King County

TECHNICAL MEMORANDUM

November 13, 2013

TO: Recipients

FM: Carly Greyell, Richard Jack, Jenée Colton, Science and Technical Support Section, Water and Land Resources Division, Department of Natural Resources and Parks

RE: Lake Washington Sediment Data Addendum to
Estimating PCB and PBDE Loadings to the Lake Washington Watershed: Data Report

1.0 Objective

Polychlorinated biphenyl (PCB) concentration data for Lake Washington sediments are needed in the Modeling PCB/PBDE Loadings Reduction Scenarios for the Lake Washington Watershed project. Sediment PCB concentration data will be used in the fate and food web models as a basis to estimate current surface sediment concentrations. See the Lake Washington PCB Modeling Quality Assurance Project Plan (QAPP) for details describing how historical sediment concentration data are used in the models (King County 2012). This addendum describes the sediment data sources, presents a data acceptability review, and summarizes these data for use in the modeling phase of this project. The origins of most sediment data presented here are described in other cited reports and documents. However, some data have never been previously published; additional information and details are presented for these data when possible.

2.0 Data Sources

This addendum compiles PCB sediment and tissue data from pre-existing reports and databases. Polybrominated diphenyl ethers (PBDEs) are not part of the loadings reduction scenario modeling and are not included. Sources were selected because: they provided ready access to electronic records with minimal manual data entry, collection methods for samples were known or documented, and data were of known quality.

Sediment data were acquired from the following four sources:

1) Washington State Department of Ecology's (Ecology) Environmental Information Management (EIM) system database.

2) King County's Laboratory Information Management System (King County, 2010) database.
3) Kenmore marina data (Ecology 2013) collected by Ecology, but not yet entered into EIM.

Downloaded data were cross-checked by laboratory sample ID, sample date and location to ensure data were not duplicated. Only data collected between January 1, 2000, and December 31, 2012, were included.

Lake Washington was defined as the lake area downstream of a perpendicular line drawn across stream and river mouths. The Montlake Bridge was the downstream boundary between Lakes Washington and Union. The sediment data were aggregated across the whole lake and for purposes of comparison; bathymetry was used to divide the sediment data into "nearshore" and "offshore" locations. The nearshore boundary was defined based on estimates of the depth of the euphotic zone, which roughly coincides with the depth of the epilimnion (King County, unpublished data). Thus, nearshore sampling locations were those within the area extending from 0 to the 30 foot water depth. Aquatic macrophytes and algae are generally limited to the euphotic zone; therefore this region of the lake has higher productivity than the deeper profundal zone. Because productivity is higher in the euphotic epilimnion, the overall food web is concentrated here and on an area basis may disproportionately influence the bioaccumulation of lipophilic contaminants compared to deeper sediments. Thus, sediment results were stratified by this physical and ecological boundary and locations are shown in Figure 1 by data source.

Parameters Reported

All sediment data were based on Aroclor analysis and total PCBs were calculated as the sum of detected Aroclors. Aroclors were detected in all samples. Non-detect Aroclors were not included in these sums and tentatively identified Aroclors were also not included. Tentatively identified Aroclors may have been a mixture of other chlorinated compounds such as DDT or chlordane, which are known to be present in Lake Washington. Sediment data were partially reviewed by King County (2011) previously; this memorandum will supplement this prior review with additional data from Ecology's EIM database and recent Kenmore investigations.

Ancillary information also collected for sediment data included sampling depth, total organic carbon (TOC) and percent solids. Both PCB concentrations and ancillary data are reported and analyzed here to support future PCB modeling efforts (King County 2012).

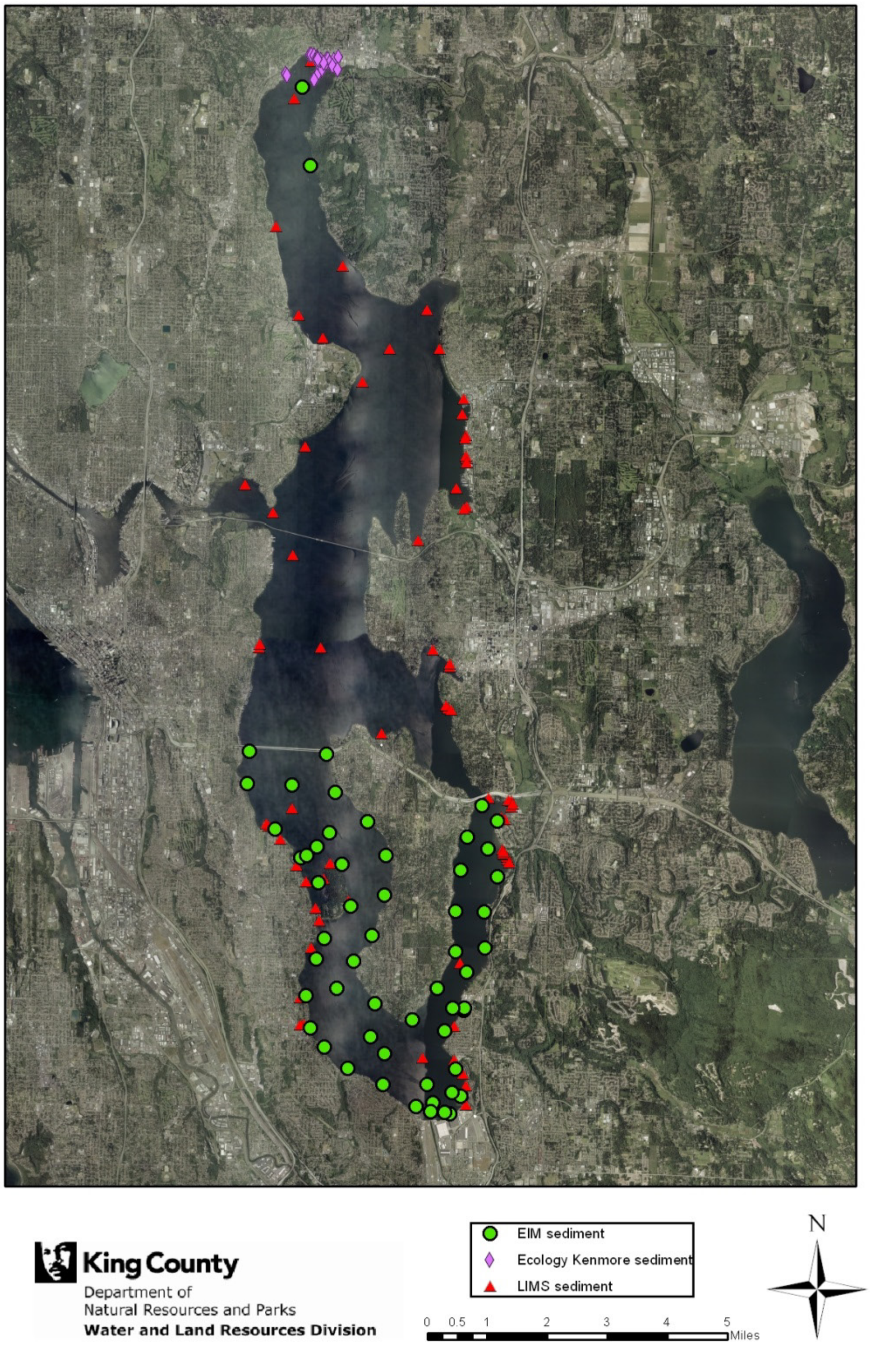

Figure 1. Sediment sampling locations by data source.

3.0 Sampling Methods

This section provides an overview of sampling methods. Only those data collected, analyzed, and reported via methods comparable to one another are reported in this memorandum. While sediment collection methods varied between studies, VanVeen, Eckman, Petite Ponar or Ponar grab samplers were generally used to collect the top 2 or 10 cm of sediment for analysis. Ecology's 2010 study focused on the top 2 cm of

sediment in an effort to characterize the most recent sources. Most other EIM studies collected sediment according to methods described in Ecology (2009) where samples were collected from the top 10 cm. While available in EIM, sediment samples collected by coring devices were excluded for this report due to their depth and methodological differences.

The Kenmore study (Ecology 2013) collected sediment from the top 10 cm using VanVeen or Ekman grab samplers or a hand trowel. Two samples collected for this study extend to 22 and 25 cm depths. These samples were included despite being below the typical biologically active zone. Sampling methods are further described in Ecology (2013). The King County (2010) study collected sediment from the top 10 cm using a VanVeen grab sampler for offshore sites and a Petite Ponar sampler at nearshore sites. Three grab samples were taken at each site and a single composite sample was created from the top 10 cm of each grab. These methods are further described in King County (2008).

All sediment sample results reported in this memorandum are composites from at least three grabs collected at each station. All samples analyzed for PCB Aroclors were also analyzed for percent solids and total organic carbon. While different laboratories were used, data were all evaluated by chemists experienced with PCB Aroclor quantitation at KCEL or Ecology's Manchester Laboratory (MEL).

4.0 Data Summary

This section summarizes data from recent studies of PCBs in Lake Washington sediment along with conventional parameters. For some locations, sediment sampling was conducted over multiple years. Because this report develops lakewide and photic vs. profundal zone average sediment concentrations, multiple samples from one location, either replicates taken during the same sampling event or samples taken over time, were averaged before being reported.

An alpha level of less than 0.05 was used to determine significant differences for all statistical tests described below. Before statistical testing, all parameter groups were analyzed for normal distributions using a Shapiro-Wilk Normality Test. Thereafter, normally distributed parameter correlations were analyzed using Pearson Product Moment Correlations and nonparametric parameter correlations were analyzed using Spearman Rank Order Correlations. Statistically significant differences between two data sets were determined using one-tailed t-tests for parametric data sets and Mann-Whitney Rank Sum Tests for nonparametric data. Sediment PCB concentrations were compared across different water depths using an ANOVA of the ranks followed by a Dunn's comparison of the averages.

Visual data summaries are presented in the form of box plots in this section. Figure 2 explains the information provided in the box plots discussed later in this addendum.

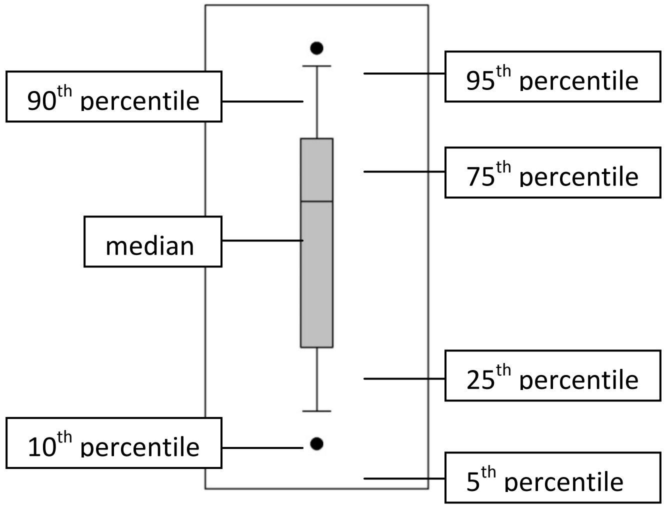

Figure 2. Box plot legend

Sediment

Sediment data are presented by location and depth strata in Appendix A. The following sections present summary statistics of these sediment PCB and conventionals data.

Conventional Parameters

Solids composition in nearshore sediment ranged from 11.6% to 67.5%. Solids composition in offshore sediment ranged from 15.6% to 57.4%. Percent solids in near and offshore sediment were not statistically different (Mann-Whitney Rank Sums).

TOC in nearshore sediment ranged from 0.6% to 16.4%, while TOC in offshore sediment ranged from 0.8% to 5.0%. TOC content was statistically greater in nearshore than in offshore sediment. (Mann-Whitney Rank Sums). Table 1 summarizes sediment conventional parameter data grouped by location.

Table 1. Data summary for sediment conventional parameter and total PCB concentrations.

Location	Number of Samples	% Solids			% TOC			Total PCBs (µg/kg *dry wt*)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Nearshore	41	11.6	67.5	27.9	0.6	16.4	5.9	3.3	577.2	71.2
Offshore	28	15.6	57.4	29.6	0.8	5.0	2.8	4.6	184.6	31.8
All locations combined	69	11.6	67.5	28.6	0.6	16.4	4.7	3.3	577.2	55.2

Sediment PCB Concentrations

Total PCB concentrations ranged from 3.3 to 577 µg/kg dry weight (dw) in nearshore sediments and 4.6 to 185 µg/kg dw in offshore sediments. PCB concentrations were statistically greater in nearshore sediment than offshore sediment (Mann-Whitney Rank Sums). Table 1 summarizes sediment PCB concentration grouped by water depth. Figure 3 shows sediment PCB concentration by water depth strata and combined.

There were no obvious spatial trends in sediment PCB concentrations in Lake Washington. Normalizing by TOC did not dramatically alter these relationships.

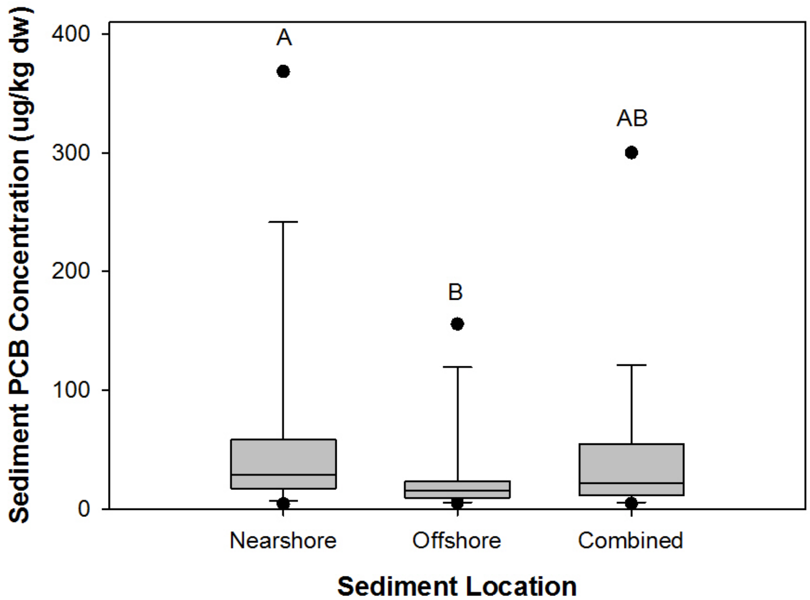

Figure 3. Dry weight sediment PCB concentrations in nearshore and offshore areas and all areas combined. (Different letters indicate statistical differences, α=0.05)

Correlations

When all sediment data were pooled, PCB concentrations were positively correlated with percent TOC (Spearman Rank Order, α= 0.05, Figure 4). While statistically significant, the relationship has little predictive power on a lake-wide basis. Because Lake Washington is quite large, Figure 4 suggests there are various sources of PCBs located in different places than sources of organic carbon causing variability in the association PCBs and TOC.

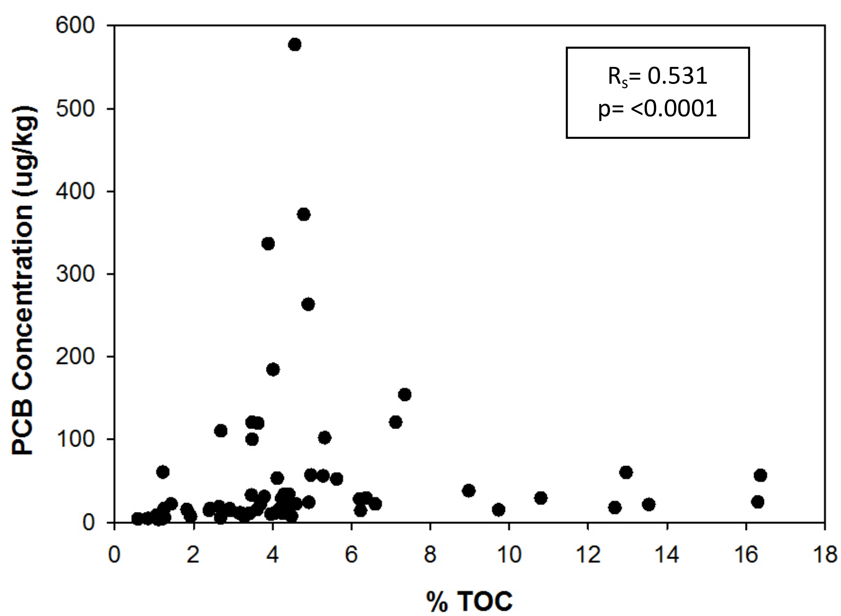

Figure 4. Dry weight PCB concentrations in all sediment samples by TOC composition.

5.0 Data Usability

This report is a compilation of "recent" sediment PCB data concentrations and associated conventionals data such as percent solids and TOC. "Recent" is defined as from January 1, 2000, to December 31, 2012. Concentrations of PCBs in ambient sediment are stable in year to year time frames (Ecology 2010 and Van Metre et al. 2004), and thus the 12 years of various sampling and analysis efforts are believed to effectively represent current conditions.

All sediments were collected using either a Van Veen, Ponar, Ekman grab samplers, or hand trowels. Sediment samples were all analyzed by KCEL or MEL. Because collection and analytical methods were all similar, these data are assumed to be comparable. Surface sediment data were compiled to develop nearshore, offshore and whole lake average sediment concentrations. To expand the dataset both spatially and temporally to the extent practicable both 0 to 2 cm and 0 to 10 cm sediment data were included as adequately representing biologically active surface sediments. Two samples collected in the vicinity of the Kenmore marina incorporated deeper sampling depths (22 to 25 cm). Limiting the dataset to a specific sampling depth would have unnecessarily limited the extent and availability of the information and increased any bias due to spatial distribution.

For the purposes of modeling the bioaccumulation of PCBs from sediment to tissues, aggregation of these different sediment sampling depths was considered a reasonable accommodation to provide the largest and most comprehensive and robust dataset possible. Sediment data were then aggregated on a whole-lake basis and also by two strata, less than and greater than 30 feet water depths. Because these data aggregate all known surface sediment PCB, TOC and solids concentrations, they represent the best current estimate of lake-wide, shallow and deep water average sediment concentrations.

The Aroclor analysis methods require some analyst discretion in determining which peaks of the chromatogram to attribute to PCBs. However, KCEL and Manchester Environmental Laboratory chemists have discussed Aroclor quantification and chromatogram integration in the past and both laboratories use comparable approaches (D. McElhany, pers. comm.).

Data included in this memorandum are considered usable for the purposes of modeling sediment and food web bioaccumulation or for comparisons with fish consumption advisories. No special qualifications or caveats are considered necessary.

6.0 Discussion and Summary

Ecology does not have numeric freshwater sediment quality standards; however, they do have freshwater sediment cleanup standards (WAC 173-204-563) effective September 2013. Sediment chemical concentrations at or below the Sediment Cleanup Objectives (SCO) are considered to have no adverse effects to the benthic community; 10 of 69 sampling locations exceeded the total PCB SCO of 110 µg/kg. Sediment chemical concentrations at or below the Cleanup Screening Level (CSL) of 2500 µg/kg are considered to have minor adverse effects to the benthic community. No stations exceeded the CSL. These values are only for the protection of the freshwater benthic community and are not based on bioaccumulation effects. In conclusion, the data presented here demonstrates that while PCBs are present in Lake Washington sediment, most concentrations are below the SCO and all are below the CSL. The extent to which PCBs bioaccumulate from these current sediment concentrations is the subject of future modeling.

7.0 References

King County. 2008. 10-Year Major Lakes Sediment Monitoring Program Plan. Prepared by Dean Wilson, Water and Land Resources Division. Seattle, Washington.

King County, 2011. Lake Washington Watershed PCB Modeling Quality Assurance Project Plan. Prepared by King County Department of Natural Resources and Parks, Water and Land Resources Division for the U.S. Environmental Protection Agency.

Van Metre, P. C., Wilson, J.T., Fuller, C.C., Callender, E., and Mahler, B.J.. 2004. Collection, Analysis, and Age-Dating of Sediment Cores From 56 U.S. Lakes and Reservoirs Sampled by the U.S. Geological Survey, 1992–2001**.** U.S. Geological Survey Scientific Investigations Report 2004–5184. Accessed August 19, 2013 http://pubs.usgs.gov/sir/2004/5184/

Washington State Department of Ecology (Ecology). 2009. Quality Assurance Project Plan: General Characterization of PCBs in South Lake Washington Sediments. Prepared by Brandee Era-Miller, Environmental Assessment Program. Olympia, Washington.

Washington State Department of Ecology (Ecology). 2010. General Characterization of PCBs in South Lake Washington Sediments. Prepared by Era-Miller, B., R. Jack (King County), and J. Colton (King County), Olympia, Washington. Accessed June 24, 2013 https://test-fortress.wa.gov/ecy/testpublications/SummaryPages/1003014.html

Washington State Department of Ecology (Ecology). 2013. Kenmore Area Sediment & Water Characterization Environmental Evaluation Report. Prepared by Toxics Cleanup Program. Bellevue, Washington. Accessed June 26, 2013 https://fortress.wa.gov/ecy/gsp/DocViewer.ashx?did=20239

Appendix A

Appendix A - Table 1. Lake Washington sediment data.

Locator	Water Depth > -30ft	Sample depth (cm)	Solids %	TOC %	Total PCB Aroclors (µg/Kg)
0544	No	0-2	18.90	7.35	100.53
0544	No	0-8	61.60	0.88	5.96
0826	Yes	0-10	19.95	3.63	119.42
0834	No	0-10	18.10	7.35	154.14
0840	Yes	0-10	24.30	3.48	120.58
0852	Yes	0-10	17.50	4.01	184.57
0890	Yes	0-10	19.96	3.48	100.12
0817A	No	0-10	33.70	3.89	336.80
0864A	No	0-10	39.90	4.56	577.19
4903A	No	0-10	40.90	4.79	371.95
4903B	No	0-8	30.40	4.90	263.49
COUL-C	No	0-10	32.60	5.28	56.04
COUL-N	No	0-10	37.50	5.63	52.24
COUL-S	No	0-10	20.30	5.32	102.17
COZYCOVE	No	0-8	28.80	4.48	7.29
EYRRWCRKMTH	No	0-10	26.70	6.37	29.36
HT-04	No	0-10	50.90	6.20	28.00
KENNYBCHPK	No	0-10	32.80	4.30	24.57
LKWABLVD-S	No	0-7	67.50	0.59	3.96
MERSLOUMTH	No	0-8	12.70	16.30	24.65
MERSLOU-N	No	0-9	12.10	16.36	56.53
MERSLOU-S1	No	0-10	14.20	12.96	60.28
MERSLOU-S2	No	0-10	11.60	13.53	21.55
S_LK_WA_SED_01	Yes	0-2	41.00	1.25	16.30
S_LK_WA_SED_03	Yes	0-2	50.80	1.06	8.70
S_LK_WA_SED_04	Yes	0-2	47.80	1.26	5.60
S_LK_WA_SED_05	Yes	0-2	57.40	0.84	4.60
S_LK_WA_SED_06	Yes	0-2	37.80	1.83	15.10
S_LK_WA_SED_07	Yes	0-2	37.60	1.92	7.20
S_LK_WA_SED_08	Yes	0-2	35.10	2.39	14.40
S_LK_WA_SED_09	Yes	0-2	33.50	2.64	18.70
S_LK_WA_SED_10	No	0-2	20.60	4.59	22.00
S_LK_WA_SED_11	No	0-2	15.80	4.26	17.00
S_LK_WA_SED_12	No	0-2	17.10	4.05	11.00
S_LK_WA_SED_13	No	0-2	20.50	4.56	22.50
S_LK_WA_SED_14	No	0-2	21.00	3.96	9.90
S_LK_WA_SED_18	Yes	0-2	17.20	4.17	16.00

Locator	Water Depth > -30ft	Sample depth (cm)	Solids %	TOC %	Total PCB Aroclors (µg/Kg)
S_LK_WA_SED_19	No	0-2	13.30	6.23	14.00
S_LK_WA_SED_20	Yes	0-2	15.60	4.24	11.00
S_LK_WA_SED_21	Yes	0-2	23.45	4.92	24.05
S_LK_WA_SED_22	Yes	0-2	32.40	3.18	11.40
S_LK_WA_SED_23	No	0-2	16.90	9.73	15.00
S_LK_WA_SED_24	No	0-2	24.10	3.28	6.90
S_LK_WA_SED_25	Yes	0-2	19.80	3.43	11.00
S_LK_WA_SED_26	Yes	0-2	29.10	2.68	6.00
S_LK_WA_SED_27	No	0-2	21.90	3.46	33.00
S_LK_WA_SED_30	Yes	0-2	38.80	1.43	22.00
S_LK_WA_SED_31	Yes	0-2	43.70	1.21	5.40
S_LK_WA_SED_33A	Yes	0-2	16.90	4.97	57.00
S_LK_WA_SED_34	Yes	0-2	21.30	3.61	15.30
S_LK_WA_SED_35	No	0-2	19.60	3.70	22.50
S_LK_WA_SED_36	Yes	0-2	30.00	2.68	5.40
S_LK_WA_SED_37	No	0-2	44.60	1.21	4.40
S_LK_WA_SED_38	No	0-2	39.50	1.11	3.30
S_LK_WA_SED_39	Yes	0-2	26.10	2.91	16.20
S_LK_WA_SED_40	No	0-2	25.50	8.97	38.00
S_LK_WA_SED_41	No	0-2	15.30	4.41	34.00
S_LK_WA_SED_42	No	0-2	22.50	4.23	29.00
S_LK_WA_SED_43	No	0-2	34.40	3.79	31.00
S_LK_WA_SED_44	Yes	0-2	31.20	2.41	16.40
S_LK_WA_SED_45	Yes	0-2	16.90	3.16	11.00
S_LK_WA_SED_48	Yes	0-2	27.70	2.93	14.00
S_LK_WA_SED_49	Yes	0-2	16.85	4.30	34.00
SD007B	No	0-10	47.70	1.22	60.59
SD017A	No	0-10	39.80	2.69	110.30
SG-02	No	0-22	25.70	7.12	121.00
SG-03	No	0-25	25.60	6.60	22.00
SG-11	No	0-10	16.90	10.80	29.00
SG-14	No	0-10	51.00	4.33	20.00
YRRWCRKMTH	No	0-10	15.70	12.68	17.64