HONG KONG OBSERVATORY

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Environmental Gamma Absorbed Dose Rates

in Air in Hong Kong Measured in 2000 to 2003

by

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摘要

香港天文台在 2000 年至 2003 年期間進行了一次全港性的環境空氣伽馬吸收劑量率的普查。在減去宇宙射線的部份後，郊區(Ψ_f)和市區(Ψ_s)的平均空氣伽馬吸收劑量率分別為 0.094 及 0.177 μGyh^{-1}。兩者的比率(Ψ_s/Ψ_f)為 1.88，與早前 1999 年進行的普查結果相若。

ABSTRACT

The Hong Kong Observatory carried out a territory-wide survey on environmental gamma absorbed dose rates in air in Hong Kong from 2000 to 2003. After correction for the cosmic component, the average gamma absorbed dose rates in air at open field (Ψ_f) and street level (Ψ_s) were 0.094 and 0.177 μGyh^{-1} respectively, and the ratio of Ψ_s to Ψ_f was 1.88. These results were comparable to those obtained in an earlier survey in 1999.

CONTENTS

FIGURES

TABLE

ANNEX

1. Introduction

In 1983, the Hong Kong Observatory embarked on a comprehensive environmental radiation monitoring programme (ERMP) in response to the construction of the nuclear power stations at Daya Bay in Guangdong.

The first phase of the ERMP, known as the Background Radiation Monitoring Programme (BRMP), was carried out before the nuclear power stations began to operate. The objective of the BRMP was to establish the baseline radiation level in Hong Kong against which changes arising from the operation of the nuclear power stations at Daya Bay would be determined. The BRMP lasted five years from 1987 to 1991.

The second phase of the ERMP (ERMP-II) contains all the essential features of the BRMP. It is an on-going programme so that any long term changes in environmental radioactivity, particularly those arising from the operation of the nuclear power stations at Daya Bay, can be determined.

The ERMP-II consists of two major components. The first component is to detect artificial radioactive materials, if any, in the environment of Hong Kong arising from the operation of the nuclear power stations. The second component is the measurement of the ambient gamma radiation level in terms of the gamma absorbed dose rate in air (Ψ) in Hong Kong by the Radiation Monitoring Network (RMN).

The RMN, which comprises 10 fixed Radiation Monitoring Stations (RMS) installed at strategic locations, monitors Ψ continuously over the territory of Hong Kong (Hong Kong Observatory, 2001-2004). The major function of the RMN is to provide an early alert of any rise in the ambient gamma radiation level in the territory in the unlikely event of a nuclear incident at the nuclear power station(s). Despite a carefully chosen network, Ψ measured by the 10 RMS cannot be taken as representative of every part of Hong Kong due to the complex topography and geological structure of the territory. Territory-wide radiological surveys are needed to fill the data gaps.

The first comprehensive territory-wide radiological survey of Ψ in Hong

Kong was conducted in 1999 at both open fields and built-up areas. In the 1999 survey, one single measurement was made at each survey site to determine Ψ in Hong Kong due to terrestrial radiation, denoted as Ψ_T (Wong *et al*, 1999). The open field Ψ_T, denoted as $\Psi_{\mathbf{f}}$, ranged from 0.051 to 0.123 μGy/h with an average of 0.087 μGy/h. The street-level Ψ_T, denoted as $\Psi_{\mathbf{s}}$, ranged from 0.135 to 0.229 μGy/h with an average of 0.179 μGy/h. The ratio of the average $\Psi_{\mathbf{s}}$ to average $\Psi_{\mathbf{f}}$ was 2.06. Both $\Psi_{\mathbf{f}}$ and $\Psi_{\mathbf{s}}$ were corrected for cosmic contribution and seasonal variation.

As urbanization in open field areas and reconstruction works in built-up areas may have affected the overall outdoor Ψ_T in Hong Kong, another territory-wide radiological study was conducted from 2000 to 2003 to measure the outdoor Ψ_T in Hong Kong so as to identify any changes. This Technical Note describes the survey strategy, the measurement methodology and data analysis procedures for determining the levels of $\Psi_{\mathbf{f}}$ and $\Psi_{\mathbf{s}}$ of Hong Kong during the period. Comparison with the results obtained in the 1999 survey is also discussed.

2. Survey Methodology and Data Analysis

2.1 Mobile radiological measurements

The following mobile radiological measurements were conducted in the period from 2000 to 2003 to determine Ψ_f and Ψ_s of Hong Kong:

(a) Territory-wide mobile surveys on a regular basis at pre-selected land survey sites to measure Ψ; and

(b) Cosmic radiation measurements on a quarterly basis at a fresh water reservoir for estimating the cosmic component (Ψ_C).

2.1.1 Survey grids and survey sites

In the 1999 survey, the territory of Hong Kong was divided into 42 grid boxes of 5 km x 5 km for open field areas and 61 grid boxes of 2.5 km x 2.5 km for built-up areas according to population and land use. The choice of the grid was in line with the practice of similar surveys in cities of high population in the mainland such as Shanghai where the size of the grid boxes were set at 5 km x 5 km with smaller grid boxes of 2 km x 2 km in the urban areas (He *et al*., 1992). For continuity and comparison purposes, the same survey sites in the 1999 survey were used for the 2000-2003 survey. A map of Hong Kong with the grid boxes and the survey sites is shown in Figure 1. For easy reference, a grid reference was assigned to each grid box. A1 – A42 and B1 – B61 are the grid references for the 42 open field and 61 street level grid boxes respectively.

The survey site for each grid box was chosen near the centre of the grid box as far as possible. The survey sites had been carefully chosen to minimize possible effects on the ambient radiation levels, for instance, by being too close to electricity power stations, refuse and construction sites.

For surveys conducted at each open field site, Ψ was measured at a location with an underlying surface not affected by human activities. The presence of concrete in the vicinity of the survey location was also avoided. The survey location of each survey site was at least 50 metres from the nearest buildings. Figure 2 illustrates the set up of the measurement of Ψ at an open field site.

As most of the population in Hong Kong is concentrated in built-up areas with concrete high-rises on both sides of the street, Ψ was also measured at street level in built-up areas for comparison purpose. Measurements were made on the curbside of pavements at a distance of at least one metre from buildings. They were not taken in the middle of the street because of personnel safety and because people rarely stay there for long. Figure 3 illustrates the set up of the measurement of Ψ at a street level site.

Following the study by Tsui *et al.* (1991), the centre of Plover Cove Reservoir was chosen as the survey site for measurement of Ψ_C. Each measurement of Ψ_C was conducted on the deck of a fibre glass boat in the reservoir. The boat was more than 1,000 metres from the shore and the depths of the water at the locations were about 60 metres (Tsui *et al.*, 1991). For such a measurement set up, the contribution to the measured radiation level from other factors was minimal and the measurement result could be regarded as a good estimate of the cosmic radiation level.

2.1.2 Measurement set up and procedures

The Model RSS-131 portable High Pressure Ionization Chamber (HPIC) was used to measure Ψ and Ψ_C. The ionization chamber is spherical with a diameter of 25.4 cm and is filled with 25 atmospheres (absolute) of ultra-high purity argon. Measurements were made at a height of 1 m above ground and above the deck of a fiber-glass boat located near the centre of Plover Cove Reservoir for open field/street level and cosmic radiation measurements respectively.

For each open field and street level measurement, 1- minute averages were taken over a 30-minute period. The overall mean and standard deviation were obtained for the 30 1-minute averages. The standard deviation for each open field and street level measurement was about 5%. For each cosmic radiation measurement, 1-minute averages were taken over a 60-minute period. The overall mean and standard deviation were obtained for the 60 1-minute averages. The standard deviation in each cosmic radiation measurement was about 13%. Since rainfall might affect the level of ambient gamma absorbed dose rate in air (Mok *et al*, 2002), all measurements were conducted when it was not raining.

2.1.3 Survey frequency

To take account of the seasonal variation of Ψ, at least one measurement as far as practicable were carried out at each survey site in different seasons in such a way that all seasons were covered. During the survey period from 2000 to 2003, 213 open field and 291 street level measurements were conducted respectively, with an average of about five measurements at each survey site.

During the same period, 14 cosmic radiation measurements were conducted with measurement frequency of about once every quarter. The measurement in the first quarter of 2000 and the second quarter of 2003 were not conducted due to bad weather in all the scheduled measurement days.

2.2 Data analysis

2.2.1 Cosmic radiation correction

Ψ is the sum of Ψ_T and Ψ_C. The cosmic component Ψ_C estimated from the cosmic radiation measurement results has to be subtracted from Ψ in order to estimate Ψ_T.

Like the 1999 survey, the cosmic contribution was subtracted from each of the measurement results obtained at the open field and built-up area survey sites. To account for the temporal variation of cosmic radiation, including seasonal variation and variation due to extra-terrestrial effects (UNSCEAR, 2000), each measurement result was subtracted by the corresponding cosmic radiation measurement result taken in the same quarter of the measurement time. Since the year-to-year variation of the cosmic radiation levels was observed to be small and within one standard deviation of all measurements (Table 1), Ψ_C for those quarters in which no measurement was made were estimated by the average of Ψ_C of the same quarter in other years. The small variation in the cosmic component in the survey period from 2000 to 2003 is corroborated by measurements elsewhere in Beijing, Calgary, Climax, Huancayo, Kiel and Moscow which had seasonal variation of less than 4% and year-to-year variation of less than 10% throughout the period (NOAA, 2000 - 2003).

2.2.2 Seasonal correction

Seasonal variations of the total environmental gamma absorbed dose rates in air had been observed from RMN data (Wong *et al.*, 1996). The seasonal variations were attributable to changes in the activity concentration of radon in air which in turn might be affected by the direction of the prevailing surface winds, the temperature difference between the soil and the overlying air, and the moisture content in the soil

(Song and Tsui, 1991; Poon and Wong, 2000; Mok and Chan, 2002; Mok and Wong, 2004).

Since measurement of the environmental gamma absorbed dose rates at each of the survey sites were not carried out continuously but at different times of a year, individual measurements of the net absorbed dose rates due to terrestrial radiation was adjusted for seasonal variation before further statistical analysis.

Like the 1999 survey, the results of continuous measurements at the 5 rural RMSs at Kat O, Ping Chau, Sha Tau Kok, Tap Mun and Tsim Bei Tsui in the study period (2000 to 2003) were used to determine the seasonal correction factors.

The monthly mean Ψ of the 5 RMSs from 2000 to 2003 were published in the annual report of the ERMP (Hong Kong Observatory, 2001-2004). After subtracting Ψ_C measured in the same quarter, the monthly mean Ψ_T at the 5 RMSs were obtained. The average of the monthly mean Ψ_T of the 5 RMSs for each month was determined and the variation from January 2000 to December 2003 is shown in figure 4. Seasonal variations of the average monthly mean Ψ_T was observed with higher values in winter months and lower values in summer months. The annual mean Ψ_T for 2000, 2001, 2002 and 2003 were found to be 0.072 μGy/h, 0.070 μGy/h, 0.073 μGy/h and 0.072 μGy/h respectively. The seasonal correction factor for each month in 2000 to 2003 was determined by the ratio of the average monthly mean Ψ_T of the 5 RMSs of the month and the annual mean Ψ_T of the year. Table 2 shows the seasonal correction factors from January 2000 to December 2003.

2.2.3 Compilation of $\Psi_{\mathbf{f}}$ and $\Psi_{\mathbf{s}}$ for each grid box

For the environmental gamma absorbed dose rate Ψ obtained in a survey at a survey site, the cosmic radiation level Ψ_C obtained in the same quarter was first subtracted and the difference was then multiplied by the seasonal correction factor of the month of the survey to determine the open field (or street-level) terrestrial gamma absorbed dose rates for that particular survey. The open field (or street level) terrestrial gamma absorbed dose rates for all surveys at the same survey site was averaged to obtain the $\Psi_{\mathbf{f}}$ (or $\Psi_{\mathbf{s}}$) for the grid box represented by the survey site.

3. Results and Discussions

3.1 Results

From 2000 to 2003, 14 cosmic radiation measurements, 231 open field and 290 street level ambient gamma dose rate measurements were conducted. In that period, the cosmic components (Ψ_C) for each quarter, the environmental gamma absorbed dose rates measured at the open field and built-up area survey sites (Ψ) are shown in Table 1, Annex 1 and Annex 2 respectively. Figure 5 and 6 respectively show the corresponding Ψ_f and Ψ_s at the grid boxes. The results show that:

(a) the cosmic radiation level ranged from 0.029 μGyh^{-1} to 0.034 μGyh^{-1} with an average of 0.031 μGyh^{-1}. The average value and the range observed agreed well with other reported values (UNSCEAR, 2000);

(b) Ψ_f ranged from 0.050 μGyh^{-1} to 0.139 μGyh^{-1} with an average of 0.094 μGyh^{-1} and a standard deviation of 0.020 μGyh^{-1};

(c) Ψ_s ranged from 0.135 μGyh^{-1} to 0.236 μGyh^{-1} with an average of 0.177 μGyh^{-1} and a standard deviation of 0.024 μGyh^{-1}; and

(d) the ratio between the average Ψ_s and the average Ψ_f was 1.88.

3.2 Discussion

Table 3 shows the results obtained in the 1999 and the 2000 – 2003 survey. The t-test was applied to the two sets of Ψ_f and Ψ_s obtained in the two surveys. It was found that their difference was not statistically significant (P<0.05), suggesting that there was no significant difference in the environmental gamma absorbed dose rate in air between these two periods.

Table 4 shows the averages and ranges of Ψ in other countries. In general, the average Ψ in Hong Kong is slightly higher than the corresponding values of other countries, probably due to the underlying geological formation. However, the range of the Ψ in Hong Kong is not as large as those in China or other countries.

Like the 1999 survey, the average Ψ_s was higher than the average Ψ_f in this survey. The proximity of high-rise buildings was believed to be a major cause for higher gamma absorbed dose rates in built-up areas. The increase in gamma absorbed dose rates in air due to radiation emanating from the natural radioactive substances in high-rise buildings was discussed in HKO (2001).

The values of Ψ_f were in general higher in the southwestern part of the territory, especially over Lantau Island. Qualitatively, the higher values may be attributed to the effect of the underlying geological formation at the measurement locations. The geological map of Hong Kong (GEO, 1999) in Figure 7 shows a geological pattern of soil and rocks in the territory, which is primarily composed of intrusive igneous rocks, volcanic rocks and sedimentary rocks of different levels of natural radioactivity. Areas of relatively high Ψ_f (coloured in red and amber) and low Ψ_f (coloured in green and blue) in Figure 8coincide well with areas comprising soil or rocks of relatively high (e.g. granite) and low (e.g. quartz) level of natural radioactivity respectively in Figure 7. However, exception could be identified in some survey sites close to sea areas (Grid Box A and B), in between two or more types of soil or rock (Grid Box C), or those disturbed by human activities in the past (Grid Box D).

4. Conclusions

After making cosmic radiation and seasonal variation corrections, the environmental gamma absorbed dose rates in air due to terrestrial radiation at open field areas as measured in a territory-wide survey conducted from 2000 to 2003 were found to be ranging from 0.050 μGyh^{-1} to 0.139 μGyh^{-1}, with an average of 0.094 μGyh^{-1} and a standard deviation of 0.020 μGyh^{-1}. The corresponding values for built-up areas ranged from 0.135 μGyh^{-1} to 0.236 μGyh^{-1}, with an average of 0.177 μGyh^{-1} and a standard deviation of 0.024 μGyh^{-1}. Statistically, the results were not significantly different from those obtained in the survey conducted in 1999.

Large spatial variation of the environmental gamma absorbed dose rate in air due to terrestrial radiation at open-field areas was observed. In general, it was higher in the southwestern part of the territory, especially over Lantau Island. The higher values may be attributed to the natural radioactivity of the underlying geological formation at the survey locations.

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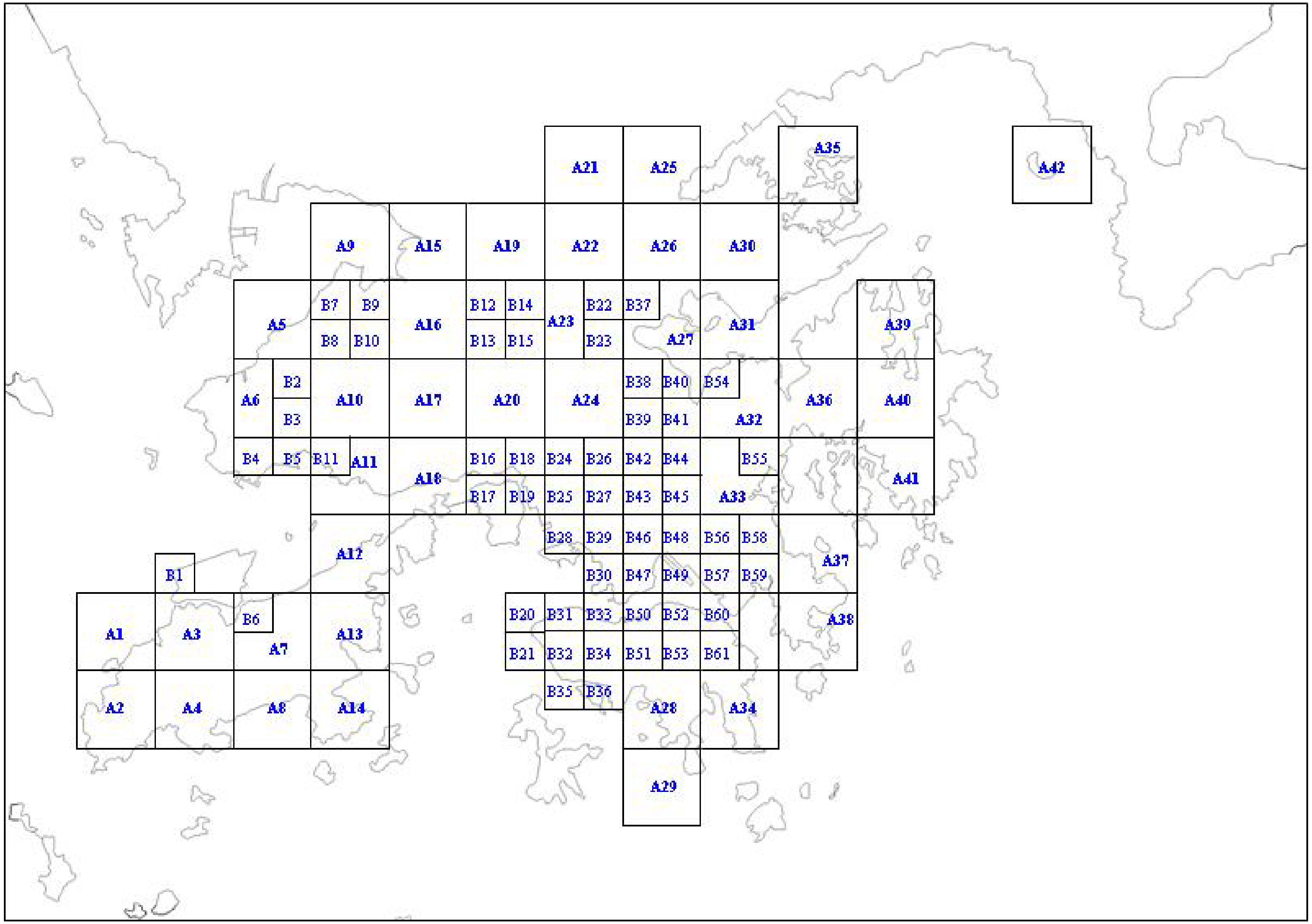

Figure 1 A map of Hong Kong showing the delineation of grid boxes for the territory-wide survey : 42 grid boxes of 5 km x 5 km for open field areas (A1-A42), 61 grid boxes of 2.5 km x 2.5 km for built-up areas (B1-B61)

Figure 2 Measurement of the gamma absorbed dose rate in air in an open field at Ngong Ping, Lantau

Figure 3 Measurement of the gamma absorbed dose rate in air at street level at Tuen Mun, New Territories

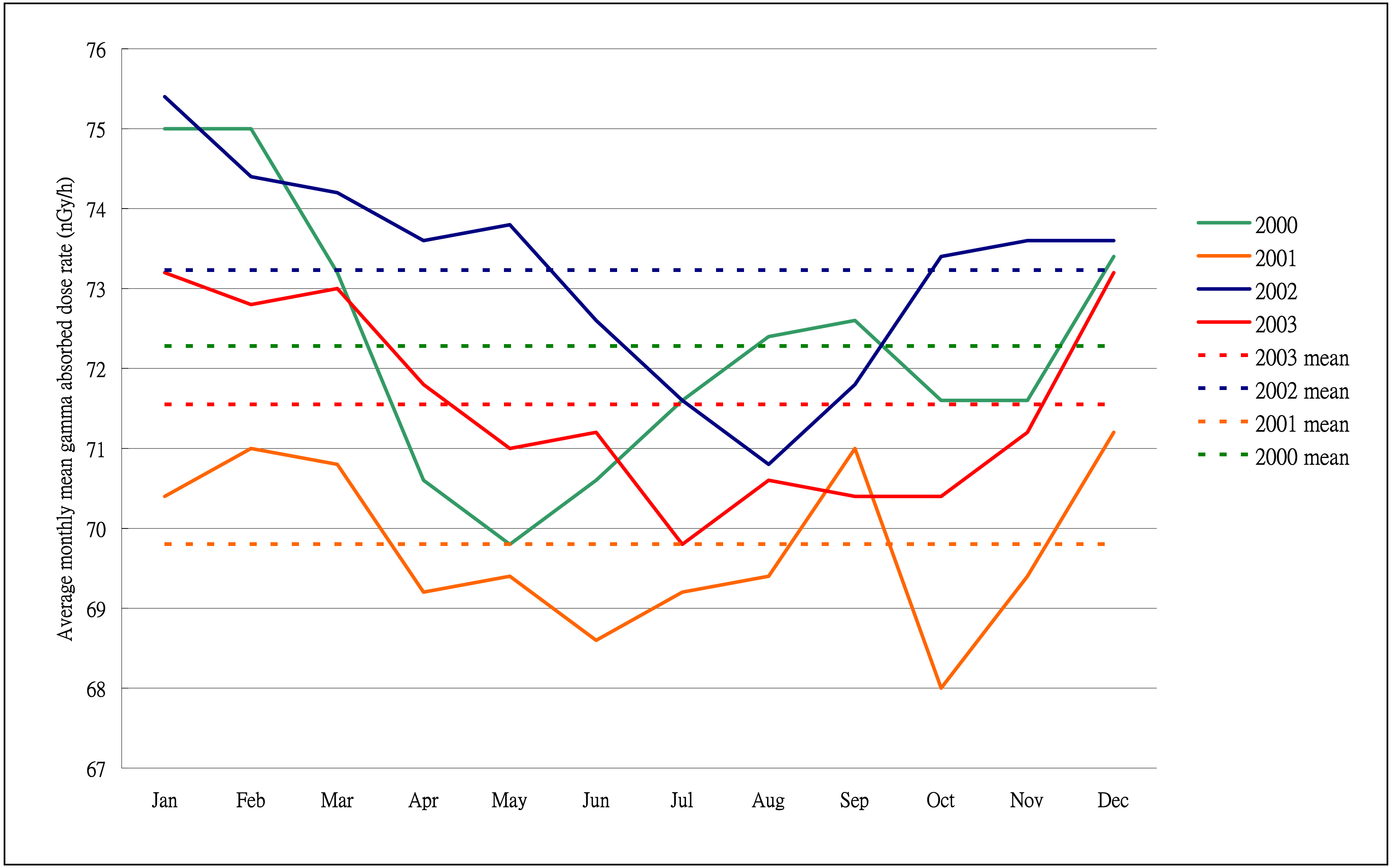

Figure 4 Seasonal variations of the average monthly mean terrestrial gamma absorbed dose rate in air (Ψ_T) measured at 5 Radiation Monitoring Stations at Kat O, Ping Chau, Sha Tau Kok, Tap Mun and Tsim Bei Tsui from 2000 to 2003

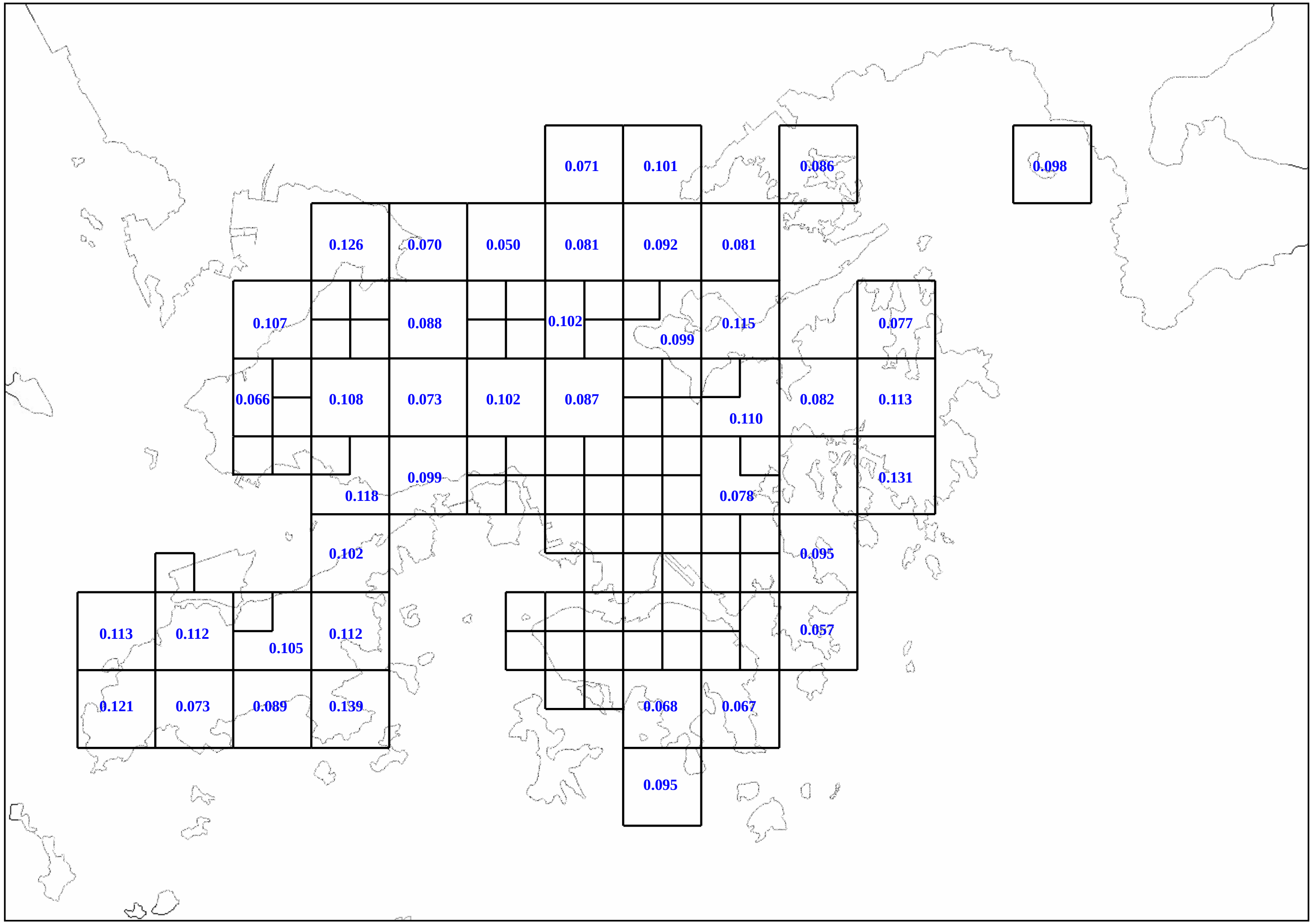

Figure 5 A map of Hong Kong showing the gamma absorbed dose rates in air at the open field grid boxes (Ψ_f) during the period 2000 to 2003

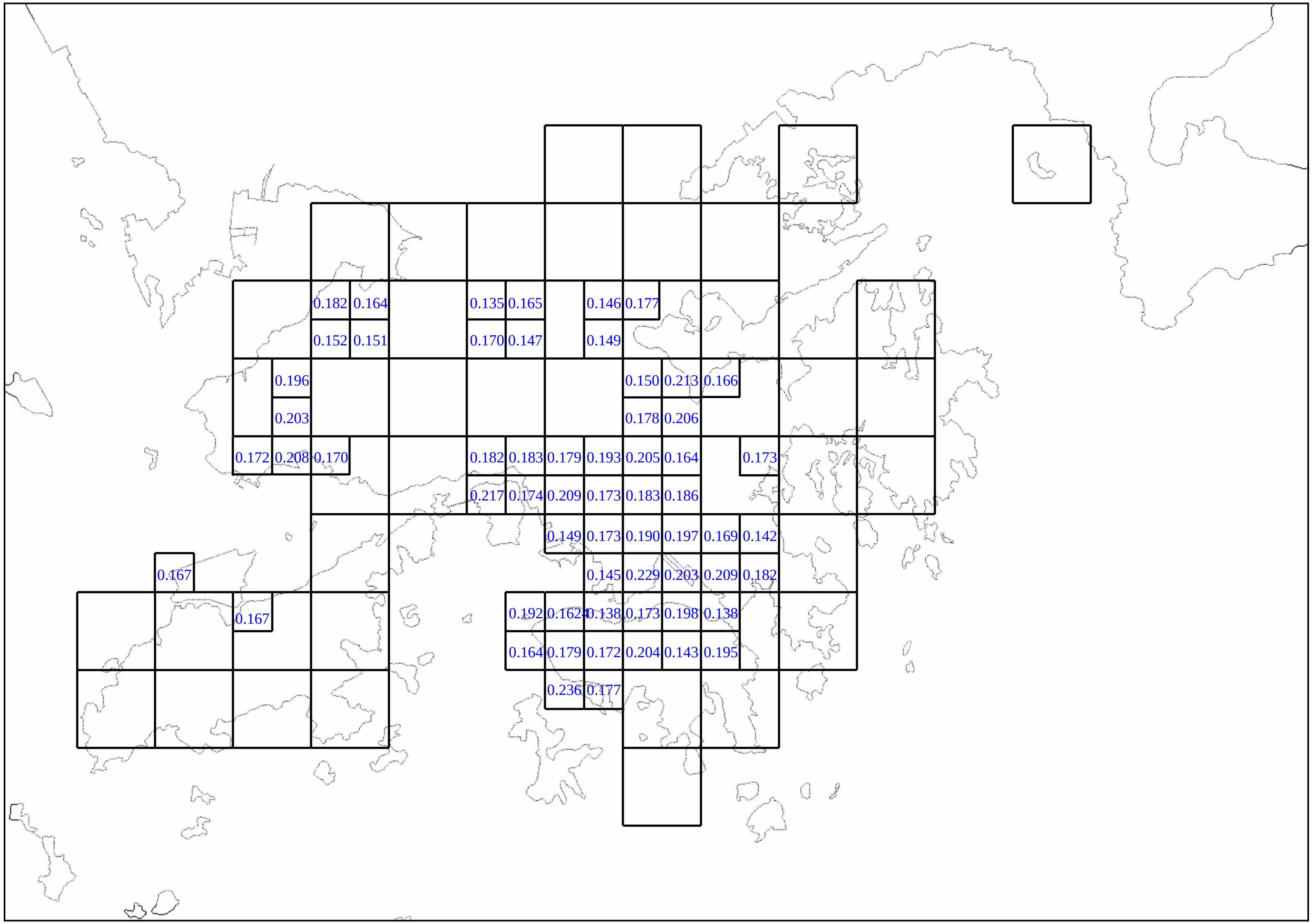

Figure 6 A map of Hong Kong showing the street level gamma absorbed dose rates in air at the built-up area grid boxes (Ψ_s) during the period 2000 to 2003

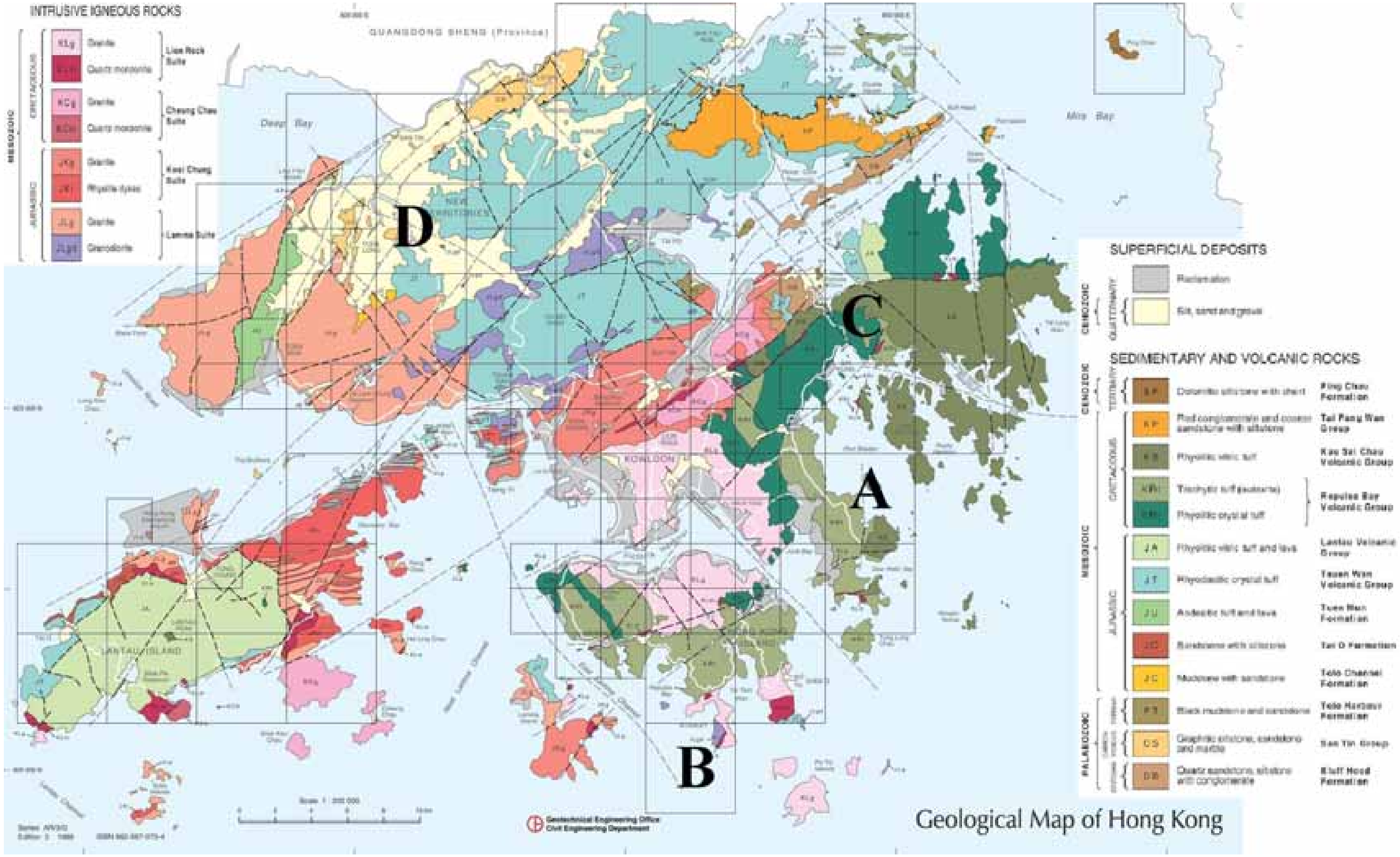

Figure 7 Geological map of Hong Kong (GEO, 1999)

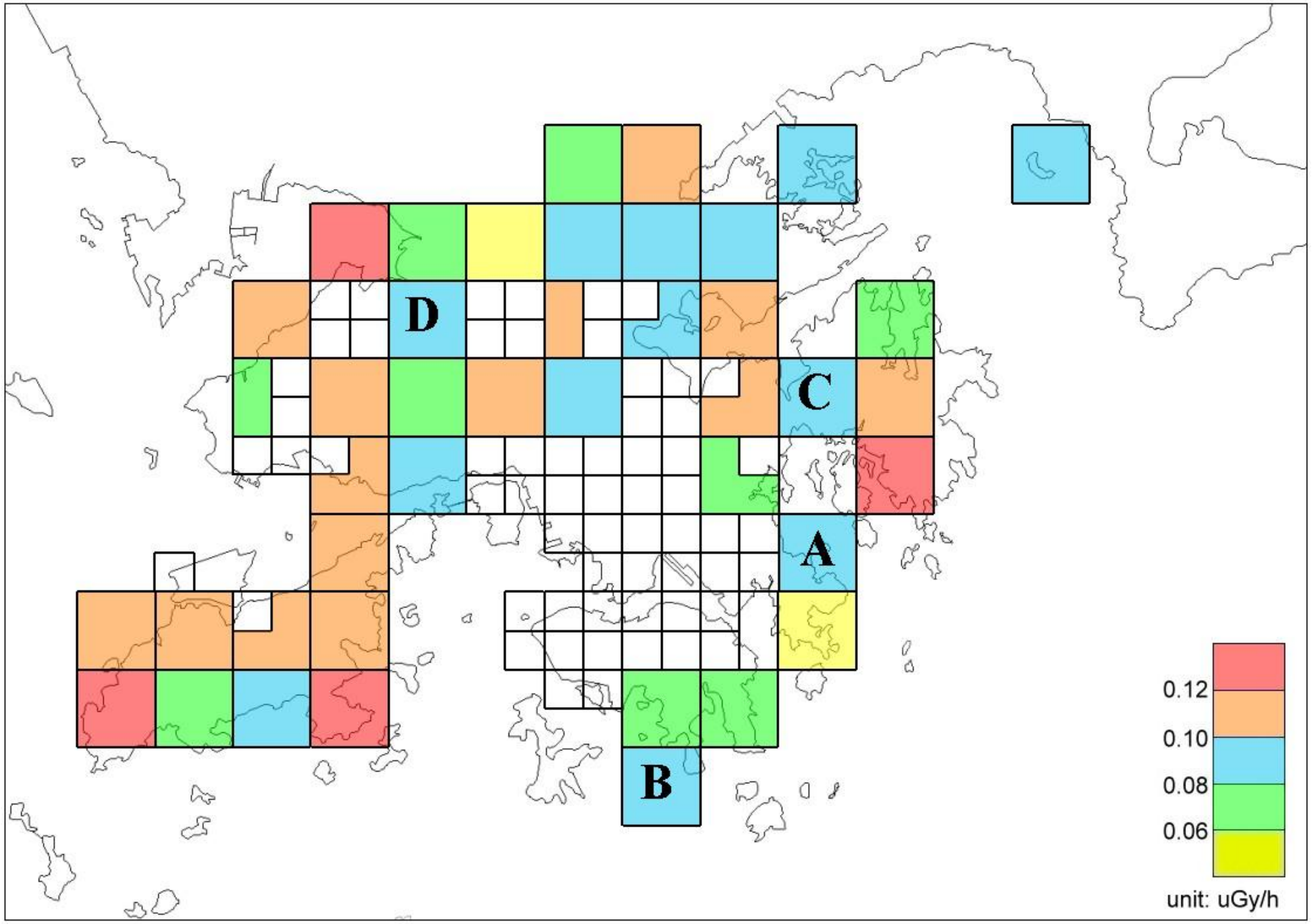

Figure 8 Spatial distribution of the gamma absorbed dose rate in air at the open field grid boxes (Ψ_f) during the period 2000 to 2003

Table 1. The cosmic radiation levels for each quarter of 2000 to 2003 at Plover Cove Reservoir

Quarters and date of measurement (in bracket)	**Results of cosmic ray measurements (μGyh^{-1})**
1^{st} quarter 2000	$0.031^{\#}$
2^{nd} quarter 2000 (15 May)	0.031
3^{rd} quarter 2000 (21 August)	0.029
4^{th} quarter 2000 (24 November)	0.030
1^{st} quarter 2001 (9 March)	0.032
2^{nd} quarter 2001 (15 June)	0.031
3^{rd} quarter 2001 (26 September)	0.031
4^{th} quarter 2001 (13 December)	0.034
1^{st} quarter 2002 (18 January)	0.030
2^{nd} quarter 2002 (19 April)	0.029
3^{rd} quarter 2002 (19 July)	0.031
4^{th} quarter 2002 (29 October)	0.030
1^{st} quarter 2003 (14 March)	0.031
2^{nd} quarter 2003	$0.030^{@}$
3^{rd} quarter 2003 (19 September)	0.031
4^{th} quarter 2003 (12 December)	0.033

$^{\#}$ estimated by the mean of the cosmic radiation measurement results of those of the first quarter in 2001, 2002 and 2003

@estimated by the mean of the cosmic radiation measurement results of those of the second quarter of 2000, 2001 and 2002

Table 2. Seasonal correction factors for January 2000 to December 2003

	2000	**2001**	**2002**	**2003**
January	0.964	0.991	0.971	0.977
February	0.964	0.983	0.984	0.983
March	0.987	0.986	0.987	0.980
April	1.024	1.009	0.995	0.997
May	1.036	1.006	0.992	1.008
June	1.024	1.017	1.009	1.005
July	1.010	1.009	1.023	1.025
August	0.998	1.006	1.034	1.013
September	0.996	0.983	1.020	1.016
October	1.010	1.026	0.998	1.016
November	1.010	1.006	0.995	1.005
December	0.985	0.980	0.995	0.977

Table 3. Comparison between the gamma absorbed dose rates in air obtained in the 1999 and 2000 – 2003 radiological surveys

	Results in 1999 (μGyh^{-1})		**Results in 2000 – 2003 (μGyh^{-1})**		**Change**
	Average	**Standard Deviation**	**Average**	**Standard Deviation**	
Open field (Ψ_f)	0.087	0.021	0.094	0.020	+8.0%
Street level (Ψ_s)	0.179	0.024	0.177	0.024	-1.1%
Ratio ($=\Psi_s/\Psi_f$)	2.06		1.88		-0.18

Table 4. Gamma absorbed dose rates in air in different countries
(extracted from Table 7 of UNSCEAR, 2000)

Country	**Average (μGyh^{-1})**	**Range (μGyh^{-1})**
Canada	0.063	0.043 – 0.101
China	0.062	0.002 – 0.340
Egypt	0.032	0.008 – 0.093
France	0.068	0.010 – 0.250
Germany	0.050	0.004 – 0.350
Japan	0.053	0.021 – 0.077
Russian Federation	0.065	0.012 – 0.102
United States	0.047	0.014 – 0.118

Annex 1

Measurement results of the environmental gamma absorbed dose rates in air at the survey sites of the open field grid boxes from 2000 to 2003

Grid Reference	Survey site	Date of measurement	Results of Measurement (μGyh^{-1})
A1	Tai O	29 Jun 2000	0.146
		28 Dec 2000	0.148
		15 Oct 2001	0.144
		15 Feb 2002	0.149
		7 Aug 2002	0.136
A2	Keung Shan	29 Jun 2000	0.155
		29 Dec 2000	0.147
		25 Apr 2001	0.149
		15 Feb 2002	0.156
		21 Oct 2003	0.151
A3	Ngong Ping	7 Aug 2000	0.130
		28 Dec 2000	0.142
		28 Jun 2001	0.136
		15 Apr 2002	0.150
		24 Feb 2003	0.153
A4	Shui Hau	30 Jun 2000	0.104
		23 Nov 2000	0.108
		17 Sep 2001	0.088
		24 Jan 2002	0.112
		10 Jul 2002	0.113
		16 May 2003	0.117
		25 Sep 2003	0.087
A5	Sheung Pak Nai	17 Oct 2000	0.120
		1 Aug 2001	0.113
		4 Jun 2002	0.144
		9 Apr 2003	0.156
		1 Dec 2003	0.158
A6	Ha Pak Lai	14 Feb 2000	0.103
		14 Jun 2001	0.091
		18 Oct 2001	0.094
		25 Apr 2002	0.099

A7	Tung Chung Au	7 Aug 2000	0.126
		21 Jun 2001	0.126
		26 Apr 2002	0.140
		24 Oct 2002	0.137
		11 Feb 2003	0.147
A8	Cheung Sha	30 Jun 2000	0.120
		29 Dec 2000	0.120
		15 Oct 2001	0.122
		4 Feb 2002	0.121
		7 Aug 2002	0.118
A9	Tsim Bei Tsui	14 Dec 2000	0.149
		29 Oct 2001	0.171
		8 Feb 2002	0.166
		5 Aug 2002	0.163
		18 Jun 2003	0.136
A10	Tai Tong	17 Apr 2000	0.152
		5 Feb 2001	0.129
		21 Dec 2001	0.119
		24 Oct 2002	0.146
		5 Aug 2003	0.153
A11	So Kwun Wat	24 Jul 2000	0.143
		24 Apr 2001	0.143
		21 Feb 2002	0.159
		4 Jun 2002	0.145
		23 Dec 2002	0.149
		10 Oct 2003	0.150
A12	Sham Shui Kok	19 Sep 2000	0.136
		26 Jul 2001	0.128
		29 May 2002	0.146
		28 Mar 2003	0.125
		2 Dec 2003	0.130
A13	Mui Wo	12 Jun 2000	0.148
		28 Dec 2000	0.145
		15 Oct 2001	0.142
		4 Feb 2002	0.143
		7 Aug 2002	0.140

A14	Chi Ma Wan	4 Sep 2000	0.167
		27 Jul 2001	0.163
		24 May 2002	0.170
		17 Mar 2003	0.172
		2 Dec 2003	0.176
A15	Mai Po	24 Jul 2000	0.094
		19 Jul 2001	0.082
		28 May 2002	0.096
		13 Mar 2003	0.108
		1 Sep 2003	0.108
		1 Dec 2003	0.116
A16	Au Tau	30 Mar 2000	0.138
		29 Jan 2001	0.109
		1 Nov 2001	0.116
		4 Sep 2002	0.116
		21 Jul 2003	0.118
A17	Tai Lam	3 Jul 2000	0.097
		13 Nov 2000	0.098
		18 Sep 2001	0.105
		22 Jan 2002	0.107
		12 May 2003	0.108
A18	Tsing Lung Tau	31 Aug 2000	0.124
		9 Aug 2001	0.124
		6 Jun 2002	0.124
		4 Apr 2003	0.134
		6 Oct 2003	0.138
		25 Nov 2003	0.135
A19	Ma Tso Lung	17 Apr 2000	0.093
		5 Feb 2001	0.070
		21 Dec 2001	0.074
		17 Oct 2002	0.081
		5 Aug 2003	0.089

A20	Tai Mo Shan	2 Feb 2000	0.140
		1 Dec 2000	0.129
		8 Oct 2001	0.135
		29 Aug 2002	0.131
		2 Jun 2003	0.130
A21	Ta Kwu Ling	8 May 2001	0.095
		12 Mar 2002	0.108
		18 Jul 2002	0.099
		9 Jan 2003	0.102
		3 Nov 2003	0.105
A22	Fanling	13 Feb 2001	0.112
		17 Apr 2001	0.108
		10 Dec 2001	0.114
		22 Oct 2002	0.114
		8 Aug 2003	0.114
A23	Lam Tsuen	3 Jul 2000	0.130
		2 May 2002	0.131
		25 Mar 2003	0.128
		24 Nov 2003	0.137
		22 Dec 2003	0.139
A24	Lead Mine Pass	31 Aug 2000	0.110
		13 Nov 2000	0.120
		9 Aug 2001	0.114
		6 Jun 2002	0.113
		4 Apr 2003	0.127
		13 Oct 2003	0.118
A25	Sha Tau Kok	15 Feb 2001	0.131
		17 Apr 2001	0.126
		10 Dec 2001	0.133
		17 Oct 2002	0.136
		12 Aug 2003	0.137
A26	Pat Sin Leng	25 Sep 2000	0.118
		20 Jul 2001	0.114
		2 May 2002	0.127
		17 Mar 2003	0.124
		23 Dec 2003	0.131

A27	Shuen Wan	11 Sep 2000	0.126
		20 Jul 2001	0.119
		7 May 2002	0.129
		6 Mar 2003	0.132
		11 Dec 2003	0.142
A28	South Bay	22 Mar 2001	0.091
		29 Jan 2002	0.102
		13 May 2002	0.094
		11 Nov 2002	0.101
		18 Sep 2003	0.103
A29	Stanley	11 Sep 2000	0.120
		9 Jul 2001	0.121
		13 May 2002	0.125
		3 Mar 2003	0.134
A30	Wu Kau Tang	21 Dec 2000	0.106
		13 Feb 2001	0.110
		22 Oct 2002	0.119
		7 Apr 2003	0.112
A31	Plover Cove	4 Sep 2000	0.136
		19 Jul 2001	0.135
		13 May 2002	0.150
		6 Mar 2003	0.157
		11 Dec 2003	0.152
A32	Nai Chung	30 Aug 2000	0.133
		14 Jun 2001	0.134
		12 Apr 2002	0.150
		10 Feb 2003	0.147
		19 Nov 2003	0.139
A33	Tsiu Hang	31 Mar 2000	0.110
		17 May 2001	0.102
		7 Mar 2002	0.115
		20 Jan 2003	0.112
		2 Jul 2003	0.103
		10 Nov 2003	0.112

A34	Shek O	25 Apr 2000	0.106
		4 Dec 2000	0.108
		22 Feb 2001	0.108
		29 Oct 2002	0.077
		11 Aug 2003	0.090
A35	Kat O	14 Jan 2000	0.127
		11 Feb 2000	0.143
		10 Mar 2000	0.125
		7 Apr 2000	0.110
		5 May 2000	0.117
		7 Jul 2000	0.107
		14 Sep 2000	0.111
		3 Nov 2000	0.112
		24 Sep 2001	0.110
		24 Jul 2002	0.113
		7 May 2003	0.114
A36	Tai Mong Tsai	30 Aug 2000	0.108
		4 Jun 2001	0.106
		23 Apr 2002	0.116
		14 Feb 2003	0.116
		25 Nov 2003	0.118
A37	Lung Ha Wan	13 Mar 2000	0.143
		2 Jan 2001	0.121
		6 Nov 2001	0.128
		13 Sep 2002	0.120
		22 Jul 2003	0.122
A38	Clear Water Bay	17 Jan 2000	0.105
		29 Oct 2001	0.087
		7 Feb 2002	0.083
		26 Aug 2002	0.086
		17 Dec 2002	0.085
		23 Jun 2003	0.081

A39	Tap Mun	19 Jan 2000	0.120
		15 Mar 2000	0.115
		19 Apr 2000	0.110
		19 Jul 2000	0.110
		8 Nov 2000	0.103
		19 Dec 2000	0.102
		10 Sep 2001	0.101
		29 Jul 2002	0.105
		21 May 2003	0.109
A40	Sai Kung	26 Oct 2000	0.139
		2 Aug 2001	0.141
		18 Jun 2002	0.140
		7 Apr 2003	0.147
		29 Dec 2003	0.152
A41	Yuen Ng Fan	8 Jan 2001	0.161
		22 Nov 2001	0.165
		10 Sep 2002	0.157
		28 Mar 2003	0.169
		22 Jul 2003	0.161
A42	Ping Chau	26 Feb 2000	0.145
		8 Mar 2000	0.135
		12 Apr 2000	0.129
		29 May 2000	0.123
		14 Jun 2000	0.120
		5 Jul 2000	0.127
		9 Aug 2000	0.118
		17 Jan 2001	0.124
		14 Nov 2001	0.130
		9 Jul 2003	0.124
		3 Sep 2003	0.137

Annex 2

Measurement results of the street level environmental gamma absorbed dose rates in air at the survey sites of the built-up area grid boxes from 2000 to 2003

Grid Reference	Location of survey site	Date of measurement	Results of Measurement (μGyh^{-1})
B1	Chek Lap Kok	18 Dec 2000	0.191
		27 Feb 2001	0.197
		16 Oct 2001	0.197
		26 Aug 2002	0.205
		2 Jun 2003	0.203
B2	Lam Tei	14 Feb 2000	0.241
		17 Oct 2000	0.224
		7 Jun 2001	0.218
		25 Apr 2002	0.221
B3	Tuen Mun	7 May 2001	0.235
		14 Mar 2002	0.229
		10 Jul 2002	0.234
		3 Jan 2003	0.241
		3 Nov 2003	0.232
B4	Pillar Point	18 Dec 2000	0.186
		18 Oct 2001	0.200
		5 Aug 2002	0.209
		19 Jun 2003	0.217
B5	Butterfly Beach	2 Feb 2000	0.252
		17 Oct 2000	0.233
		7 Jun 2001	0.236
		1 Aug 2001	0.231
		25 Apr 2002	0.240
B6	Tung Chung	12 Jun 2000	0.198
		29 Dec 2000	0.195
		8 Oct 2001	0.187
		26 Aug 2002	0.208
		11 Feb 2003	0.202
B7	Ting Shing Road, Tin Shui Wai	28 Jan 2000	0.257
		1 Mar 2001	0.181
		27 Nov 2001	0.224
		3 Sep 2002	0.227
		4 Jul 2003	0.180

B8	Ping Ha Road, Tin Shui Wai	30 Mar 2000	0.198
		29 Jan 2001	0.191
		1 Nov 2001	0.169
		4 Sep 2002	0.192
		4 Jul 2003	0.170
B9	Fuk Shun Street, Tin Shui Wai	23 Jan 2001	0.190
		1 Mar 2001	0.190
		13 Nov 2001	0.191
		3 Sep 2002	0.212
		7 Jul 2003	0.198
B10	Yuen Long	23 Jan 2001	0.179
		1 Mar 2001	0.181
		1 Nov 2001	0.186
		3 Sep 2002	0.194
		7 Jul 2003	0.175
B11	Nim Wan	18 Dec 2000	0.196
		21 Feb 2002	0.194
		5 Aug 2002	0.209
		19 Jun 2003	0.204
		10 Oct 2003	0.201
B12	Kai Kung Leng	26 Jan 2000	0.209
		2 Nov 2000	0.162
		14 Sep 2001	0.152
		4 Jul 2002	0.160
		2 May 2003	0.147
B13	Ta Shek Wu	26 Jan 2000	0.214
		2 Nov 2000	0.203
		18 Sep 2001	0.205
		18 Jul 2002	0.207
		2 May 2003	0.176
B14	Chuk Hang	31 Jan 2000	0.201
		2 Nov 2000	0.195
		14 Sep 2001	0.192
		4 Jul 2002	0.187
		2 May 2003	0.202

B15	Pak Heung	26 Jan 2000	0.162
		14 Sep 2001	0.192
		4 Jul 2002	0.179
		5 Nov 2002	0.178
		12 May 2003	0.177
B16	Yau Kom Tau	3 May 2001	0.207
		24 Jul 2001	0.200
		1 Mar 2002	0.213
		23 Jan 2003	0.222
		24 Nov 2003	0.222
B17	Tsing Yi	3 May 2001	0.246
		1 Jul 2001	0.245
		4 Mar 2002	0.265
		13 Jan 2003	0.236
B18	Tsuen Wan	3 May 2001	0.227
		3 Jul 2001	0.229
		1 Mar 2002	0.196
		23 Jan 2003	0.203
B19	Kwai Chung	3 May 2001	0.202
		3 Jul 2001	0.198
		1 Mar 2002	0.202
		13 Jan 2003	0.215
B20	Kennedy Town	29 May 2000	0.233
		20 Mar 2001	0.226
		11 Jan 2002	0.216
		4 Nov 2002	0.228
		5 Sep 2003	0.213
B21	Sandy Bay	29 May 2000	0.203
		6 Mar 2001	0.194
		11 Jan 2002	0.191
		4 Nov 2002	0.202
		18 Sep 2003	0.183

B22	Fu Heng Estate	26 Sep 2000	0.158
		13 Feb 2001	0.182
		9 Apr 2001	0.175
		6 Dec 2001	0.181
		22 Oct 2002	0.181
		8 Aug 2003	0.184
B23	Wan Tau Tong Estate	31 Jan 2000	0.185
		3 Oct 2000	0.172
		3 Aug 2001	0.175
		21 Jun 2002	0.178
		22 Apr 2003	0.185
B24	Sheung Kwai Chung	7 May 2001	0.213
		4 Mar 2002	0.217
		5 Jul 2002	0.203
		23 Jan 2003	0.215
		1 Sep 2003	0.200
B25	Ha Kwai Chung	7 May 2001	0.244
		4 Mar 2002	0.249
		10 Jul 2002	0.232
		13 Jan 2003	0.240
		1 Sep 2003	0.235
		10 Nov 2003	0.242
B26	Granville Garden	3 Feb 2000	0.252
		20 Dec 2000	0.219
		29 Oct 2001	0.223
		8 Aug 2002	0.209
		23 Jun 2003	0.217
B27	Shatin Heights	30 Aug 2000	0.204
		21 Jun 2001	0.201
		12 Apr 2002	0.212
		10 Feb 2003	0.201
		19 Nov 2003	0.202
B28	Lai Chi Kok	29 Jan 2001	0.191
		14 Mar 2002	0.164
		4 Sep 2002	0.190
		21 Jul 2003	0.175

B29	Mongkok	28 Jan 2000	0.216
		24 Sep 2001	0.198
		8 Nov 2001	0.205
		22 Jul 2002	0.200
		9 May 2003	0.204
B30	Yau Ma Tei	30 Jan 2001	0.177
		19 Mar 2002	0.176
		6 Sep 2002	0.171
		21 Jul 2003	0.180
		6 Nov 2003	0.178
B31	Sai Ying Pun	14 May 2001	0.193
		14 Mar 2002	0.208
		6 Jan 2003	0.178
B32	Wah Fu Estate	18 May 2001	0.211
		14 Mar 2002	0.211
		6 Jan 2003	0.207
B33	Central	5 Sep 2000	0.164
		24 Jul 2001	0.175
		9 May 2002	0.162
		3 Mar 2003	0.168
		18 Dec 2003	0.173
B34	Victoria Peak	1 Sep 2000	0.201
		17 Jul 2001	0.198
		9 May 2002	0.198
		3 Mar 2003	0.202
		18 Dec 2003	0.216
B35	Ap Lei Chau	29 May 2000	0.266
		6 Mar 2001	0.256
		11 Jan 2002	0.260
		6 Nov 2002	0.276
		16 Sep 2003	0.274
B36	Wong Chuk Hang	6 Mar 2001	0.215
		18 May 2001	0.221
		22 Jan 2002	0.211
		6 Nov 2002	0.202
		16 Sep 2003	0.191

B37	Tai Po Industrial Estate	26 Sep 2000	0.196
		20 Jul 2001	0.206
		2 May 2002	0.209
		6 Mar 2003	0.216
B38	Tai Po Mei Village	3 Oct 2000	0.188
		11 Apr 2001	0.180
		21 Feb 2002	0.182
		4 Jun 2002	0.174
		13 Dec 2002	0.175
B39	Fo Tan	29 Sep 2000	0.206
		9 Apr 2001	0.193
		1 Feb 2002	0.210
		10 Jun 2002	0.207
		13 Dec 2002	0.223
		9 Oct 2003	0.214
B40	Ma Liu Shui	24 Apr 2001	0.230
		1 Feb 2002	0.242
		10 Jun 2002	0.234
		17 Dec 2002	0.255
		9 Oct 2003	0.259
B41	A Kung Kok	29 Sep 2000	0.230
		11 Apr 2001	0.238
		1 Feb 2002	0.235
		10 Jun 2002	0.232
		16 Dec 2002	0.243
		13 Oct 2003	0.242
B42	Shatin Centre	3 Oct 2000	0.236
		3 Aug 2001	0.240
		10 Jun 2002	0.232
		22 Apr 2003	0.231
B43	Shatin Pass Road	3 Jan 2000	0.233
		20 Nov 2001	0.208
		5 Jul 2002	0.206
		9 May 2003	0.210

B44	Kwong Yuen Estate	2 Aug 2001	0.187
		21 Jun 2002	0.186
		9 Apr 2003	0.205
		2 Oct 2003	0.201
B45	Fei Ngo Shan	3 Jan 2000	0.245
		6 Nov 2001	0.210
		5 Jul 2002	0.205
		12 May 2003	0.211
B46	Kowloon City	9 May 2000	0.229
		5 Mar 2001	0.213
		7 Jan 2002	0.215
		18 Nov 2002	0.226
		8 Sep 2003	0.220
B47	Hunghom	4 Jan 2000	0.254
		5 Mar 2001	0.250
		20 Nov 2002	0.269
		9 May 2003	0.261
		5 Sep 2003	0.264
B48	Choi Wan Estate	9 May 2000	0.239
		8 Mar 2001	0.223
		7 Jan 2002	0.223
		18 Nov 2002	0.232
		8 Sep 2003	0.223
B49	Kwun Tong	9 May 2000	0.225
		8 Mar 2001	0.227
		7 Jan 2002	0.233
		18 Nov 2002	0.252
		18 Sep 2003	0.230
B50	Causeway Bay	20 Mar 2001	0.199
		17 Jan 2002	0.201
		9 May 2002	0.200
		4 Nov 2002	0.210
		5 Sep 2003	0.207
B51	Happy Valley	1 Jun 2001	0.234
		23 Apr 2002	0.242
		14 Feb 2003	0.226

B52	Quarry Bay	22 Feb 2001	0.228
		25 Apr 2001	0.238
		18 Dec 2001	0.229
		28 Oct 2002	0.227
		11 Aug 2003	0.225
B53	Tai Fung Au	28 Aug 2000	0.165
		11 Dec 2000	0.175
		1 Jun 2001	0.166
		23 Apr 2002	0.181
		14 Feb 2003	0.180
B54	Ma On Shan	20 Dec 2000	0.192
		4 Jun 2001	0.196
		12 Apr 2002	0.214
		10 Feb 2003	0.203
		9 Oct 2003	0.180
B55	Sai Kung Town	17 May 2001	0.200
		7 Mar 2002	0.208
		20 Jan 2003	0.209
		2 Jul 2003	0.206
		6 Nov 2003	0.198
B56	Clear Water Bay	26 May 2000	0.211
		8 Mar 2001	0.210
		17 Jan 2002	0.203
		5 Nov 2002	0.176
		15 Sep 2003	0.199
B57	Lam Tin	31 Oct 2000	0.240
		15 Feb 2001	0.241
		18 Dec 2001	0.235
		17 Apr 2003	0.248
B58	Tai Po Tsai	13 Mar 2000	0.188
		8 Jan 2001	0.171
		6 Nov 2001	0.173
		6 Sep 2002	0.168
		11 Jul 2003	0.168
B59	Tseung Kwan O	13 Mar 2000	0.233
		8 Jan 2001	0.208
		8 Nov 2001	0.208

B59	Tseung Kwan O	6 Sep 2002	0.206
		11 Jul 2003	0.213
B60	Shau Kei Wan	26 May 2000	0.187
		20 Mar 2001	0.188
		17 Jan 2002	0.153
		11 Nov 2002	0.150
		15 Sep 2003	0.165
B61	Chai Wan	25 Apr 2000	0.251
		22 Feb 2001	0.233
		18 Dec 2001	0.212
		28 Oct 2002	0.209
		11 Aug 2003	0.227