531	0.647	0.57	11.5	0.535	0.589
U05		0.264	0.266	0.395	0.31	24.3	0.264	0.331
U06		0.645	0.643	0.907	0.73	20.8	0.645	0.775
U07		0.409	0.694	0.539	0.55	26.1	0.409	0.617
U08		0.594	0.909	0.768	0.76	20.8	0.594	0.839
U09		0.519			0.52		0.519	
U10		0.512	0.827	0.604	0.65	25.0	0.512	0.716
U11		0.603	0.771	0.728	0.70	12.4	0.603	0.749
U12		1.171	2.454	2.705	2.11	39.0	1.171	2.580
U13		0.832	0.562	0.617	0.67	21.3	0.832	0.590
U14		0.562	0.846	0.642	0.68	21.4	0.562	0.744
U15		0.512	0.286	0.610	0.47	35.4	0.512	0.448

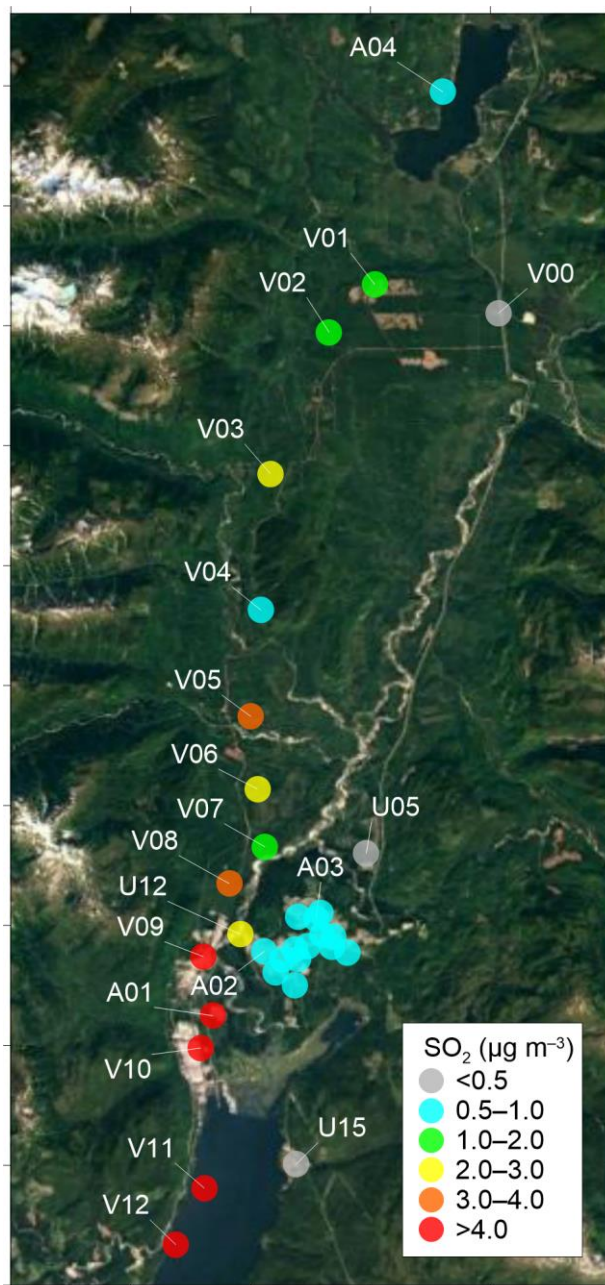
E01 22 June to 20 July 2016

E02 20 July to 19 August 2016

E03 19 August to 13 September 2016

E04 13 September to 13 October 2016





**Figure A1. Average atmospheric sulphur dioxide (SO<sub>2</sub>) concentration (µg m<sup>-3</sup> [= ppb × 2.62]) during June–October 2016 (average of three to four monthly exposures) in the Kitimat valley and urban passive diffusive monitoring networks (Site IDs are shown for the Kitimat valley network, see Figure A2 for remaining sites). Note: monthly exposures under the Kitimat valley network started mid-June 2016, compared with the urban network, which started mid-July 2016. For further details on passive samplers see: IVL: [www.diffusivesampling.ivl.se](http://www.diffusivesampling.ivl.se).**



**Figure A2. Site locations and IDs for the Kitimat urban passive sampler network (see Table A2 for further details on site locations). Note: monthly exposures under the urban network started mid-July 2016. For further details on passive samplers see: IVL: [www.diffusivesampling.ivl.se](http://www.diffusivesampling.ivl.se).**

**Table A3. Analysis of replicated passive diffusive sampler deployments during exposures 1 to 4. The average and the percent difference between the two replicates are presented. Replicate exposures with a difference greater than 25% are highlighted. See Table A1 for a description of the Site ID (SID).**

Exposure	SID	Sampler A	Sampler B	Average	Difference
1	A04	0.90	0.78	0.84	14.3
1	V02	2.53	2.10	2.32	18.3
1	V07	1.43	1.38	1.41	3.8
1	V09	5.78	6.03	5.91	4.2
1	V11	1.48	1.37	1.42	7.7
2	A01	11.24	11.12	11.18	1.1
2	U01	0.43	0.41	0.42	4.0
2	U02	0.43	0.54	0.48	22.3
2	U06	0.65	0.65	0.65	0.0
2	U07	0.38	0.44	0.41	14.2
2	U12	1.35	0.99	1.17	30.3
2	V03	6.45	2.94	4.70	74.7
2	V08	3.78	3.92	3.85	3.9
2	V10	11.22	10.40	10.81	7.6
2	V12	2.10	2.51	2.30	17.6
3	A03	0.60	0.80	0.70	28.2
3	U03	0.54	0.66	0.60	20.3
3	U11	0.70	0.84	0.77	17.3
3	U13	0.56	0.56	0.56	0.0
3	U14	0.91	0.79	0.85	14.4
3	V00	0.30	0.30	0.30	0.0
3	V04	0.68	0.26	0.47	90.1
3	V09	2.00	3.45	2.73	53.2
3	V11	4.74	6.31	5.53	28.3
4	A01	8.25	7.67	7.96	7.3
4	U04	0.72	0.57	0.65	22.4
4	U05	0.38	0.41	0.40	8.6
4	U10	0.59	0.62	0.60	4.3
4	U15	0.63	0.59	0.61	5.6
4	V01	1.11	1.08	1.10	3.1
4	V05	2.17	2.48	2.32	13.2
4	V06	2.36	2.73	2.54	14.7
4	V12	11.59	12.20	11.89	5.1

E01 22 June to 20 July 2016

E02 20 July to 19 August 2016

E03 19 August to 13 September 2016

E04 13 September to 13 October 2016