The Hongkong Electric
Company Limited

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) STUDY

FOR

UNITS L7 AND L8 AT LAMMA POWER STATION

# Key Issue Report on Air Quality

Consultants
Kennedy & Donkin International
In Association with
- Ashdown Environmental Ltd.
- BMT Fluid Mechanics Ltd.

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18 MAR 1992


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**Key Issue Report:Air Quality Impact of Proposed L7,L8 Extension to Lamma Power Station**

## CONTENTS

## 1. EXECUTIVE SUMMARY

1.1 The draft IAR on the EIA for the proposed new units, L7 and L8, was presented in December 1990. Chapter 5 dealt with the aspects of air quality impacts. This report was supported by the detailed report on wind tunnel modelling of Lamma Power Station emissions conducted by BMT Fluid Mechanics in late 1990.

1.2 The IAR concluded that the one hour concentrations due to the Power Station emissions were generally well below the relevant AQO. This was predicted to be the case for all areas for nitrogen dioxide and total suspended particulates and true for sulphur dioxide on Hong Kong Island and Cheung Chau. On rare occasions on parts of Lamma Island, $SO_2$ concentrations might exceed the $800 \mu g/m^3$ limit, but it was shown that the likely probability and frequency was sufficiently small to render exceedance of the AQO most unlikely.

1.3 As a result of the discussions between EPD, HEC and its consultants, some further analysis was requested and this is reported here. The objective of the work was :

* To derive further estimates of concentrations at certain elevated positions on Hong Kong Island.
* To consider impacts on a daily and annual basis.
* To quantify background levels of air pollution and AQO margins in areas where developments are planned on Western Hong Kong Island.
* To consider any planning constraints or mitigation measures which may be suggested by the analysis.

1.4 The report contains detailed tables and annotated maps for the worst cases of ground level and elevated concentrations. Generally no significant variation with height for these worst cases is found.

1.5 A method for converting the wind tunnel measured 1 hour concentrations to hourly concentrations not exceeded on average more than three hours per year and to daily concentrations not exceeded on average more than one day per year is described. It is argued that this method is conservative.

1.6 Background air quality was assessed from the EPD and HEC network of monitoring stations. An assessment of the likely correlation of high background and worst case Lamma Power Station impact was made and the likelihood of combined incidence is considered highly unlikely in view of the high wind conditions leading to the greatest concentrations. The estimates of background were made on a conservative basis.

1.7 The zoning plans for the West and South Hong Kong districts of Kennedy Town, Mount Davis, Central, Pok Fu Lam, Mid-Levels West, Peak Area, Aberdeen, Ap Lei Chau, and N.E. Lamma were addressed. In these areas, the percentage of AQO used up solely by the Lamma Power Station is predicted to be small and is on average conservatively estimated to be:

| FORECAST OF THE PERCENTAGE OF THE AQO USED UP SOLELY BY LAMMA POWER STATION IN THE YEAR 2000 | | | |
|---|---|---|---|
| | $SO_2$ % (FGD L6,L7,L8) | $SO_2$ % (FGD L4,L5,L6,L7,L8) | $NO_2$ % |
| **Hourly Maximum** | 21 - 54 | 13 - 34 | 16 - 44 |
| **Daily Maximum** | 10 - 42 | 6 - 26 | 7 - 29 |
| **Annual Average** | 3 - 24 | 2 - 15 | 1 - 8 |

1.8 For the developments envisaged it is demonstrated that the Power Station impacts provide no new constraints on the intended developments in the areas considered. The estimation procedure has been conservative and the hourly and daily maxima were estimated using the July 2000 peak day load profile and the burning of 1% sulphur coal. In fact between 1982 and 1989, the statistical average sulphur content was 0.7%. Furthermore, the peak day load profile will normally occur only in summer.

1.9 The analysis does not support the need for FGD retrofitting on existing Lamma units. On a probabilistic basis the likely joint occurrence of high winds, full operating load and the burning of 1% sulphur coal is very remote, so the $SO_2$ margins are almost certain to be larger (even in the worst case) than those tabulated.

1.10 An examination of the data has shown that concerns on $NO_2$ levels are at least equally driven by local sources and that the Power Station impacts, which should never exceed more than 44% of the AQO on Hong Kong Island, should not create planning constraints. It is suggested that examination of further mitigation measures is unnecessary.

1.11 As stated in the IAR, exceedances of the AQO on Lamma Island are unlikely even though the very occasional high concentration can occur. The Lamma development plans emphasise a retention of present land use (village, agriculture and Countryside Conservation). There should be no new planning demands on the AQO budget. The $SO_2$ levels will remain substantially unchanged by the L7, L8 extension and $NO_2$ levels are predicted to preserve large margins of the AQO.

## 2. INTRODUCTION

### 2.1 Initial Assessment Report

2.1.1 The draft IAR on the EIA for the proposed new units, L7 and L8, [ref.1] has been submitted. Chapter 5 dealt with the aspects of air quality impacts. This report contained conclusions and extracts from the report on wind tunnel modelling of Lamma Power Station emissions conducted by BMT Fluid Mechanics in late 1990 [ref.2].

2.1.2 The IAR concluded (paragraphs 5.203 - 5.206) that the one hour concentrations due to the Power Station emissions in the areas studied, were generally well below the relevant AQO. This was predicted to be the case for all areas for nitrogen dioxide and total suspended particulates and true for sulphur dioxide on Hong Kong Island and Cheung Chau.

2.1.3 On rare occasions on parts of Lamma Island at the worst case with all eight coal-fired units and maximum number of gas turbines operating continuously at the rated output and with burning 1% sulphur coal, $SO_2$ concentration might exceed $800\mu g/m^3$ limit, but it was shown that the likely probability and frequency was sufficiently small to render exceedance of the AQO most unlikely.

2.1.4 It was predicted that FGD retrofitting to L4 and L5 would guarantee $SO_2$ level below $800\mu g/m^3$, but at unjustifiably excessive cost considering that concentration values exceeding $800\mu g/m^3$ only occur for wind speeds (at 10m) above around 11m/s, an extremely rare event for the wind directions in question. For the worst direction (SSW), the frequency of occurrence of such winds was calculated to be 3.5 hours per year. Even rarer still, is the condition of high winds blowing in the right direction together with all eight coal-fired units and maximum number of gas turbine operating continuously at the rated output.

2.1.5 A further case against FGD retrofitting is that the wind tunnel modelling simulated the worst scenario where all eight generating units are operating continuously at the rated output (i.e. peak load) with the burning of 1% sulphur coal. Between 1982 and 1989, however, the statistical average sulphur coal burned at the Lamma Power Station was 0.7%. Furthermore, peak load would occur only in summer and normally only for a few minutes in a day.

2.1.6 In response to the IAR [ref.1] and the wind tunnel report [ref.2], EPD produced comments and discussions took place at the SMG meeting on 6th March 1991. As a result of the discussions between EPD, HEC and its consultants, some further analysis was requested and is the subject of this Key Issue Report.

### 2.2 Objectives

2.2.1 The primary objective is to study more precisely the need for FGD retrofitting and in so doing, address the issues raised by EPD. EPD expressed concern about the coverage both in terms of wind speeds and number of receptors, plume height simulation, accuracy of measurements, and the margin between the maximum concentration and the AQO. They also wanted further information on the enhanced scaling technique.

2.2.2 In order to address EPD concerns and to achieve the primary objective stated above, the aims of this Key Issue Report are:

(i) Derive further estimates of concentrations at elevated positions at:
Sandy Bay (sensor [1,4])
Pok Fu Lam (sensor [2,5])
Wah Fu Estate (sensor [3,3])
and Ap Lei Chau (sensor [4,4])
and generally assess the impact at receptors in Aberdeen (and hence Wong Chuk Hang*).

(ii) Consider impacts on a daily and annual basis.

(iii) Quantify background levels of air pollution in areas where developments are planned on Western and Southern Hong Kong Island.

(iv) Estimate the margin of AQO remaining in the areas studied in (i) above, in order to assess the likelihood of constraint on the proposed Development Plans.

(v) In the light of any identified constraints, review the contribution of the Lamma Power Station and the need or otherwise to consider mitigation measures.

2.2.3 Plume height simulation is discussed in Appendix B.

2.2.4 The accuracy of measurements have been discussed in the final wind tunnel report.

* The wind tunnel data indicate that Lamma Power Station generates similar concentrations at Aberdeen and Wong Chuk Hang. Hence in this report, data are presented only for Aberdeen.

# 3. DERIVATION OF FURTHER AIR QUALITY DATA

## 3.1 Further Analysis of Wind Tunnel Results

3.1.1 The wind tunnel test programme covered wind directions and sensors as shown in Figure 3.1.1 (equivalent to IAR Figure 5.28). The maximum ground level concentrations of $SO_2$ and $NO_2$ (with minor corrections) are repeated here as Tables 3.1.1 and 3.1.2.

3.1.2 Following EPD's request, the elevated concentration data is similarly presented in Tables 3.1.3 and 3.1.4. The associated graphical representations are provided as Figures 3.1.2 - 3.1.6 ($SO_2$, 1994); 3.1.7 - 3.1.21 ($SO_2$, 2000); 3.1.22 - 3.1.26 ($NO_2$, 1994) and 3.1.27 - 3.1.31 ($NO_2$, 2000) for ground level and different elevations. Generally, in the worst case high wind conditions, the vertical profiles are relatively flat and the plume is well mixed near the ground. Sensor (2,10), east of Victoria Peak, exhibits a somewhat different behaviour in terms of vertical profile. It should be noted, however, that the ground level concentration maxima derive from measurements at 12 m/s, whereas elevated measurements were only made at 15 m/s.

3.1.3 Included in the tables and figures for the elevated sensors are the positions referred to in paragraph 2.2.2. These have been estimated by interpolation within the measured elevated data and via the measured ground level concentrations at these locations together with representative non-dimensional vertical profiles. The interpolation is further described in Appendix A.

## 3.2 Estimates of Long Term Concentrations

3.2.1 The potential development areas on Western and Southern Hong Kong Island to be considered are Kennedy Town, Mount Davis, Central, Pok Fu Lam, Mid-levels West, Peak Area, Aberdeen and Ap Lei Chau. They can be affected by Lamma Power Station when the wind is in the 90° sector between 180° (i.e. S) and 270° (i.e. W), as also are the N.E. Lamma Island areas which potentially suffer the greatest impact.

3.2.2 Table 3.2.1 shows the long term probabilities of wind speed at Cheung Chau for the sector between 180° and 270°. The observation period was ten years, and probability of occurrence is shown for each 22.5° sector. Within the sector 180°-270°, the SSW sector has the highest probability of occurrence.

3.2.3 In Table 3.2.1 wind speeds greater than 11 m/s form a class while lower wind speeds have been separated into the following bands 0-1.5m/s, 2-3.5m/s, 4-5.5m/s, 6-7.5m/s and 8-9.5m/s. Overall, the dominant band (i.e. the bands that occur most commonly) is 4-5.5m/s. The annual frequency of occurrence of the dominant band is 105 hours, 152 hours, 96 hours, 80 hours, and 16 hours for S, SSW, SW, WSW and W sectors respectively.

3.2.4 The wind tunnel measurements have shown that at low wind speeds ($< 5$ m/s), ground level concentration in the study area is low because the plume is borne aloft. By contrast, the plume is downwashed at high wind speeds (i.e. $> 8$ m/s), and high ground level concentrations occur.

3.2.5 Full-scale hourly, daily, and yearly concentrations were derived from the wind tunnel measured 1 hour concentration by using values of Cheung Chau's wind speed and wind direction measured every hour over the ten years from 1981 to 1990. The wind data was provided by the Royal Observatory, Hong Kong.

3.2.6 The peak day load profile for July 2000 was used for the analysis. This is presented in the IAR (ref. 1) as Table 5.4. For a given hour, let the wind speed be u and the wind direction be $\theta_w$. If $|\theta_s-\theta_w|$ is less than or equal to 11°, where $\theta_s$ is the angular bearing of a particular sensor, pollutant concentration associated with u is read from the curve of the variation of concentration with wind speed measured in the wind tunnel for the particular sensor. The concentration was multiplied by the load factor for that hour of the day, the load factor being obtained from the peak load profile for July 2000. If $|\theta_s-\theta_w|$ is greater than 11°, the concentration is set to zero. Thus the time history of concentration was built up over ten years for each sensor. For $NO_2$ it was assumed that conversion from $NO_x$ was 30% in the near field on Lamma Island and 50% in the far field on Hong Kong Island. Note that $|\theta_s-\theta_w| \leq 11°$ implies a wind sector of about 22.5°. It was stated in the final Wind Tunnel report (Reference 2) that although an individual plume has a smaller angular influence, this wind sector is appropriate to cover the influence of the different chimneys.

3.2.7 Daily and yearly average concentrations were calculated and the fifty largest hourly and daily concentrations observed over the ten years period were stored.

3.2.8 With regard to the AQO, the value of hourly concentration, which is not exceeded on the average more than three hours per year (i.e. the 99.97th percentile) is the 31st largest hourly concentration measured over the ten years period. The daily average concentration, which is not exceeded on the average more than one day per year (i.e. the 99.7th percentile), is the 11th largest daily concentration measured over the ten years period.

3.2.9 The impact of Lamma Power Station at the potential development areas listed in 3.2.1 has been assessed by calculating the hourly concentration not exceeded on average more than three hours per year, the daily concentration not exceeded on average more than one day per year, and the yearly concentration. The results are presented both in $\mu g/m^3$ and as percentage of the AQO. Data for $SO_2$ are presented in Tables 5.1, 5.2, and 5.3. $NO_2$ data are presented in Tables 5.4, 5.5, and 5.6.

3.2.10 As reported in 3.2.3, the wind speed band that occurs most commonly is 4-5.5m/s. The concentration measured in the wind tunnel at a wind speed of 5.4m/s (10m height) is therefore a conservative estimate of the typical maximum hourly concentration. These results are presented in Tables 5.7 and 5.8.

3.2.11 Lamma Power Station impacts presented in Tables 5.1 to 5.8 are deemed to be conservative due to the assumptions that the station operates continuously at the peak day load profile for July 2000 with 1% sulphur coal. According to present forecast, in the year 2000 the power station will operate at the peak day load profile only in summer. Furthermore, between 1982 and 1989, the statistical average sulphur coal burned at the Lamma Power Station was 0.7%.

3.2.12 It should be noted that all results shown are based on 1% sulphur coal and the peak daily profile. The conclusions drawn use these results and do not depend on reduced sulphur content or seasonal adjustments to the daily load profile. The qualifying statements in 3.2.11 are expressed **only** to emphasise that the results are likely to be conservative.

### 3.3 Assessment of Background

3.3.1 In order to consider the margin remaining within the AQO after account has been taken of the Power Station and other sources, an assessment of the background concentration at the various locations of interest is required.

3.3.2 Measurements from the HEC and EPD network of monitoring stations were analysed and discussed in the IAR (paragraphs 5.05 - 5.17).

3.3.3 Ideally, it would be desirable to analyse the data for background as a function of location, wind speed, direction and averaging time, with the effect of the existing Lamma Power Station emissions removed.

3.3.4 Clearly this is not entirely possible, so rather more generalised arguments must be used.

3.3.5 **Annual** figures for existing levels of $SO_2$, $NO_2$ and TSP are readily available from the EPD and HEC sources, though inevitably contaminated by any contribution from Lamma Island.

3.3.6 The EPD data for 1989 suggests an annual average for $SO_2$ levels of around 15 to 20$\mu g/m^3$ for Central and Causeway Bay and the HEC Hong Kong Island measurements for 1990 are in the range of 5 to 18$\mu g/m^3$. The lowest value derives from Chung Hum Kok, on the southern part of the Island. $NO_2$ annual averages were 35 (1988) and 60 (1989) in Central and 45$\mu g/m^3$ in 1989 at Causeway Bay. As shown in the IAR, the HEC Hong Kong Island data for 1989/1990 provides annual averages around 40 to 50$\mu g/m^3$. No air quality measurements exist for Lamma Island but generally good air quality is expected.

3.3.7 Values of the annual background concentration presented in Tables 5.3 and 5.6 are in fact the monitored annual averages. The background concentration is clearly conservative because it contains the influence of the existing Lamma Power Station. Note, however, that the process of long term averaging and, particularly, the relative infrequency of westerly winds, means that the values, though probably slightly pessimistic, are reasonable.

3.3.8 As discussed in the IAR, dust levels (TSP) can be unacceptably high in many areas and AQO's are frequently exceeded. The sources are generally local traffic and construction activity and it was shown in the IAR that even the maximum 1 hour TSP concentration carried in the plume was only 28$\mu g/m^3$ with values closer to 10$\mu g/m^3$ predicted for Hong Kong Island. On an annual basis the Power Station TSP contribution is estimated to be completely negligible. Any problems remain the locally generated existing problems, so TSP will not be treated further in this report.

3.3.9 For daily **maximum** and hourly maximum background estimates a somewhat different view is required.

3.3.10 The EPD 1989 data for Central/Western show daily maxima of 80$\mu g/m^3$ for $SO_2$ and 329$\mu g/m^3$ for $NO_2$, whilst the HEC data for Southern Hong Kong Island show occasional 1 hour peaks around 300$\mu g/m^3$ for both $SO_2$ and $NO_2$, with $NO_2$ daily maxima up to 150$\mu g/m^3$.

3.3.11 On Western and Southern Hong Kong Island the maximum $SO_2$ concentrations are likely to be due to the Power Station itself and certainly, for the worst cases of high winds from the SW it is difficult to imagine any other significant $SO_2$ source upwind of the receptors. It is arguable, therefore, that the "background" to the worst case pollution from the Power Station should be taken as zero.

3.3.12 For $NO_2$, the larger short term peaks are more pronounced in winter time. The contribution from the Power Station is likely to be small, due to the prevailing wind and as discussed in the IAR such peaks (paragraph 5.12) are probably found in still, winter conditions. Certainly there should be no correlation with the higher wind speed SW conditions which will cause the greatest impact from Lamma Power Station.

3.3.13 Therefore, when assessing the impacts of Lamma Power Station on Western and Southern Hong Kong Island, a case can be made for taking the background concentration as zero. While the principle involved is sound, zero background concentration may, however, not be acceptable on psychological grounds and can also be criticised for being unconservative. Hence, a more acceptable estimate of background concentration is required.

3.3.14 An analysis of monthly 1-hour $SO_2$ data measured by HEC in July 1989 at Aberdeen, Queen Mary Hospital, Ap Lei Chau, and Victoria Road indicated that the value of the corresponding 99.97th $SO_2$ percentile is 84, 140, 121, and 105$\mu g/m^3$ respectively. For the same locations the computer analysis of the wind tunnel data described in 3.2.5 indicates that the contribution of units L1-L5 to the 99.97th $SO_2$ percentile is 60, 180, 37, and 47$\mu g/m^3$ respectively with the burning of 1% sulphur coal and 42, 126, 26, and 33$\mu g/m^3$ respectively with the burning of statistical average of 0.7% sulphur coal. Hence it was estimated that hourly background concentration of $SO_2$ ranges from about 0 to 95$\mu g/m^3$. Hence a conservative estimate of the hourly background concentration of $SO_2$ is 95$\mu g/m^3$.

3.3.15 Following reasoning similar to those described above, the daily average background of $SO_2$ was estimated to be 33$\mu g/m^3$.

3.3.16 In the case of $NO_2$, the hourly and daily average background was estimated in the manner described above to be between 41 and 53$\mu g/m^3$. Hence consistent application of the principle of conservative estimation gives a daily average $NO_2$ background concentration of 53$\mu g/m^3$. For Central/Western, however, EPD has reported that in 1989 maximum daily concentration of $NO_2$ of 329$\mu g/m^3$ occurred. Since the computer analysis suggests that at Central, units L1-L5 produce a daily average concentration of $NO_2$ of only 12$\mu g/m^3$, the hourly background is estimated to be 317$\mu g/m^3$. Such a high background is probably caused by vehicle traffic and construction activity. Since significant traffic is expected at Mid-Levels West, a background concentration, which is the average of the value used for Aberdeen and Central, is considered appropriate. Thus for development areas, daily average background concentration was estimated to range from 53$\mu g/m^3$ to 317$\mu g/m^3$ - see Table 5.5.

3.3.17 Following arguments similar to those described above and applying the principle of conservative estimation, an hourly $NO_2$ background concentration ranging from 80 to 461$\mu g/m^3$ (Table 5.4) was estimated.

3.3.18 The background hourly concentration at a wind speed of 5.4m/s, which is the sort of value that occurs most commonly, was estimated by using the wind tunnel and full-scale data as described above. The hourly background concentrations of $SO_2$ and $NO_2$ (Tables 5.7 and 5.8) are estimated to be higher than in Tables 5.1 and 5.4 because at lower wind speeds the pollutant concentration generated by the power station is smaller.

**Table 3.1.1 Maximum 1 hour ground level concentrations of $SO_2$ (AQO = 800$\mu g/m^3$)**

| Direction, Sensor | July 1994 (B1/B2) FGD:L6 | July 2000 (T1/T4) FGD:L6-L8 | July 2000 (T2/T5) FGD:L5-L8 | July 2000 (T3/T6) FGD:L4-L8 |
|---|---|---|---|---|
| 1,1 | 223 | 218 | 187 | 152 |
| 1,2 | 1156 | 1156 | 960 | 737 |
| 1,3 | 841 | 840 | 715 | 573 |
| 1,4 | 589 | 598 | 506 | 401 |
| 1,5 | 573 | 583 | 492 | 388 |
| 1,6 | 418 | 427 | 363 | 292 |
| 2,11 | 421 | 427 | 379 | 350 |
| 2,1 | 1063 | 1107 | 945 | 761 |
| 2,3 | 560 | 590 | 498 | 395 |
| 2,5 | 502 | 528 | 444 | 348 |
| 2,8 | 389 | 415 | 355 | 287 |
| 2,10 | 309 | 350 | 325 | 298 |
| 3,1 | 655 | 717 | 636 | 545 |
| 3,2 | 1012 | 1067 | 934 | 784 |
| 3,3 | 216 | 225 | 196 | 164 |
| 3,4 | 303 | 319 | 276 | 228 |
| 3,5 | 327 | 344 | 290 | 230 |
| 3,6 | 143 | 150 | 128 | 104 |
| 4,1 | 335 | 333 | 317 | 298 |
| 4,2 | 683 | 702 | 626 | 541 |
| 4,3 | 578 | 601 | 504 | 394 |
| 4,4 | 389 | 403 | 339 | 266 |
| 4,5 | 376 | 394 | 324 | 244 |
| 4,6 | 172 | 175 | 147 | 116 |
| 5,1 | 675 | 704 | 596 | 473 |
| 5,2 | 590 | 669 | 560 | 475 |
| 5,3 | 275 | 285 | 247 | 203 |
| 5,4 | 297 | 309 | 267 | 218 |
| 6,1 | 439 | 486 | 384 | 276 |
| 6,2 | 827 | 851 | 709 | 548 |
| 6,3 | 745 | 779 | 641 | 485 |
| 6,4 | 382 | 402 | 329 | 247 |
| 7,1 | 605 | 623 | 461 | 277 |
| 7,2 | 464 | 545 | 413 | 264 |
| 7,3 | 767 | 825 | 636 | 421 |
| 7,4 | 420 | 462 | 363 | 251 |
| 8,1 | 287 | 334 | 274 | 206 |
| 8,2 | 480 | 480 | 403 | 317 |
| 8,3 | 261 | 267 | 225 | 178 |

**Table 3.1.2 Maximum 1 hour ground level concentrations of $NO_2$ (AQO = 300$\mu g/m^3$)**

| Direction, Sensor | July 1994 (B1/B2) | July 2000 (T1/T4) |
|---|---|---|
| 1,1 | 41 | 38 |
| 1,2 | 188 | 199 |
| 1,3 | 180 | 192 |
| 1,4 | 157 | 179 |
| 1,5 | 157 | 176 |
| 1,6 | 111 | 128 |
| 2,11 | 71 | 79 |
| 2,1 | 171 | 188 |
| 2,3 | 151 | 193 |
| 2,5 | 134 | 166 |
| 2,8 | 100 | 125 |
| 2,10 | 80 | 116 |
| 3,1 | 97 | 121 |
| 3,2 | 151 | 174 |
| 3,3 | 54 | 63 |
| 3,4 | 76 | 93 |
| 3,5 | 83 | 101 |
| 3,6 | 36 | 42 |
| 4,1 | 47 | 47 |
| 4,2 | 100 | 114 |
| 4,3 | 118 | 145 |
| 4,4 | 100 | 121 |
| 4,5 | 97 | 122 |
| 4,6 | 45 | 51 |
| 5,1 | 103 | 121 |
| 5,2 | 97 | 126 |
| 5,3 | 57 | 72 |
| 5,4 | 71 | 91 |
| 6,1 | 72 | 118 |
| 6,2 | 131 | 160 |
| 6,3 | 119 | 155 |
| 6,4 | 102 | 136 |
| 7,1 | 100 | 117 |
| 7,2 | 77 | 163 |
| 7,3 | 125 | 180 |
| 7,4 | 68 | 107 |
| 8,1 | 74 | 94 |
| 8,2 | 116 | 135 |
| 8,3 | 75 | 87 |

**Table 3.1.3** Maximum 1 hour concentrations of $SO_2$ at elevated receptors (AQO = $800\mu g/m^3$)

| Direction,Sensor | Height (m) | July 1994 (B1/B2) FGD:L6 | July 2000 (T1/T4) FGD:L6-L8 | July 2000 (T2/T5) FGD:L5-L8 | July 2000 (T3/T6) FGD:L4-L8 |
|---|---|---|---|---|---|
| 1,4 | 30 | 550 | 560 | 480 | 380 |
| | 60 | 540 | 550 | 470 | 370 |
| | 90 | 540 | 540 | 460 | 370 |
| | 120 | 530 | 540 | 450 | 360 |
| 1,5 | 30 | 397 | 411 | 337 | 254 |
| | 60 | 410 | 424 | 347 | 260 |
| | 90 | 388 | 401 | 325 | 240 |
| | 120 | 380 | 393 | 320 | 237 |
| 2,3 | 30 | 574 | 582 | 476 | 356 |
| | 60 | 544 | 552 | 451 | 337 |
| | 90 | 525 | 532 | 435 | 324 |
| | 120 | 512 | 520 | 423 | 312 |
| 2,5 | 30 | 500 | 530 | 450 | 350 |
| | 60 | 480 | 500 | 420 | 330 |
| | 90 | 480 | 480 | 400 | 320 |
| | 120 | 450 | 470 | 400 | 310 |
| 2,8 | 60 | 421 | 438 | 364 | 280 |
| | 120 | 400 | 415 | 345 | 265 |
| | 180 | 507 | 534 | 450 | 355 |
| 2,10 | 30 | 153 | 153 | 141 | 127 |
| | 60 | 142 | 143 | 131 | 119 |
| | 90 | 151 | 153 | 140 | 125 |
| | 120 | 161 | 162 | 146 | 128 |
| 3,3 | 30 | 210 | 220 | 190 | 160 |
| | 60 | 200 | 210 | 180 | 150 |
| | 90 | 200 | 200 | 180 | 150 |
| | 120 | 200 | 200 | 180 | 140 |
| 3,4 | 30 | 205 | 209 | 184 | 155 |
| | 60 | 164 | 168 | 144 | 117 |
| | 90 | 138 | 141 | 120 | 96 |
| | 120 | 121 | 123 | 104 | 83 |
| 4,4 | 30 | 340 | 350 | 300 | 230 |
| | 60 | 370 | 380 | 320 | 280 |
| | 90 | 350 | 360 | 310 | 240 |
| | 120 | 350 | 360 | 310 | 240 |
| 4,6 | 30 | 197 | 201 | 169 | 132 |
| | 60 | 191 | 195 | 164 | 130 |
| | 90 | 215 | 222 | 186 | 145 |
| | 120 | 218 | 224 | 189 | 149 |
| 6,2 | 30 | 855 | 881 | 729 | 557 |
| | 60 | 897 | 921 | 757 | 572 |
| 7,4 | 30 | 447 | 489 | 387 | 270 |
| | 60 | 506 | 549 | 434 | 304 |
| 8,3 | 30 | 286 | 292 | 243 | 187 |
| | 60 | 298 | 305 | 256 | 199 |
| | 90 | 298 | 308 | 258 | 201 |

**Table 3.1.4 Maximum 1 hour concentrations of $NO_2$ at elevated receptors (AQO = 300$\mu g/m^3$)**

| Direction, Sensor | Height (m) | July 1994 (B1/B2) | July 2000 (T1/T4) |
|---|---|---|---|
| 1,4 | 30 | 150 | 170 |
| | 60 | 140 | 160 |
| | 90 | 140 | 160 |
| | 120 | 140 | 160 |
| 1,5 | 30 | 103 | 123 |
| | 60 | 106 | 127 |
| | 90 | 101 | 121 |
| | 120 | 99 | 120 |
| 2,3 | 30 | 156 | 178 |
| | 60 | 147 | 169 |
| | 90 | 142 | 163 |
| | 120 | 129 | 163 |
| 2,5 | 30 | 140 | 170 |
| | 60 | 130 | 160 |
| | 90 | 120 | 150 |
| | 120 | 120 | 150 |
| 2,8 | 60 | 110 | 135 |
| | 120 | 105 | 127 |
| | 180 | 87 | 172 |
| 2,10 | 30 | 40 | 43 |
| | 60 | 40 | 40 |
| | 90 | 40 | 44 |
| | 120 | 43 | 53 |
| 3,3 | 30 | 50 | 60 |
| | 60 | 50 | 60 |
| | 90 | 50 | 60 |
| | 120 | 50 | 60 |
| 3,4 | 30 | 51 | 57 |
| | 60 | 41 | 47 |
| | 90 | 35 | 40 |
| | 120 | 30 | 34 |
| 4,4 | 30 | 90 | 110 |
| | 60 | 100 | 110 |
| | 90 | 90 | 110 |
| | 120 | 90 | 110 |
| 4,6 | 30 | 66 | 77 |
| | 60 | 64 | 74 |
| | 90 | 74 | 89 |
| | 120 | 76 | 90 |
| 6,2 | 30 | 135 | 165 |
| | 60 | 142 | 169 |
| 7,4 | 30 | 72 | 112 |
| | 60 | 81 | 123 |
| 8,3 | 30 | 82 | 99 |
| | 60 | 85 | 103 |
| | 90 | 84 | 104 |

**Table 3.2.1 Wind Speed Probabilities at Cheung Chau 1979-88**

| | 0-1.5m/s | 2-3.5m/s | 4-5.5m/s | 6-7.5m/s | 8-9.5m/s | >11 m/s | Totals |
|---|---|---|---|---|---|---|---|
| S | 0.01450 | 0.01170 | 0.01200 | 0.00420 | 0.00040 | 0.00020 | 0.04300 |
| SSW | 0.01080 | 0.01080 | 0.01740 | 0.01280 | 0.00120 | 0.00040 | 0.05340 |
| SW | 0.00820 | 0.00760 | 0.01100 | 0.00710 | 0.00050 | 0.00020 | 0.03460 |
| WSW | 0.00850 | 0.00690 | 0.00910 | 0.00540 | 0.00040 | 0.00030 | 0.03060 |
| W | 0.00550 | 0.00250 | 0.00180 | 0.00100 | 0.00020 | 0.00020 | 0.01120 |

## 4. REVIEW OF DEVELOPMENT PLANS

The outline Zoning Plans for Kennedy Town and Mount Davis (S/H1/2); for Central (S/H4/3); for Pok Fu Lam (S/H10/2); for Mid-Levels West (S/H11/4); for the Peak Area (S/H10/2) and for Aberdeen and Ap Lei Chau (S/H15/5) and the Outline Development Plan for Lamma Island (D/I-LI/1) have been examined.

Major changes to the character of development in these areas is not planned and for the purposes of Section 5, the areas have been classified as follows:

| | |
|---|---|
| Kennedy Town | Mostly Residential (R), Government/Institution/Community (G/IC), Commercial (C), very limited Industry (I), New Highway (Route 7) and Green Belt (GB) |
| Mount Davis | G/IC |
| Central | C and G/IC |
| Pok Fu Lam | R, G/IC I, Route 7, GB |
| Mid-Levels West | R, G/IC and GB |
| Peak Area | GB and R |
| Aberdeen | GB, G/IC, R, Light Industrial (LI) and Highway (H) |
| Ap Lei Chau | GB, G/IC, R, LI and H |
| Lamma Island | Countryside Conservation Area (CCA), Agricultural (A), Village Development Area (VDA) |

## 5. IMPACT OF LAMMA STATION EMISSIONS ON OTHER DEVELOPMENTS

5.1 From the categorisation of zoning and development plans in Section 4, together with the estimates of longer term average concentration and background levels in Section 3, it is possible to assess the likely impact of the Lamma Power Station in terms of Constraints to the development plan envisaged.

5.2 This analysis is set out in Tables 5.1 - 5.3 for $SO_2$ and Tables 5.4 - 5.6 for $NO_2$. As discussed in paragraph 3.3.8, the contribution of TSP from the Power Station is negligible by comparison with locally generated background levels.

### 5.3 Hourly Maxima for $SO_2$ (Table 5.1)

The 1-hour $SO_2$ 99.97th percentile (i.e. the hourly concentration not exceeded on average more than 3 times per year) generated by Lamma Power Station in the year 2000 is predicted to be 443$\mu g/m^3$ (i.e. 55% of the AQO) for the worst case (N.E. Lamma) and about 170$\mu g/m^3$ (i.e. 21% of the AQO) in the development areas of Aberdeen and Ap Lei Chau. The background concentration for these areas is conservatively estimated to be 95$\mu g/m^3$ (i.e. 12% of the AQO). Subtracting the impact of the Power Station plus the background still leaves a margin of 262$\mu g/m^3$ even for the worst case (N.E. Lamma) with around 530$\mu g/m^3$ (66% of the AQO) in the development areas of Aberdeen and Ap Lei Chau. Hence even on Lamma, no planning constraint to the village and agricultural land use is implied by the Power Station impact.

### 5.4 Daily Maxima for $SO_2$ (Table 5.2)

A similar situation to the hourly maxima exists. Subtracting the impacts of the Power Station and the background from the AQO leaves a margin of 170-212$\mu g/m^3$ at Mt. Davis and Pok Fu Lam. This margin should be more than adequate in conditions of high winds from the South West for all planned developments.

### 5.5 Annual Averages for $SO_2$ (Table 5.3)

The Table suggests an entirely satisfactory situation particularly as a very conservative approach has been used. The present background must include the impact of L1-L5 and the proposed $SO_2$ emission increase by the year 2000 is only about 7%. In the Table, it is seen that even for the worst case (Mount Davis), subtracting the impacts of the Power Station and the background from the AQO still leaves a margin of 55% of the AQO.

### 5.6 Hourly and Daily Maxima for $NO_2$ (Tables 5.4 and 5.5)

With the exception of Central and Mid-Levels West a margin of at least 30% of the AQO is available. AQO exceedance is predicted at Central and Mid-Levels West mainly because of the pollution generated by other sources such as traffic and construction activity. Unlike $SO_2$ increased local development of the type planned could produce significant increases in $NO_2$. Fortunately, these are likely to be readily dispersed in the high wind conditions giving rise to the maximum Power Station impact. For Pok Fu Lam, Kennedy Town and the Aberdeen area, new highway developments could produce $NO_2$ sources upwind of the receptors and aligned with the Power Station plumes. Detailed traffic pollution calculations cannot be undertaken at this stage.

5.7 Under calm winter conditions high $NO_2$ concentrations may arise, of course, as discussed earlier and in the IAR, but these should be uncorrelated with significant Power Station pollution.

## 5.8 Annual Averages for $NO_2$ (Table 5.6)

The Power Station makes a negligible impact to the annual $NO_2$ average values. The margin is dictated by the existing background levels (determined from the EPD and HEC measurement network) and no new constraint on development is imposed by the Lamma Power Station.

## 5.9 Elevated Receptors

In Tables 5.1 - 5.6, the ground level concentrations predicted from the wind tunnel tests were used. It was checked, however, that the similar conclusions would be drawn if the concentration at any height in the lowest 120m relative to local ground level were used. The reason is because maximum hourly and daily concentration are usually associated with high winds (usually about 15m/s). For such winds, the plume is blown down and is generally well mixed. Consequently the variation of concentration with height tends to be small, and maximum concentration tends to occur near the ground.

| DEVELOPMENT AREA | HOURLY CONCENTRATION NOT EXCEEDED ON AVERAGE MORE THAN 3 TIMES PER YEAR | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 373 | 47 | 95 | 332 | 42 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 434 | 54 | 95 | 271 | 34 | G/IC | No new constraints |
| CENTRAL | 206 | 26 | 95 | 499 | 62 | C and G/IC | No new constraints |
| POK FU LAM | 391 | 49 | 95 | 314 | 39 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 235 | 29 | 95 | 470 | 59 | R, G/IC and GB | No new constraints |
| PEAK AREA | 271 | 34 | 95 | 434 | 54 | GB and R | No new constraints |
| ABERDEEN | 176 | 22 | 95 | 529 | 66 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 169 | 21 | 95 | 536 | 67 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 443 | 55 | 95 | 262 | 33 | CCA, A, VDA | No new constraints |

Table 5.1 Hourly Averages, $SO_2$ (AQO = $800 \mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | DAILY CONCENTRATION NOT EXCEEDED ON AVERAGE MORE THAN ONCE PER YEAR | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 125 | 36 | 33 | 192 | 55 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 147 | 42 | 33 | 170 | 49 | G/IC | No new constraints |
| CENTRAL | 57 | 16 | 33 | 260 | 74 | C and G/IC | No new constraints |
| POK FU LAM | 105 | 30 | 33 | 212 | 61 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 65 | 19 | 33 | 252 | 72 | R, G/IC and GB | No new constraints |
| PEAK AREA | 68 | 19 | 33 | 249 | 71 | GB and R | No new constraints |
| ABERDEEN | 36 | 10 | 33 | 281 | 80 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 34 | 10 | 33 | 283 | 81 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 72 | 21 | 33 | 245 | 70 | CCA, A, VDA | No new constraints |

Table 5.2 Daily Averages, $SO_2$ (AQO = 350$\mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | YEARLY AVERAGE CONCENTRATION | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 16 | 20 | 17 | 47 | 59 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 19 | 24 | 17 | 44 | 55 | G/IC | No new constraints |
| CENTRAL | 7 | 9 | 15 | 58 | 73 | C and G/IC | No new constraints |
| POK FU LAM | 12 | 15 | 13 | 55 | 69 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 9 | 11 | 17 | 54 | 68 | R, G/IC and GB | No new constraints |
| PEAK AREA | 9 | 11 | 17 | 54 | 68 | GB and R | No new constraints |
| ABERDEEN | 3 | 4 | 13 | 64 | 80 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 2 | 3 | 14 | 64 | 80 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 8 | 10 | 13 | 59 | 74 | CCA, A, VDA | No new constraints |

Table 5.3 Annual Averages, $SO_2$ (AQO = $80\mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | HOURLY CONCENTRATION NOT EXCEEDED ON AVERAGE MORE THAN 3 TIMES PER YEAR | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 112 | 37 | 80 | 108 | 36 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 131 | 44 | 80 | 89 | 30 | G/IC | No new constraints |
| CENTRAL | 47 | 16 | 461 | -208 | -69 | C and G/IC | No new constraints |
| POK FU LAM | 118 | 39 | 80 | 102 | 34 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 72 | 24 | 268 | -40 | -13 | R, G/IC and GB | No new constraints |
| PEAK AREA | 83 | 28 | 80 | 137 | 46 | GB and R | No new constraints |
| ABERDEEN | 54 | 18 | 80 | 166 | 55 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 51 | 17 | 80 | 169 | 56 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 87 | 29 | 80 | 133 | 44 | CCA, A, VDA | No new constraints |

Table 5.4 Hourly Averages, $NO_2$ (AQO = $300\mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | DAILY CONCENTRATION NOT EXCEEDED ON AVERAGE MORE THAN ONCE PER YEAR | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 34 | 23 | 53 | 63 | 42 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 44 | 29 | 53 | 53 | 35 | G/IC | No new constraints |
| CENTRAL | 16 | 11 | 317 | -183 | -122 | C and G/IC | No new constraints |
| POK FU LAM | 32 | 21 | 53 | 65 | 43 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 23 | 15 | 185 | -58 | -39 | R, G/IC and GB | No new constraints |
| PEAK AREA | 25 | 17 | 53 | 72 | 48 | GB and R | No new constraints |
| ABERDEEN | 12 | 8 | 53 | 85 | 57 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 10 | 7 | 53 | 87 | 58 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 17 | 11 | 53 | 80 | 53 | CCA, A, VDA | No new constraints |

Table 5.5 Daily Averages, $NO_2$ (AQO = $150\mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | YEARLY AVERAGE CONCENTRATION | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 5 | 6 | 50 | 25 | 31 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 6 | 8 | 50 | 24 | 30 | G/IC | No new constraints |
| CENTRAL | 2 | 3 | 60 | 18 | 23 | C and G/IC | No new constraints |
| POK FU LAM | 4 | 5 | 40 | 36 | 45 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 3 | 4 | 50 | 27 | 34 | R, G/IC and GB | No new constraints |
| PEAK AREA | 3 | 4 | 50 | 27 | 34 | GB and R | No new constraints |
| ABERDEEN | 1 | 1 | 43 | 36 | 45 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 1 | 1 | 43 | 36 | 45 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 2 | 3 | 43 | 35 | 44 | CCA, A, VDA | No new constraints |

Table 5.6 Annual Averages, $NO_2$ (AQO = $80\mu g/m^3$)

True background concentration is expected to be less than the indicated values

| DEVELOPMENT AREA | HOURLY WORST CASE POWER STATION POLLUTION | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 193 | 24 | 98 | 509 | 64 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 235 | 29 | 98 | 467 | 58 | G/IC | No new constraints |
| CENTRAL | 84 | 11 | 98 | 618 | 77 | C and G/IC | No new constraints |
| POK FU LAM | 115 | 14 | 98 | 587 | 73 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 98 | 12 | 98 | 604 | 76 | R, G/IC and GB | No new constraints |
| PEAK AREA | 93 | 12 | 98 | 609 | 76 | GB and R | No new constraints |
| ABERDEEN | 70 | 9 | 98 | 632 | 79 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 26 | 3 | 98 | 676 | 85 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 33 | 4 | 98 | 669 | 84 | CCA, A, VDA | No new constraints |

Table 5.7 Maximum hourly concentration of $SO_2$ at the most commonly occurring wind speed (5.4m/s). (AQO = $800\mu g/m^3$)

| DEVELOPMENT AREA | HOURLY WORST CASE POWER STATION POLLUTION | | ESTIMATED BACKGROUND $\mu g/m^3$ | MARGIN TO AQO | | DEVELOPMENT PLAN | DEVELOPMENT CONSTRAINT AGAINST REQUIREMENT |
|---|---|---|---|---|---|---|---|
| | $\mu g/m^3$ | PERCENT OF AQO | | $\mu g/m^3$ | PERCENT OF AQO | | |
| KENNEDY TOWN | 57 | 19 | 116 | 127 | 42 | R, G/IC, C, I, Route 7 and GB | No new constraints |
| MOUNT DAVIS | 70 | 23 | 116 | 114 | 38 | G/IC | No new constraints |
| CENTRAL | 31 | 10 | 448 | -179 | -149 | C and G/IC | No new constraints |
| POK FU LAM | 35 | 12 | 116 | 149 | 50 | R, G/IC, Route 7 and GB | No new constraints |
| MID-LEVELS WEST | 38 | 13 | 282 | -20 | -7 | R, G/IC and GB | No new constraints |
| PEAK AREA | 37 | 12 | 116 | 147 | 49 | GB and R | No new constraints |
| ABERDEEN | 24 | 8 | 116 | 160 | 53 | GB, G/IC, R, LI and H | No new constraints |
| AP LEI CHAU | 10 | 3 | 116 | 174 | 58 | GB, G/IC, R, LI and H | No new constraints |
| N.E. LAMMA ISLAND | 9 | 3 | 116 | 175 | 58 | CCA, A, VDA | No new constraints |

Table 5.8 Maximum hourly concentration of $NO_2$ at the most commonly occurring wind speed (5.4m/s). (AQO = $300\mu g/m^3$)

## 6. IMPACT OF DEVELOPMENT PLANS ON POWER STATION CONFIGURATION

6.1 The margins deduced for Western and Southern Hong Kong Island in Section 5, confirm that the power station does not produce extreme impacts in the development areas. On the average, the fraction of the AQO used up by Lamma Power Station is predicted to be small and hence a generous margin is left for other sources of pollutant. This margin is, on average, conservatively estimated to be:

| | $SO_2$ Margin % (FGD L6,L7,L8) | $SO_2$ Margin % (FGD L4,L5,L6,L7,L8) | $NO_2$ Margin % |
|---|---|---|---|
| **Hourly Maximum** | 46 - 79 | 66 - 87 | 56 - 84 |
| **Daily Maximum** | 58 - 90 | 74 - 94 | 71 - 93 |
| **Annual Average** | 76 - 97 | 85 - 98 | 92 - 99 |

Table 6.1 The impact produced at Western and Southern Hong Kong Island by Lamma Power Station

6.2 For the developments envisaged it has been argued in Section 5 that the Power Station impacts provide no new constraints on the intended developments in the areas considered. The estimation procedure has been conservative and the hourly and daily maxima relate to extremely infrequent events (typically one occurrence per year). The maximum Power Station impacts are virtually guaranteed by the meteorological conditions **not** to coincide with peaks in the local background.

6.3 The analysis does not support the need for FGD retrofitting on existing Lamma units. FGD on L4 and L5 would reduce $SO_2$ values by around 30%, but this reduction is routinely being achieved by the use of lower sulphur coal. On a probabilistic basis the likely joint occurrence of high winds, full operating load and the burning of 1% sulphur coal is very remote, so the $SO_2$ margins are almost certain to be larger (even in the worst case) than in Table 6.1.

6.4 An examination of the data has shown that concerns on $NO_2$ levels are at least equally driven by local sources and that the Power Station impacts, which should never exceed more than 56% of the AQO on Hong Kong Island, should not create planning constraints. It is suggested that examination of further mitigation measures is unnecessary.

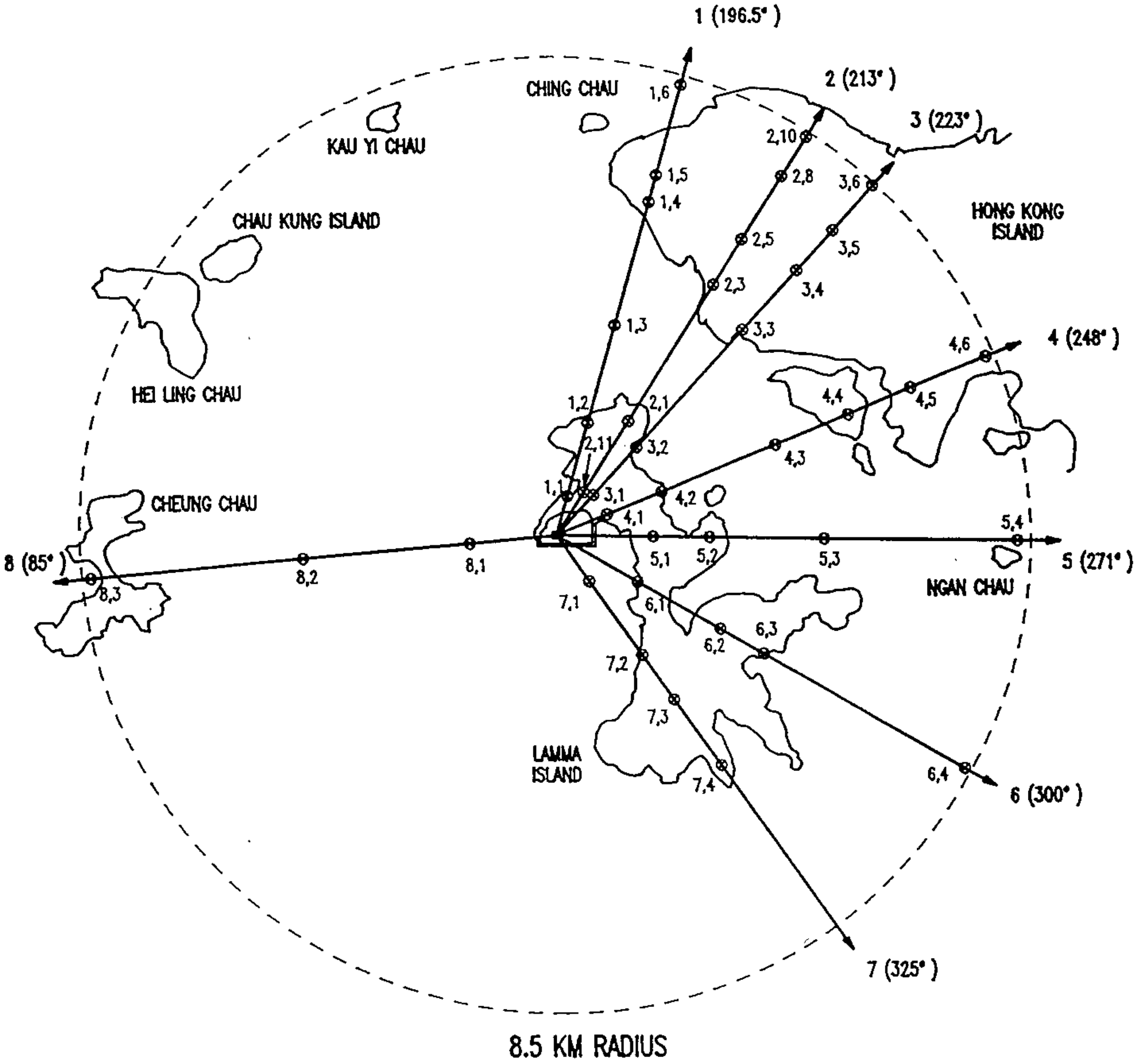
## 7. REFERENCES

1. Hong Kong Electric Company
"Environmental Impact Assessment (EIA) Study for Units L7 and L8 at Lamma Power Station." Initial Assessment Report, December 1990.

2. BMT Fluid Mechanics Limited
"The Hong Kong Electric Company Limited Lamma Power Station EIA for Units L7 & L8: Wind Tunnel Assessment of Air Quality." April 1991.

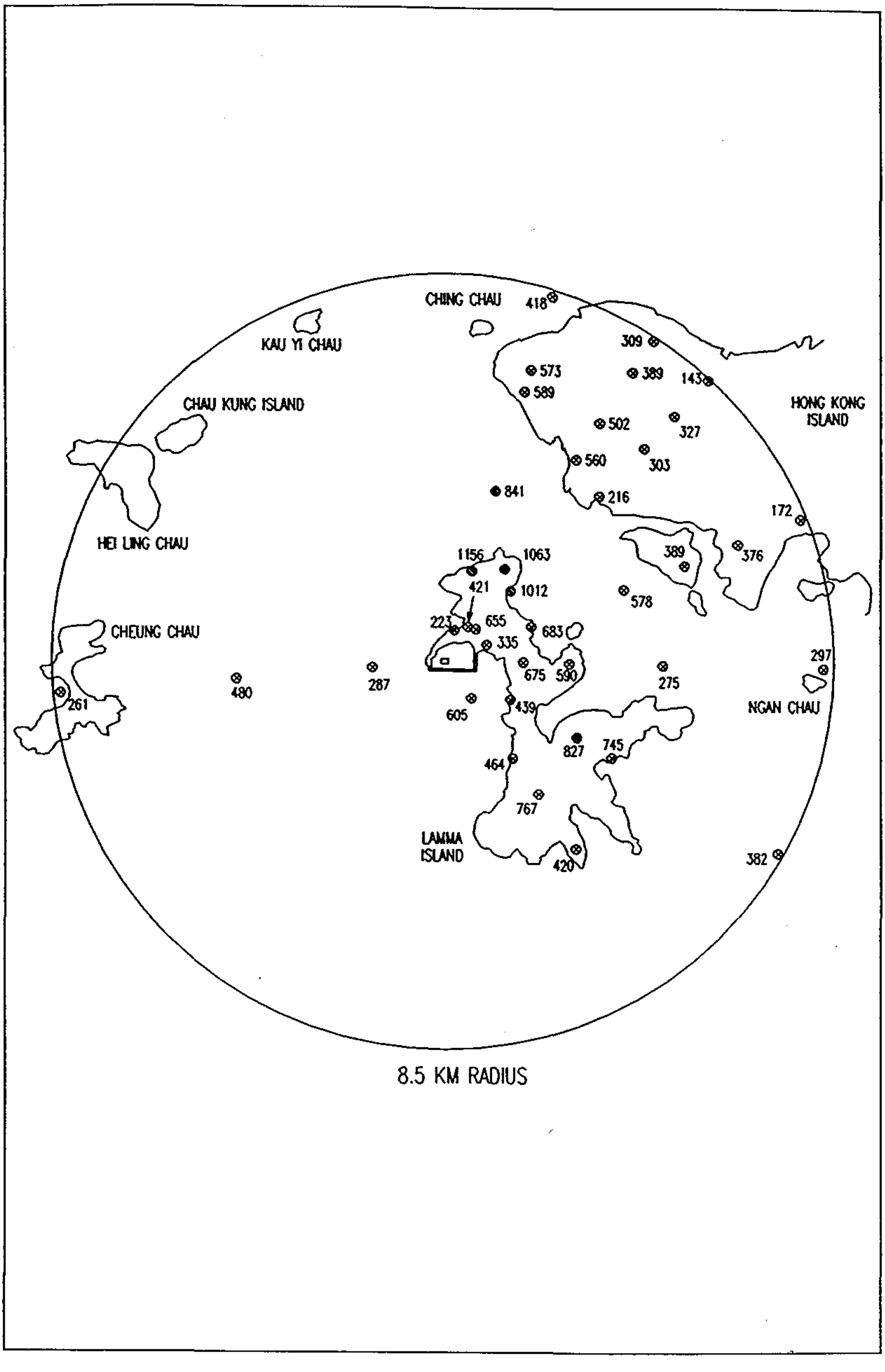
**Figure**

**Figure 3.1.1**



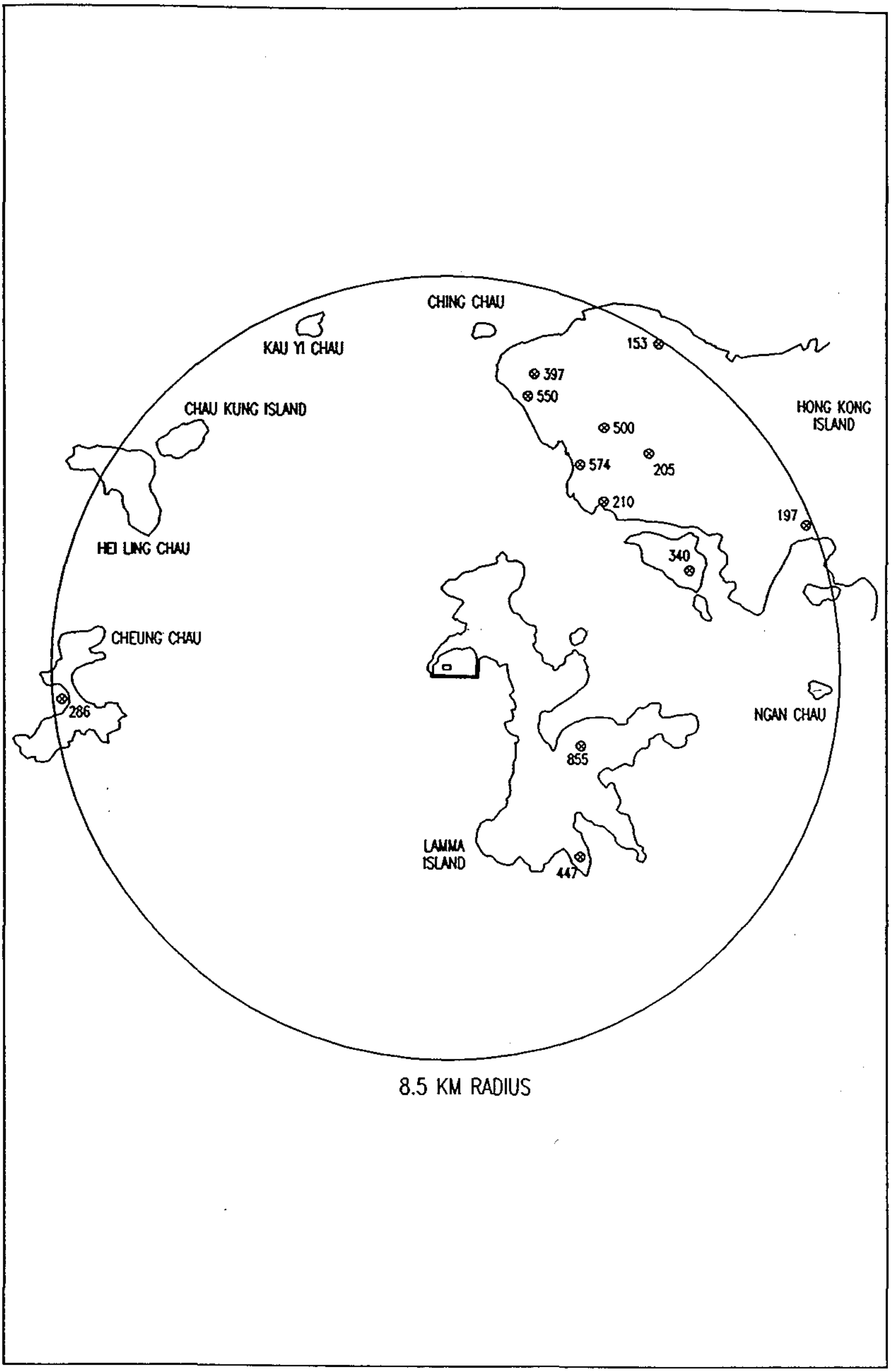

Map showing study area, wind angles and sensor locations.

**Figure 3.1.2**




**Maximum hourly $SO_2$ concentrations for July 1994 (B1, B2) at ground level**

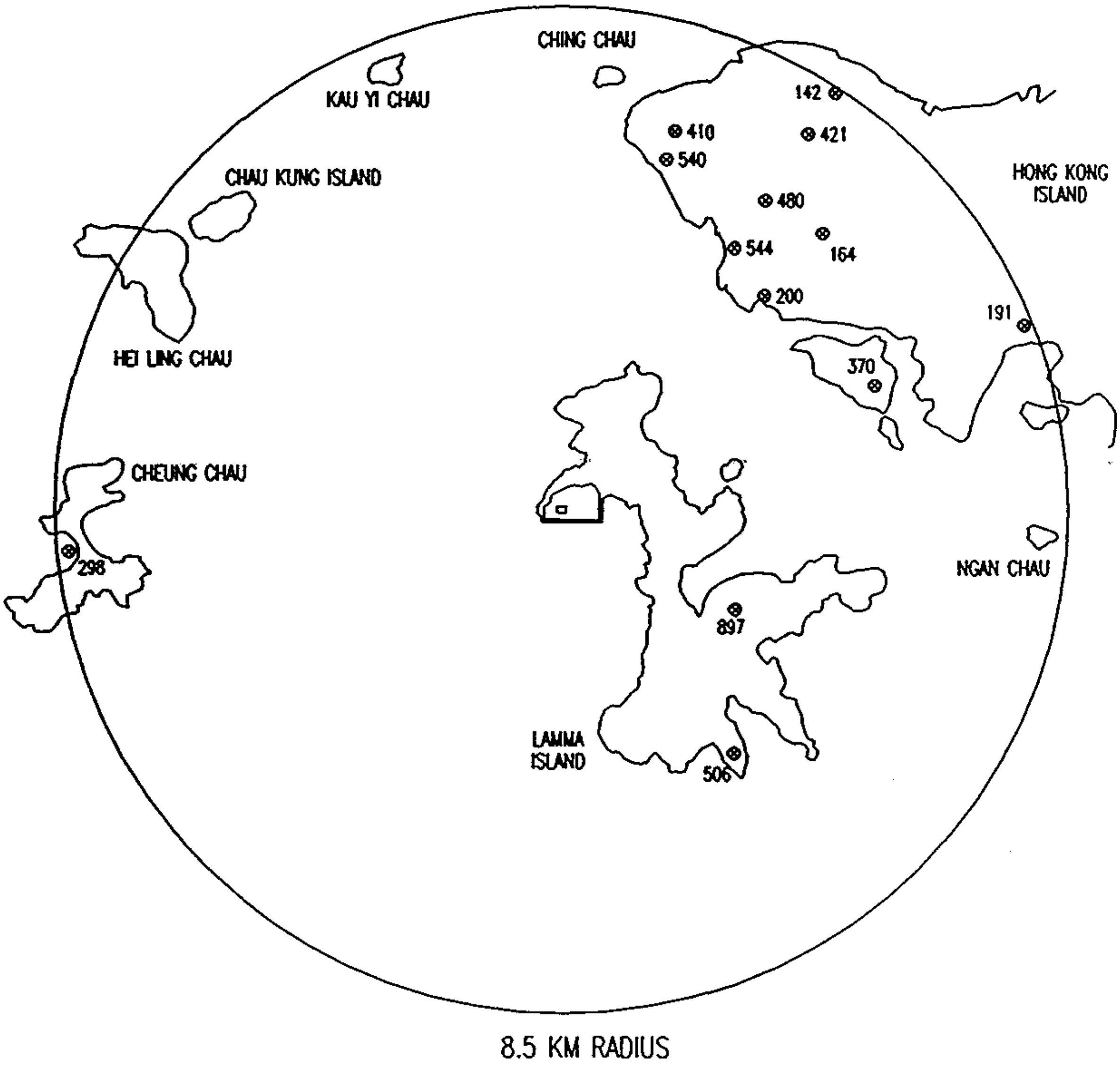
**Figure 3.1.3**




**Maximum hourly $SO_2$ concentrations for July 1994 (B1, B2) at 30m**

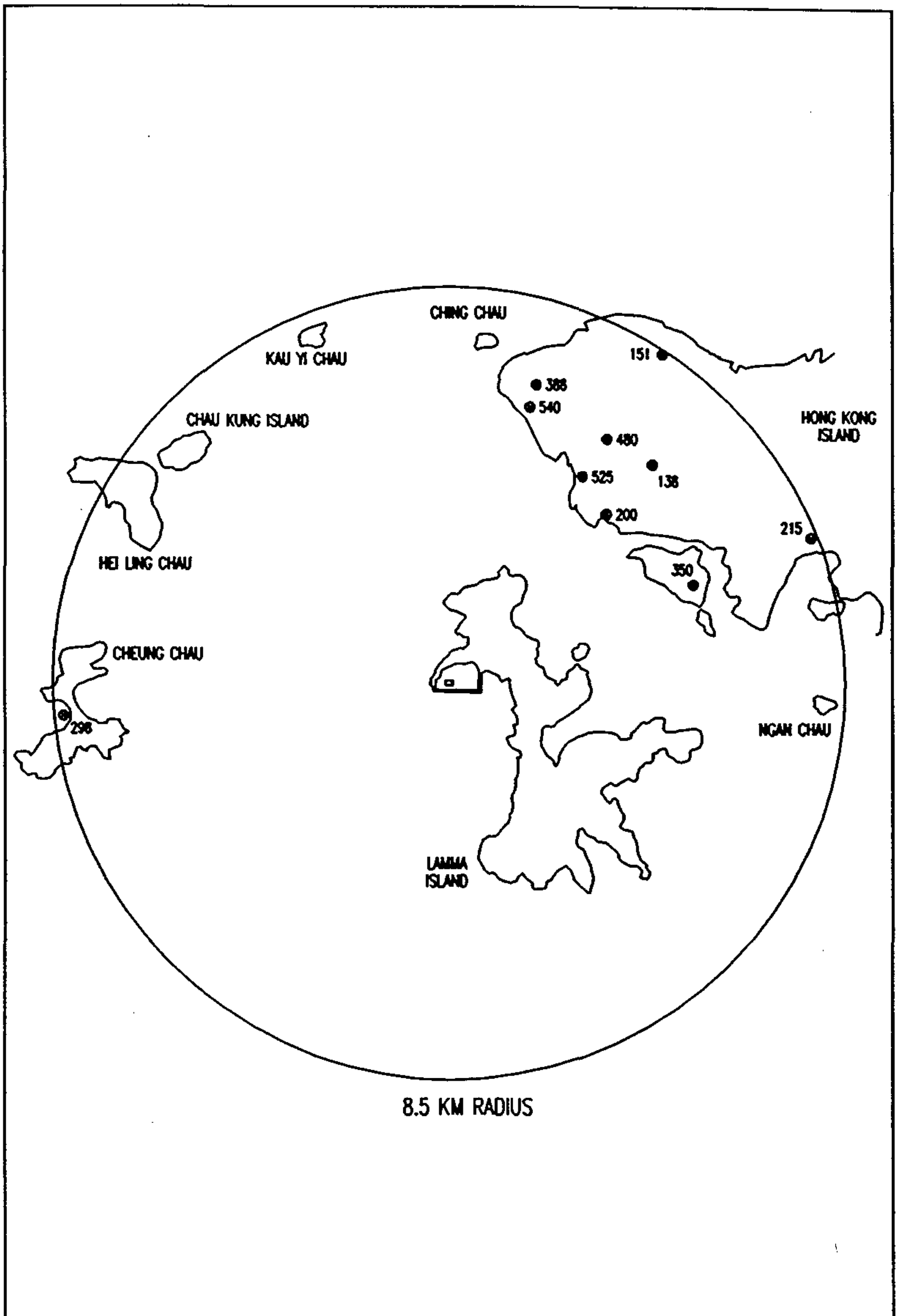
1 8 MAR 1992

**Figure 3.1.4**



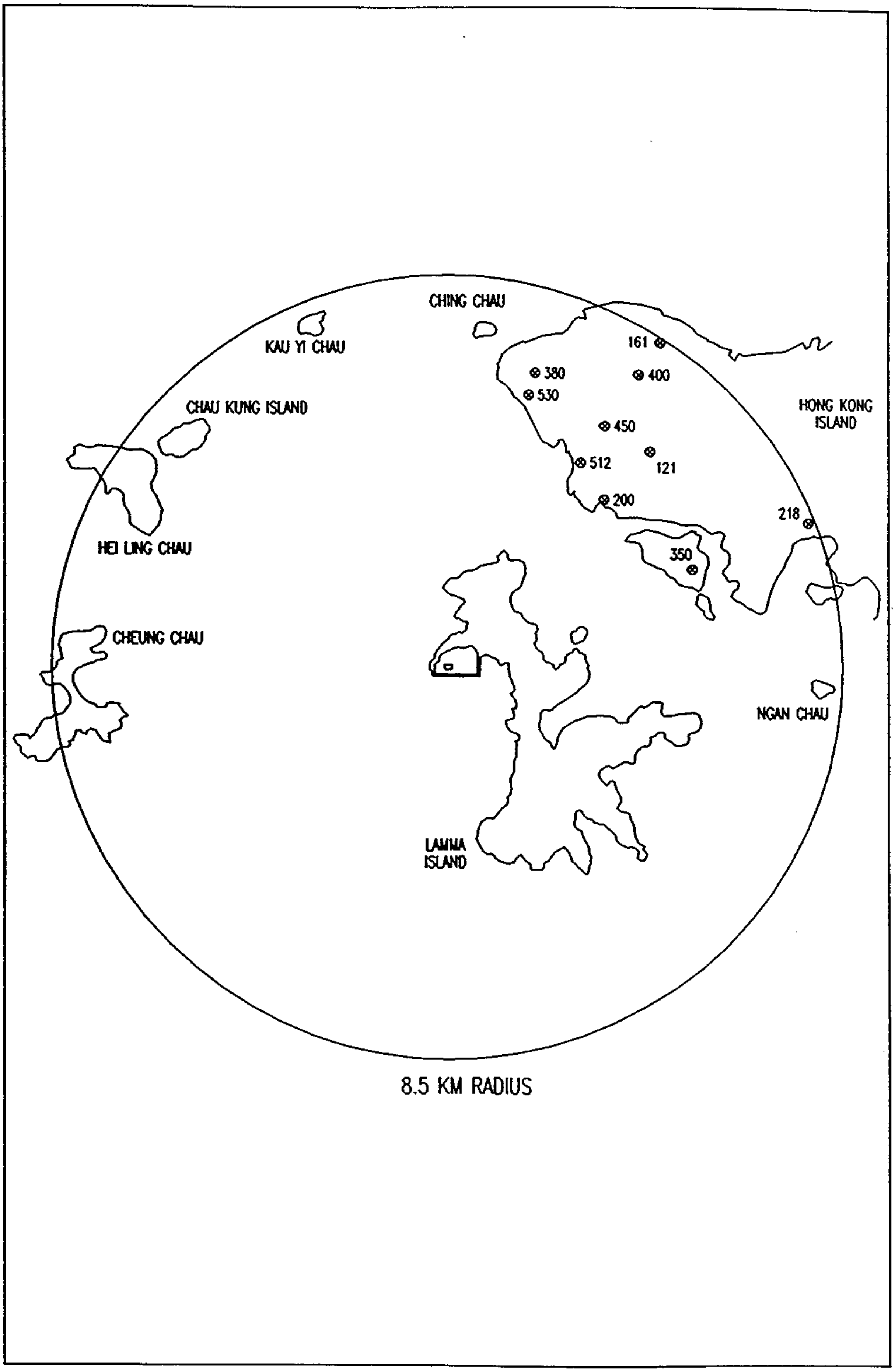

**Maximum hourly $SO_2$ concentrations for July 1994 (B1, B2) at 60m**

Figure 3.1.5

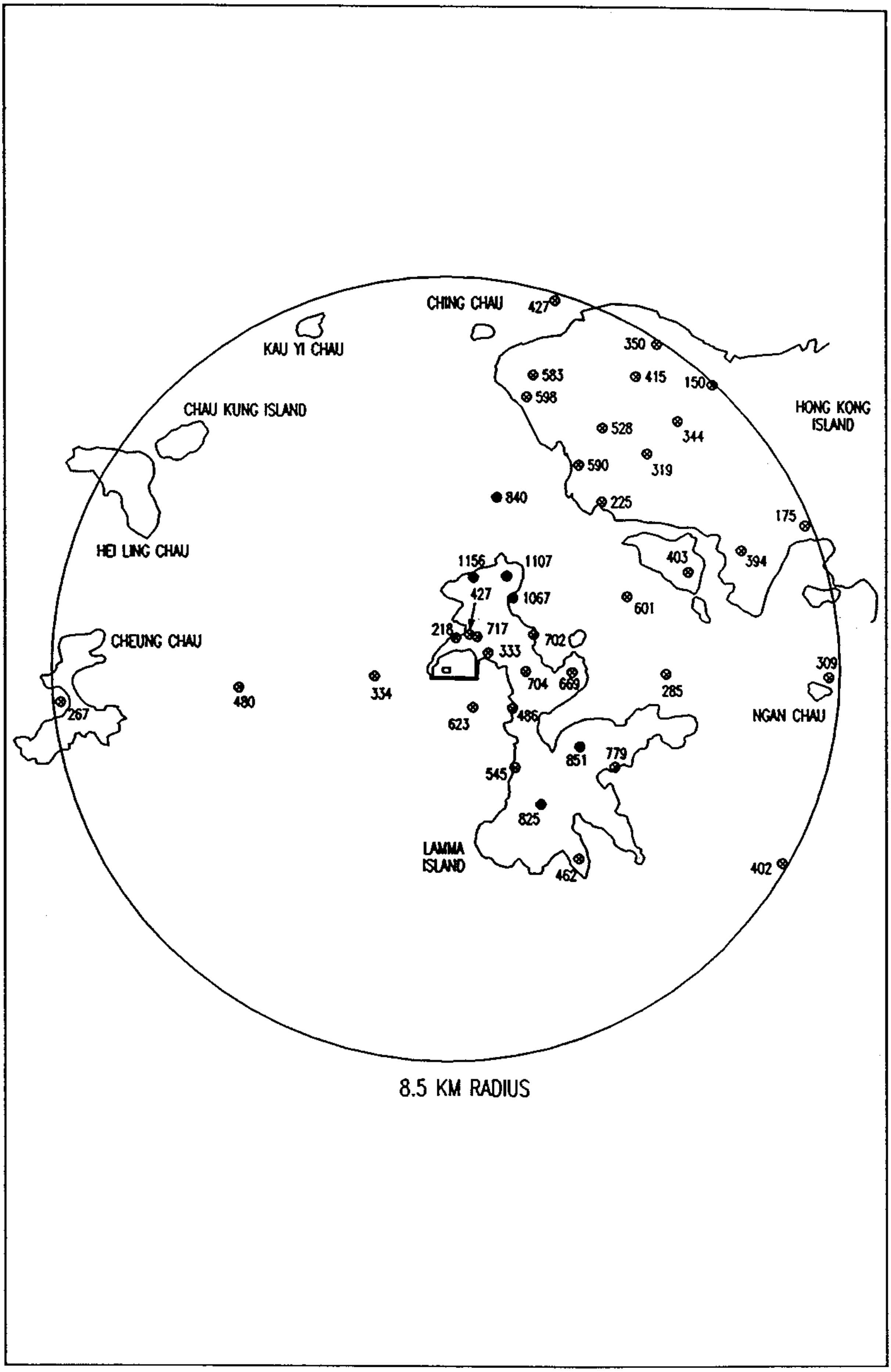



**Maximum hourly $SO_2$ concentrations for July 1994 (B1, B2) at 90m**

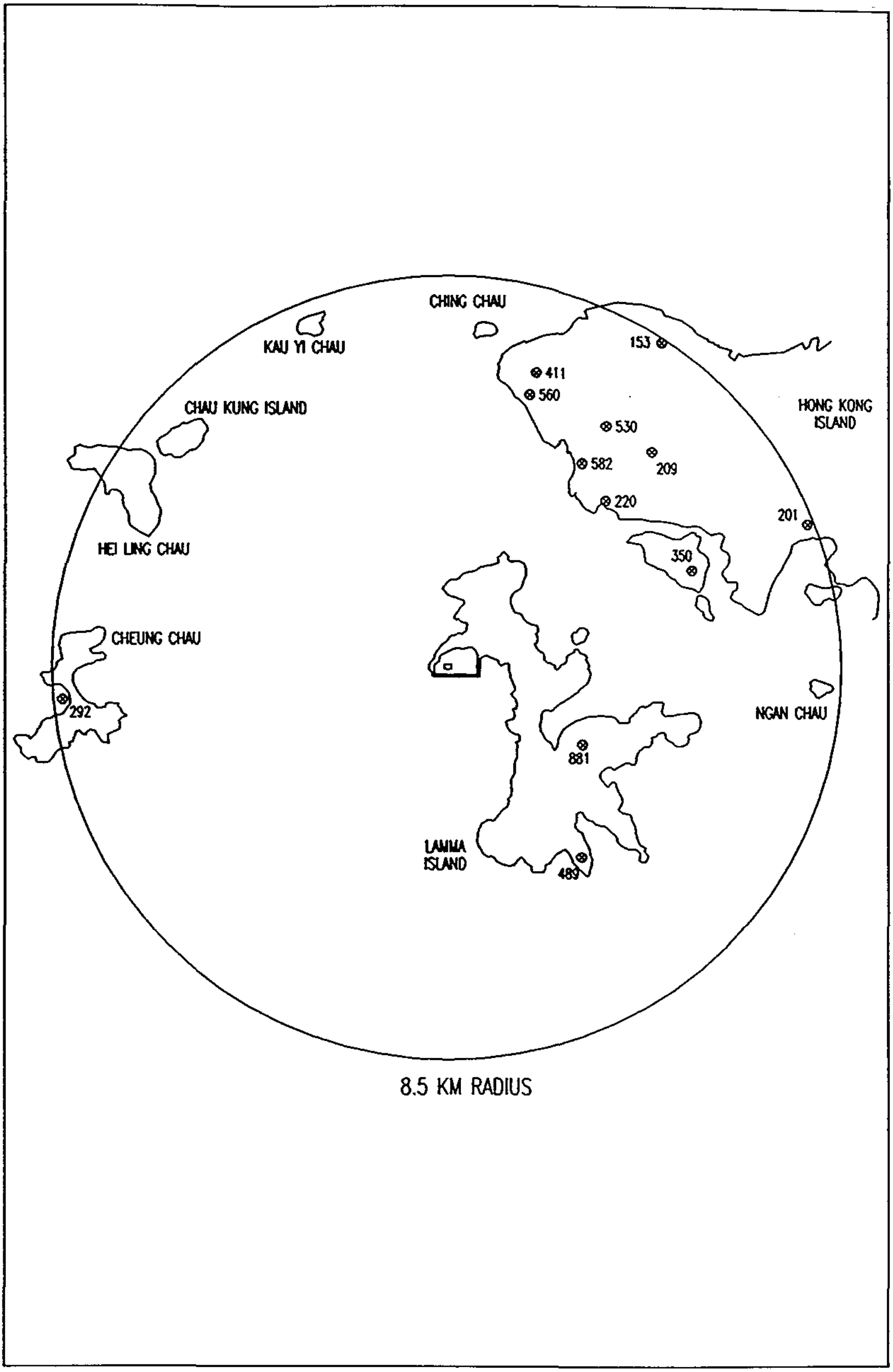
Figure 3.1.6




**Maximum hourly $SO_2$ concentrations for July 1994 (B1, B2) at 120m**

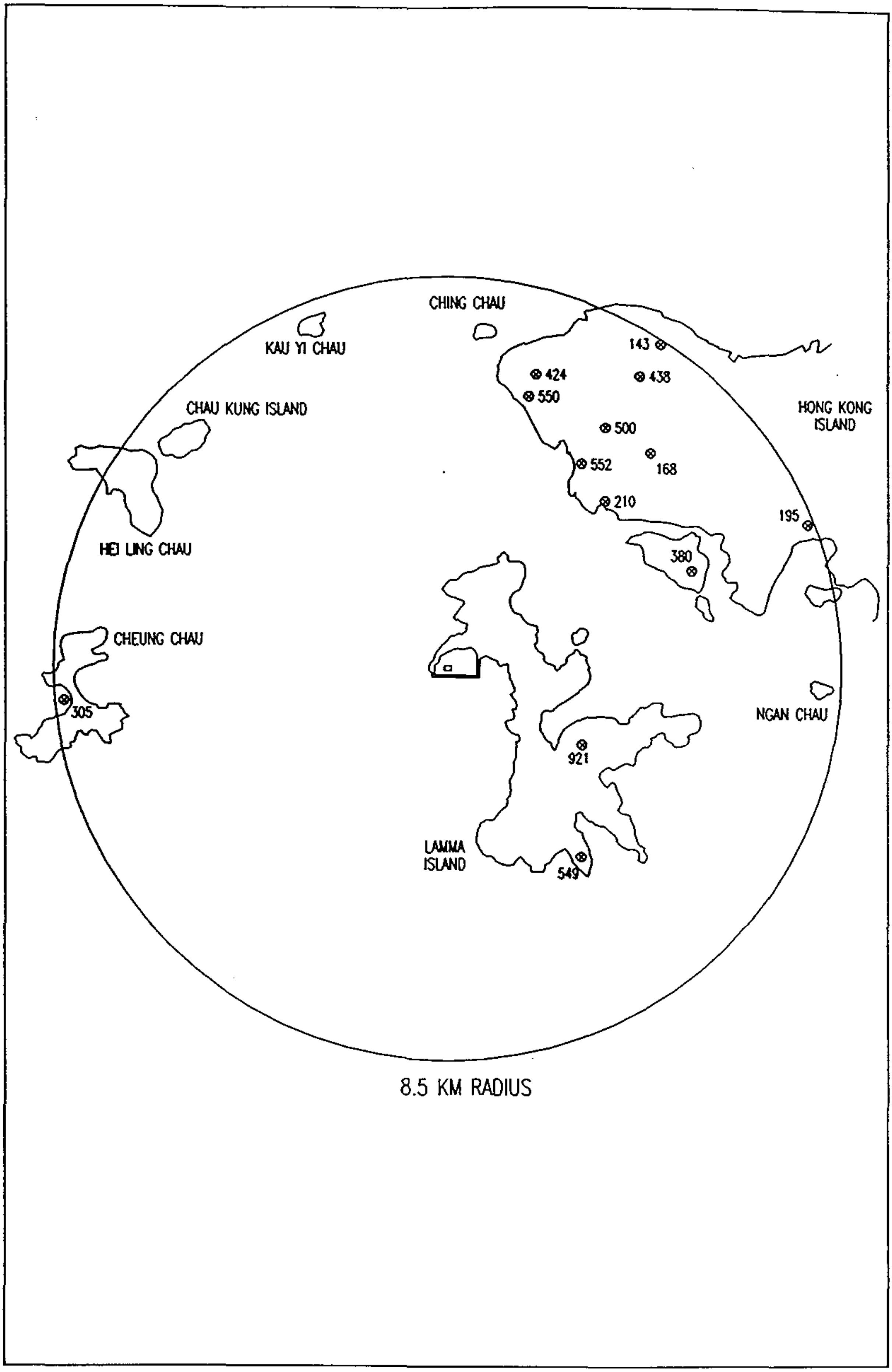



Maximum hourly $SO_2$ concentrations for July 2000 (T1, T4) at ground level



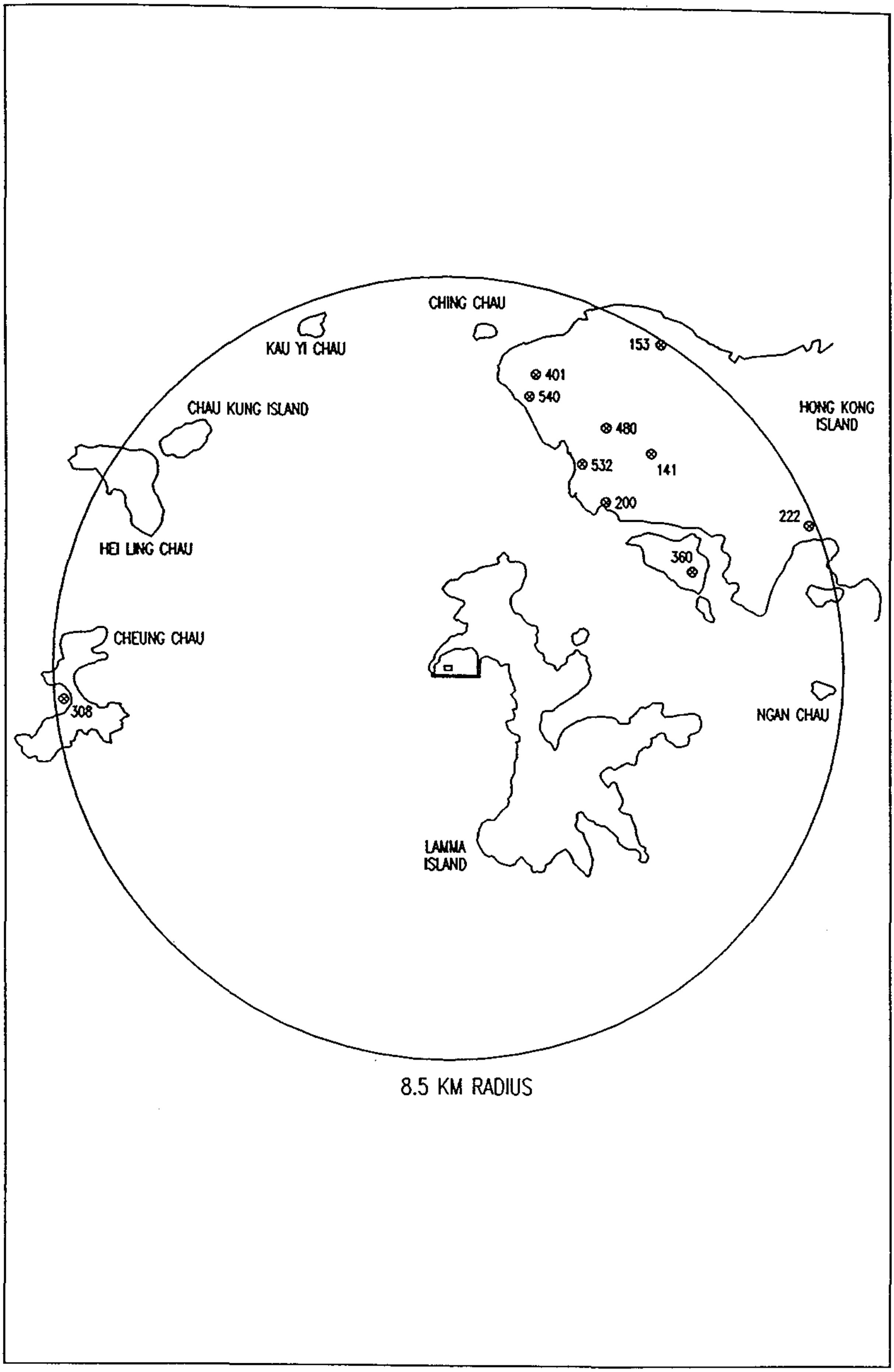

**Maximum hourly $SO_2$ concentrations for July 2000 (T1, T4) at 30m**

Figure 3.1.9



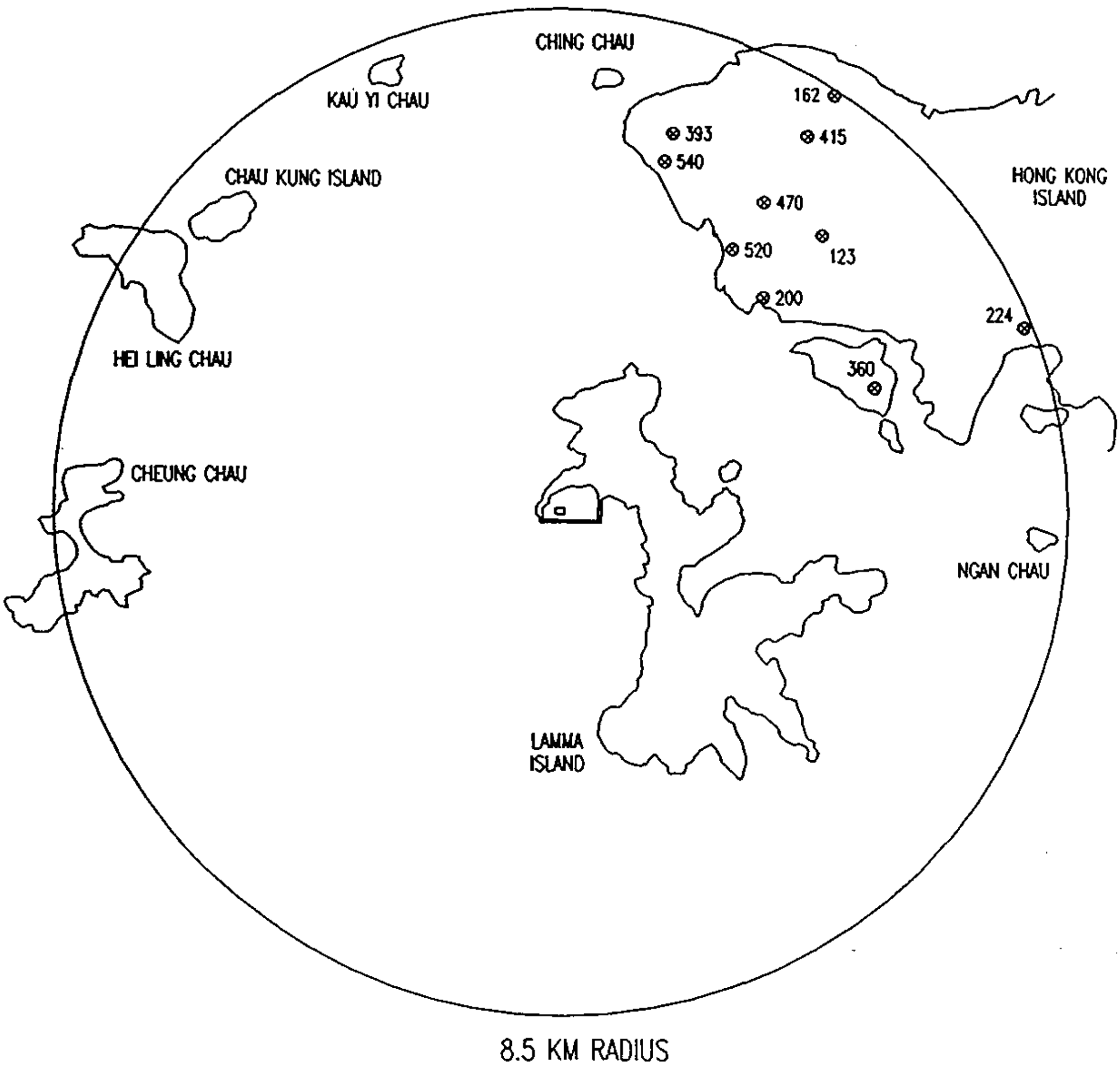

**Maximum hourly $SO_2$ concentrations for July 2000 (T1, T4) at 60m**

Figure 3.1.10



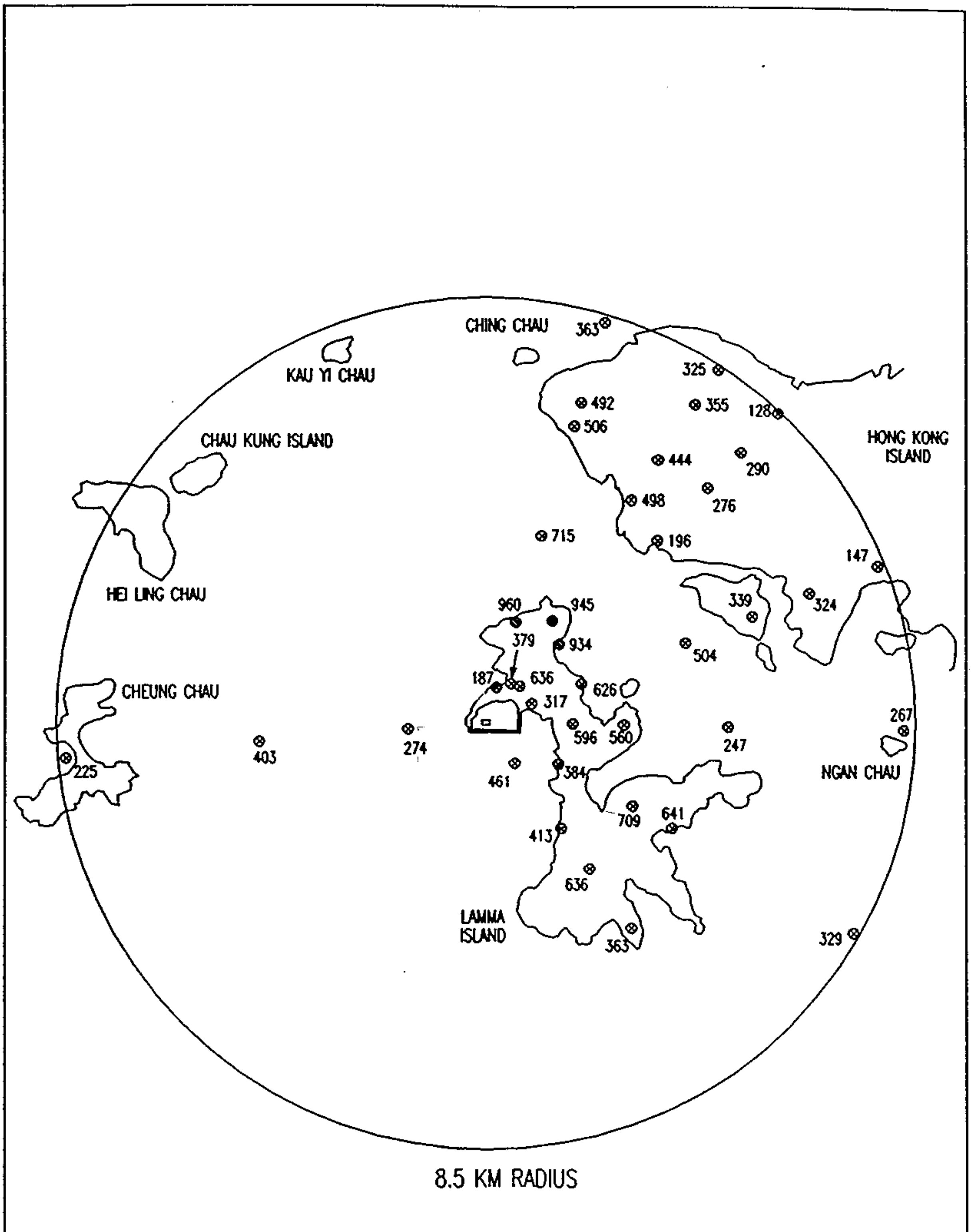

Maximum hourly $SO_2$ concentrations for July 2000 (T1, T4) at 90m

**Figure 3.1.11**



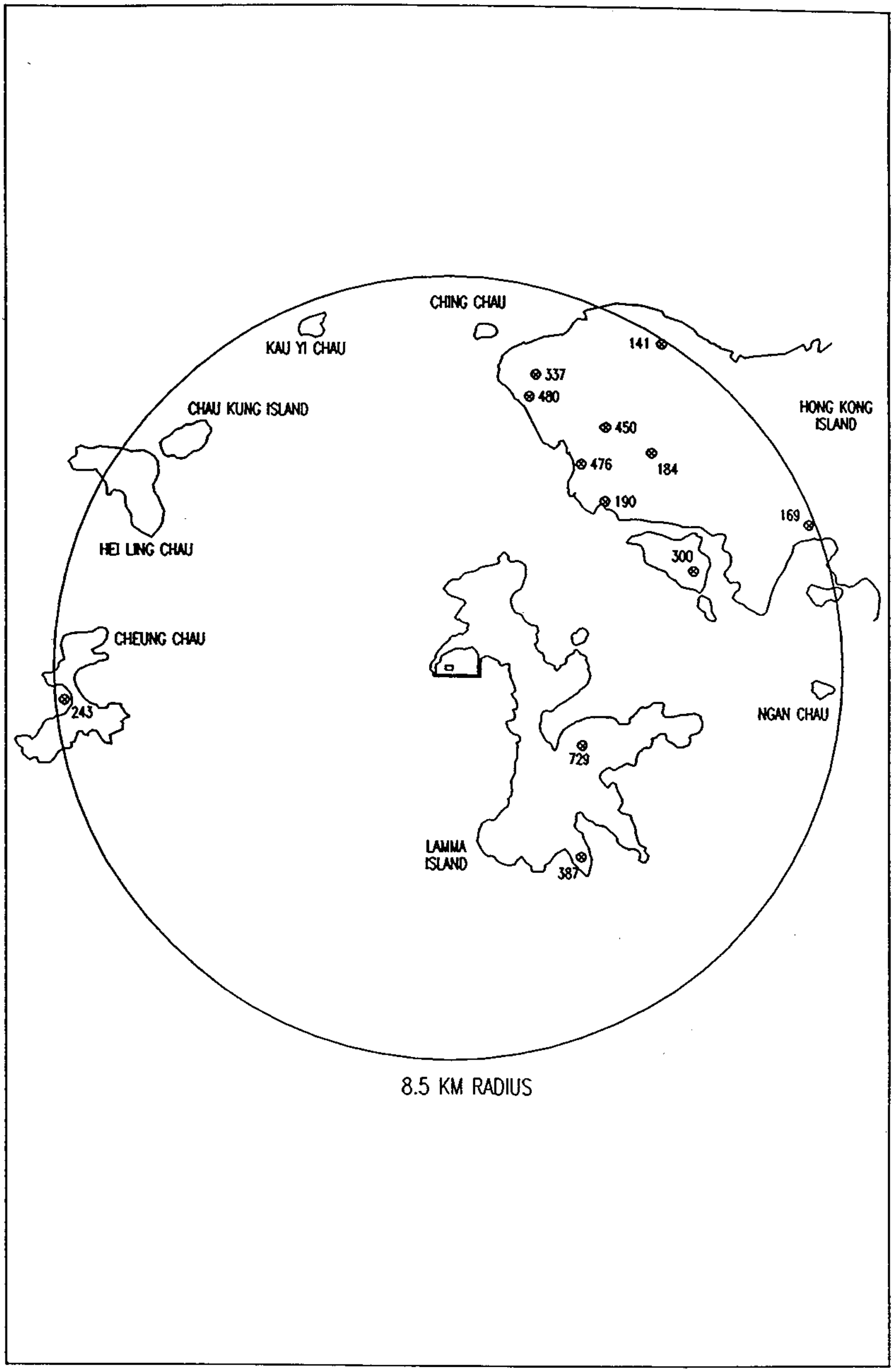

**Maximum hourly $SO_2$ concentrations for July 2000 (T1, T4) at 120m**

Figure 3.1.12



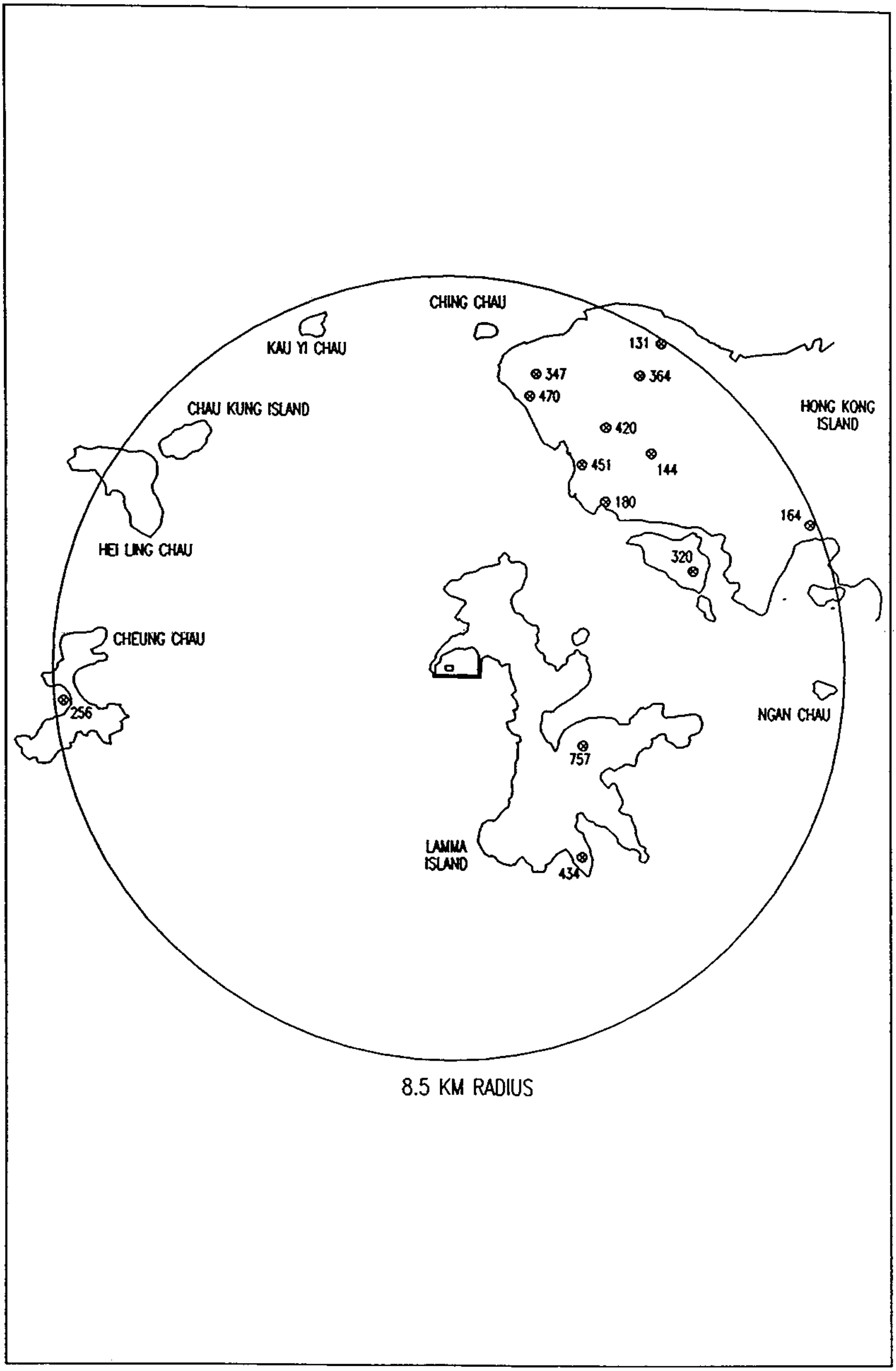

Maximum hourly $SO_2$ concentrations for July 2000 (T2, T5) at ground level

**Figure 3.1.13**



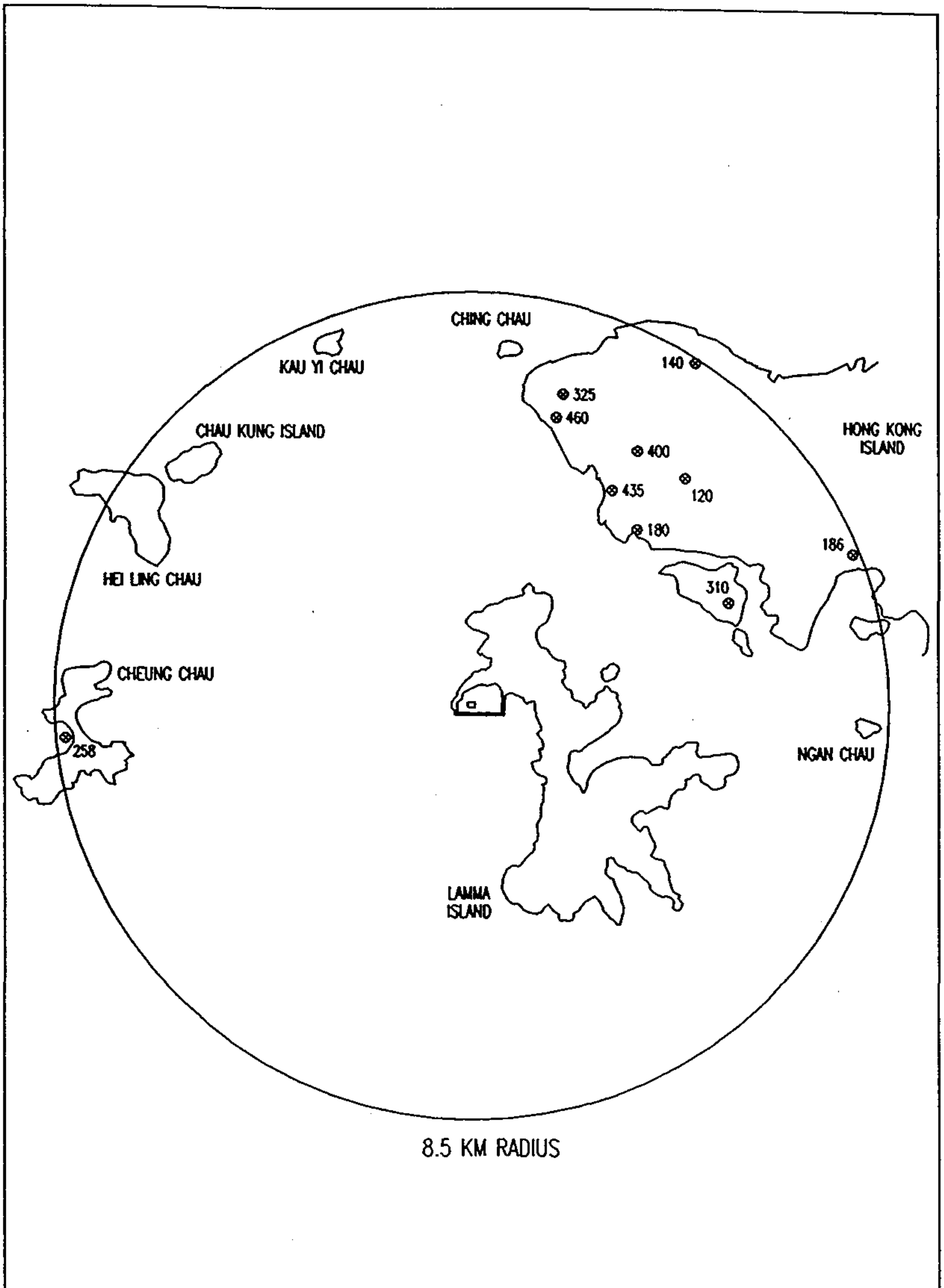

**Maximum hourly $SO_2$ concentrations for July 2000 (T2, T5) at 30m**

**Figure 3.1.14**

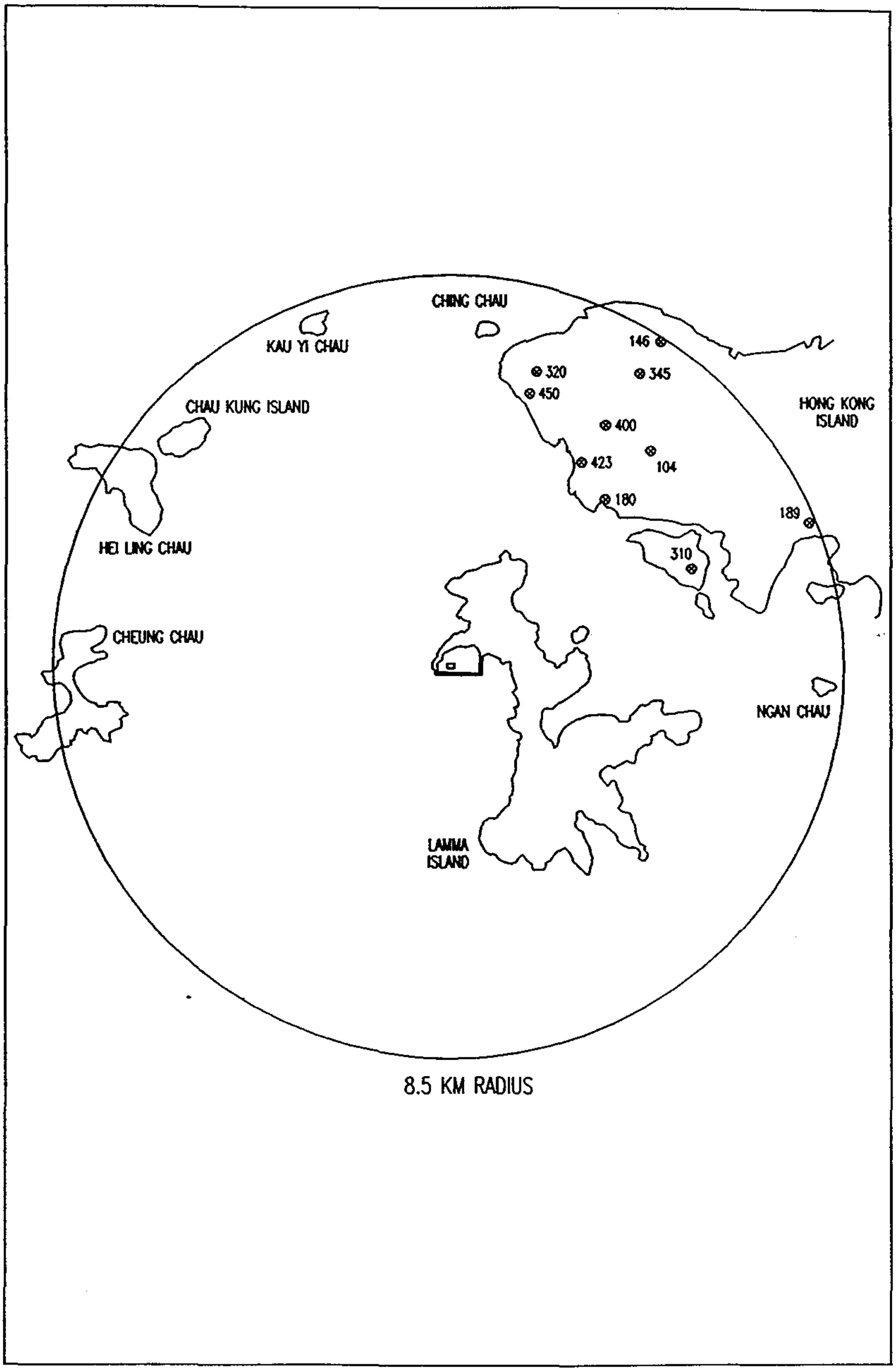



Maximum hourly $SO_2$ concentrations for July 2000 (T2, T5) at 60m

**Figure 3.1.15**

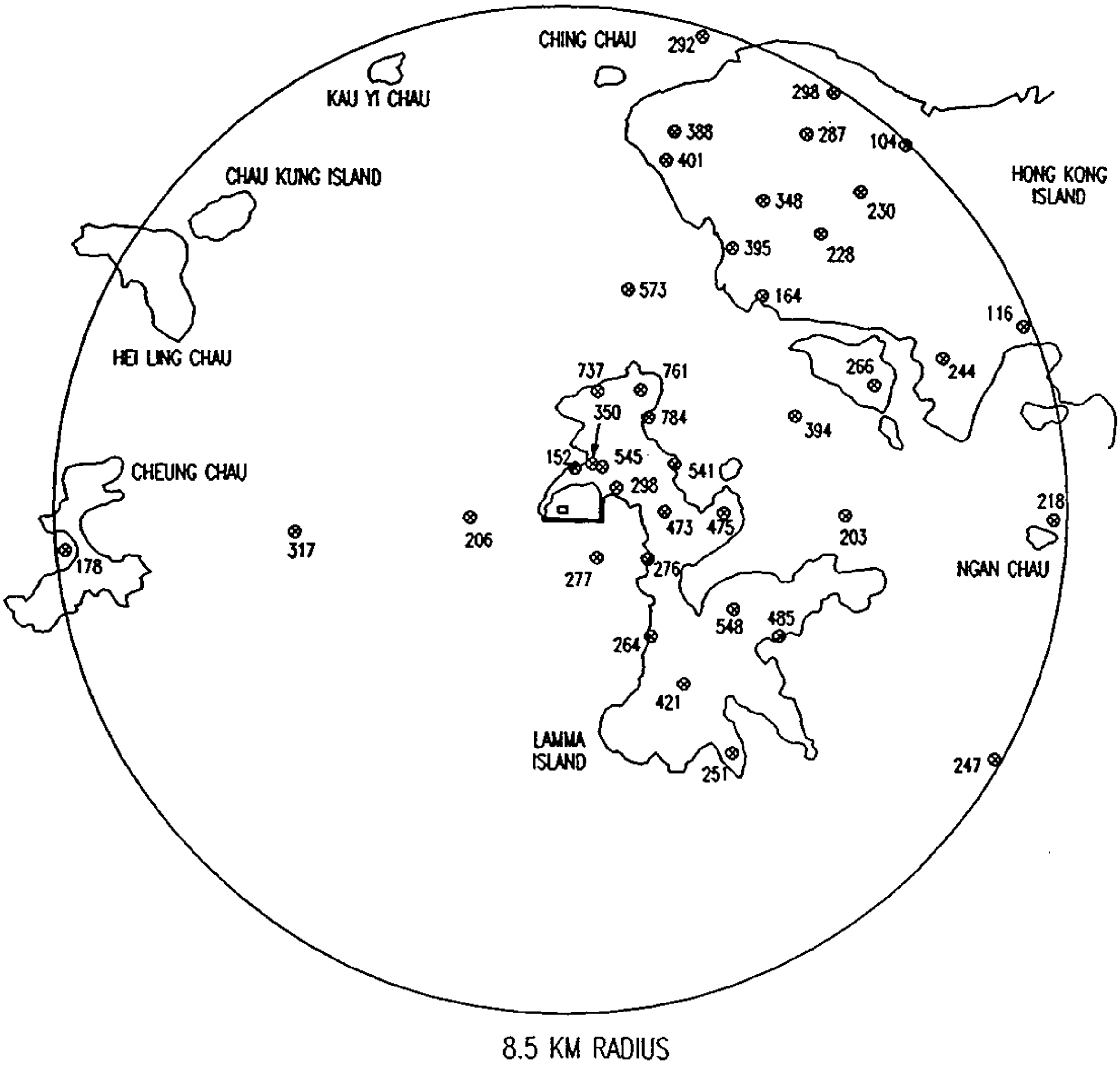



**Maximum hourly $SO_2$ concentrations for July 2000 (T2, T5) at 90m**



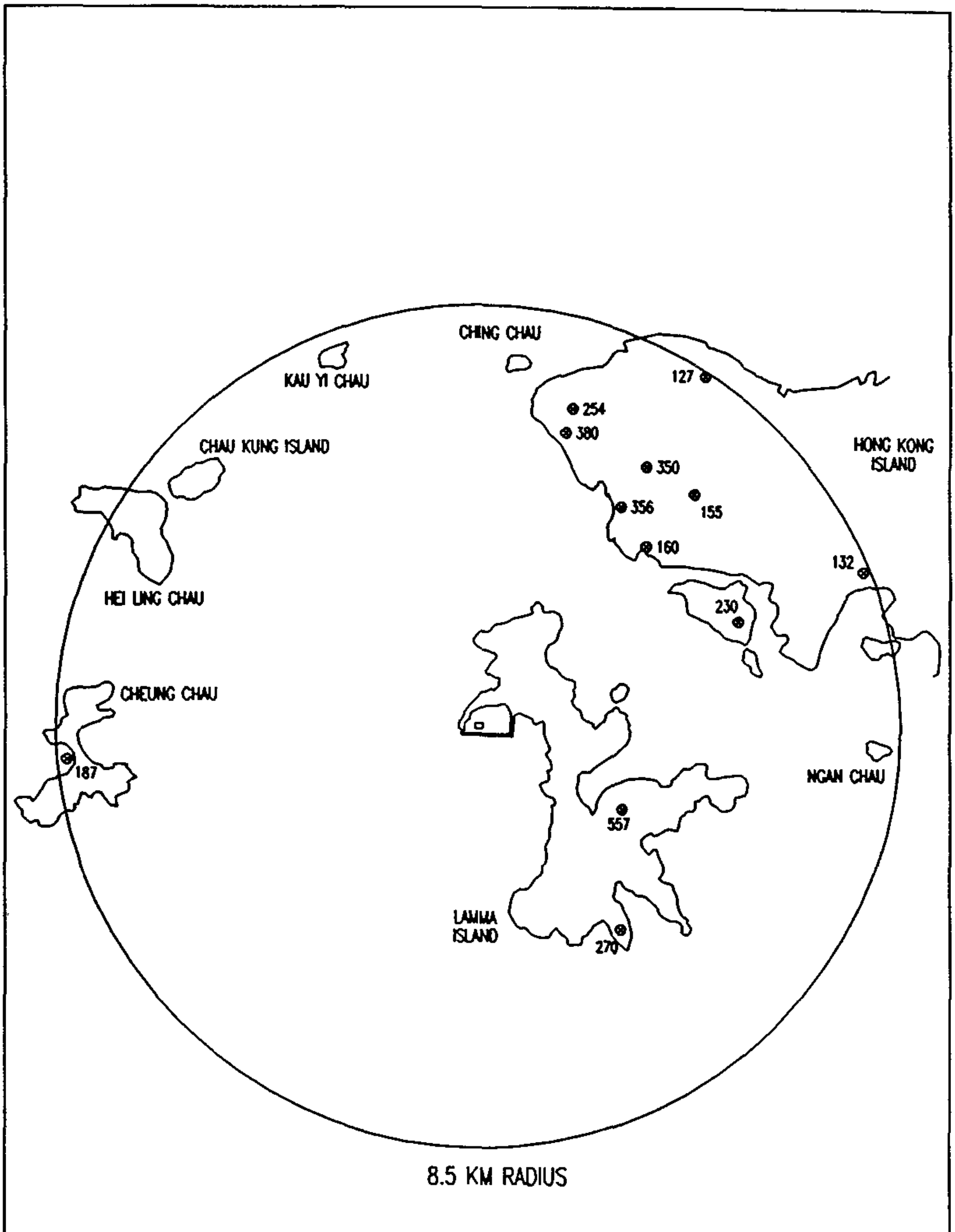

Maximum hourly $SO_2$ concentrations for July 2000 (T2, T5) at 120m

**Figure 3.1.17**



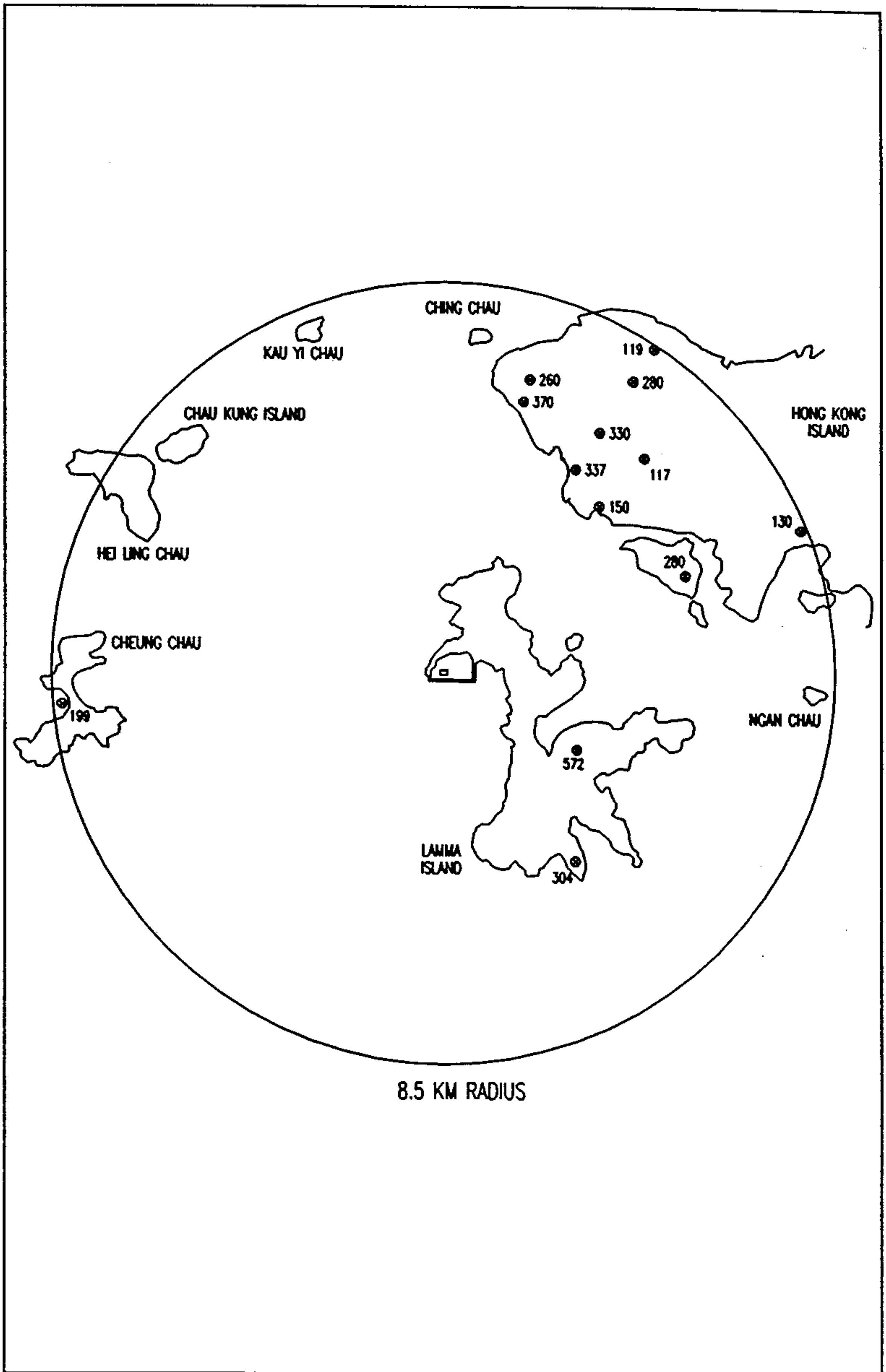

**Maximum hourly $SO_2$ concentrations for July 2000 (T3, T6) at ground level**

Figure 3.1.18



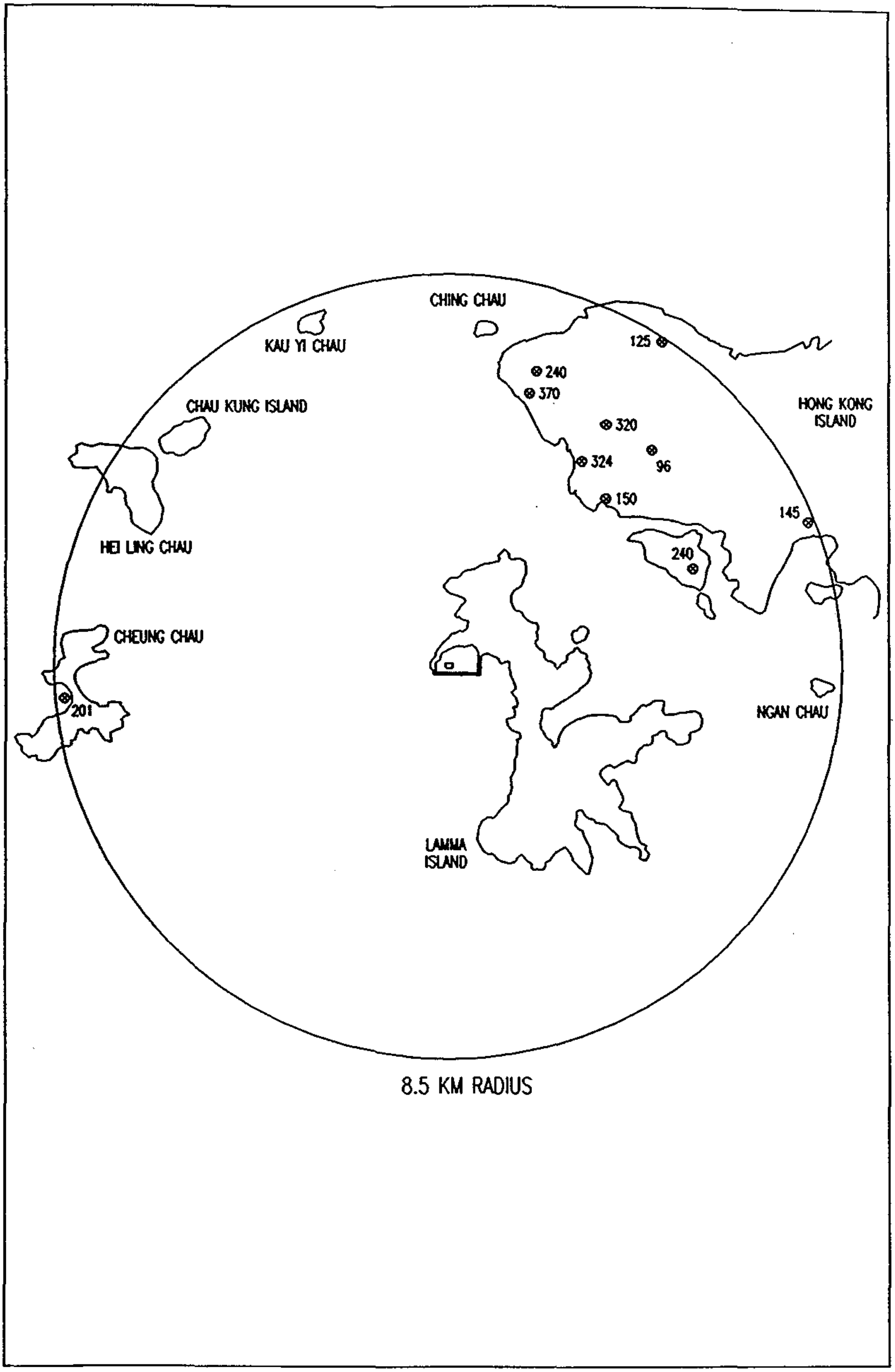

Maximum hourly $SO_2$ concentrations for July 2000 (T3, T6) at 30m

Figure 3.1.19

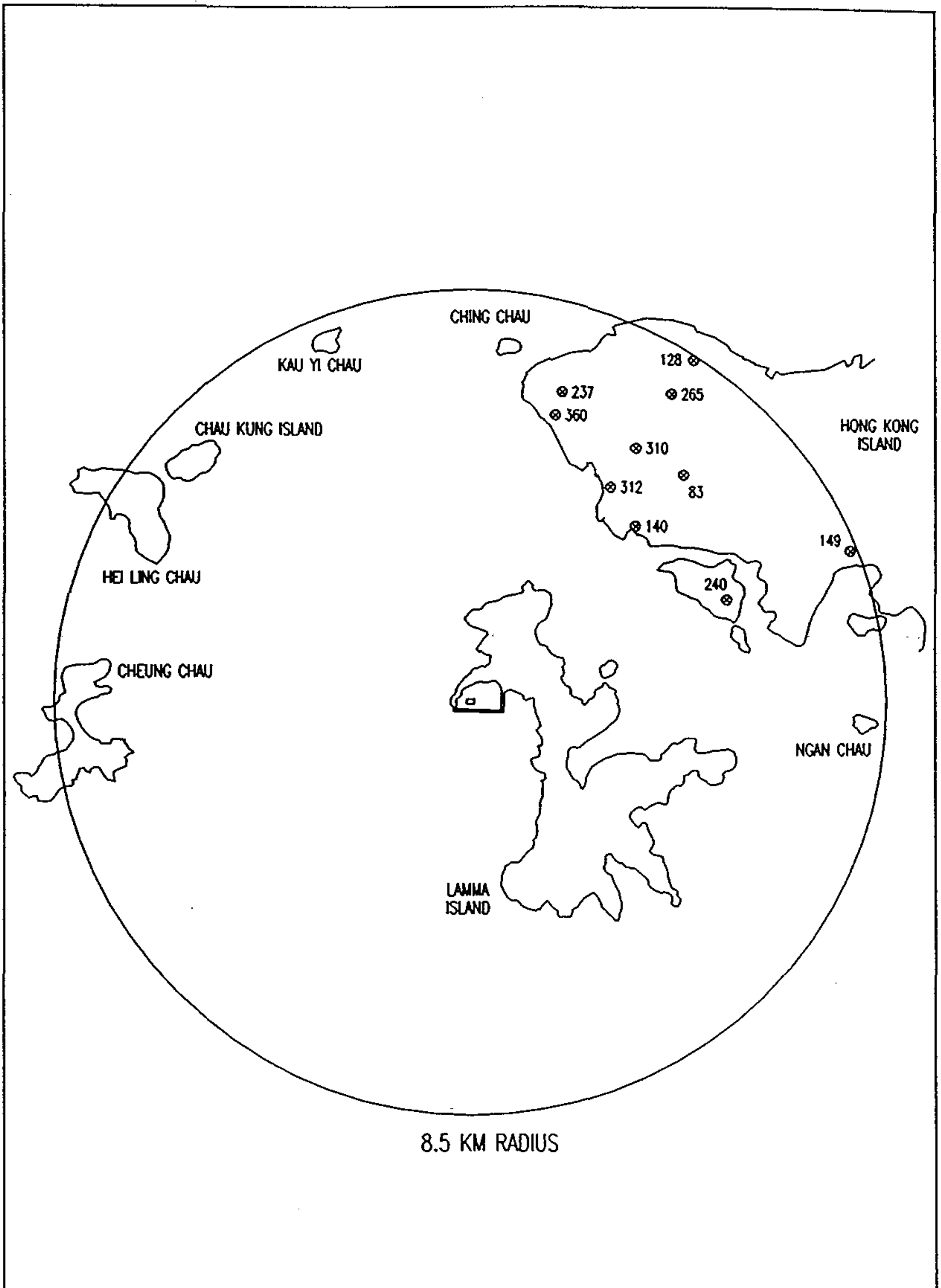



**Maximum hourly $SO_2$ concentrations for July 2000 (T3, T6) at 60m**

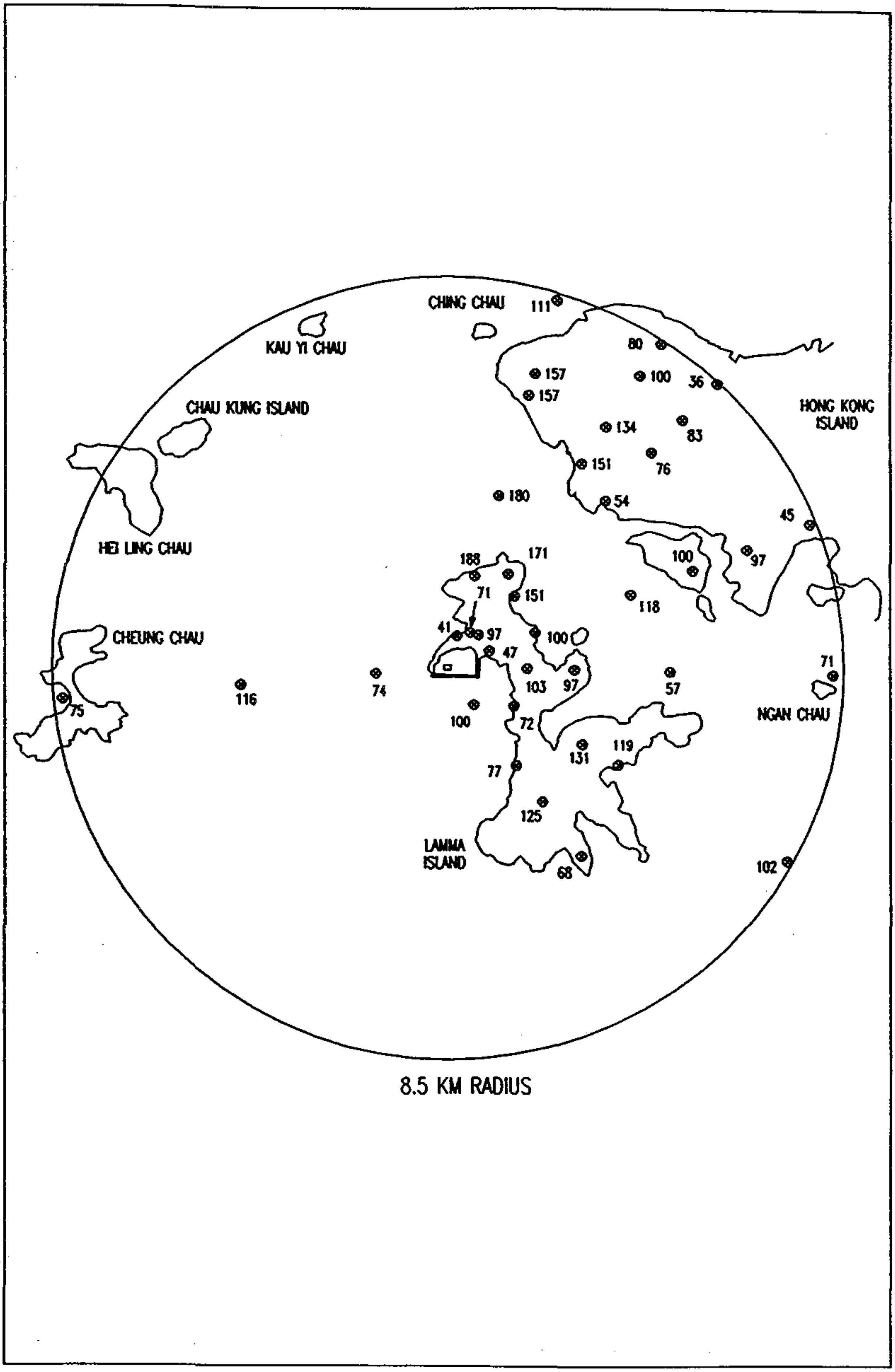
**Figure 3.1.20**




**Maximum hourly $SO_2$ concentrations for July 2000 (T3, T6) at 90m**

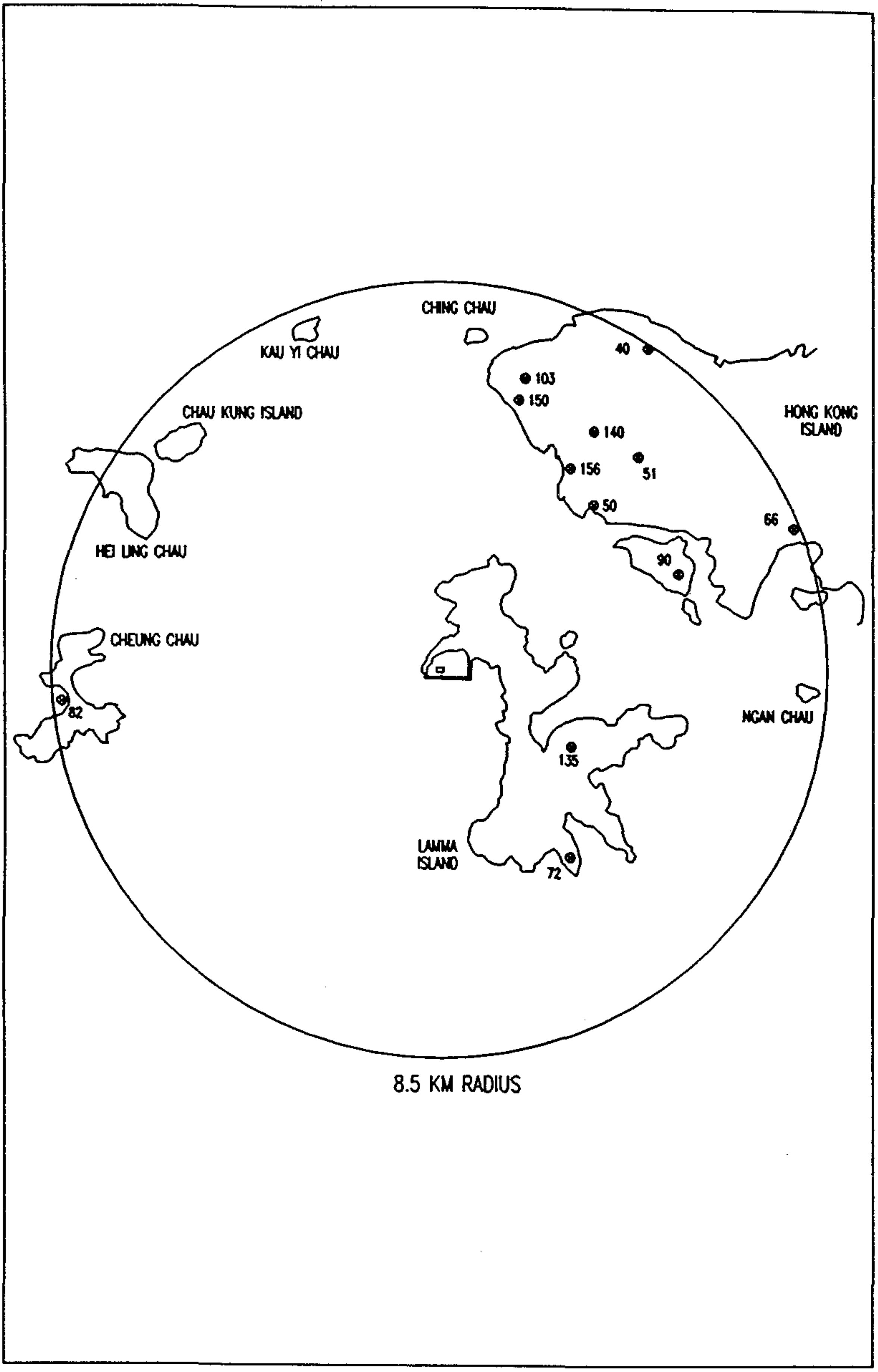



**Maximum hourly $SO_2$ concentrations for July 2000 (T3, T6) at 120m**



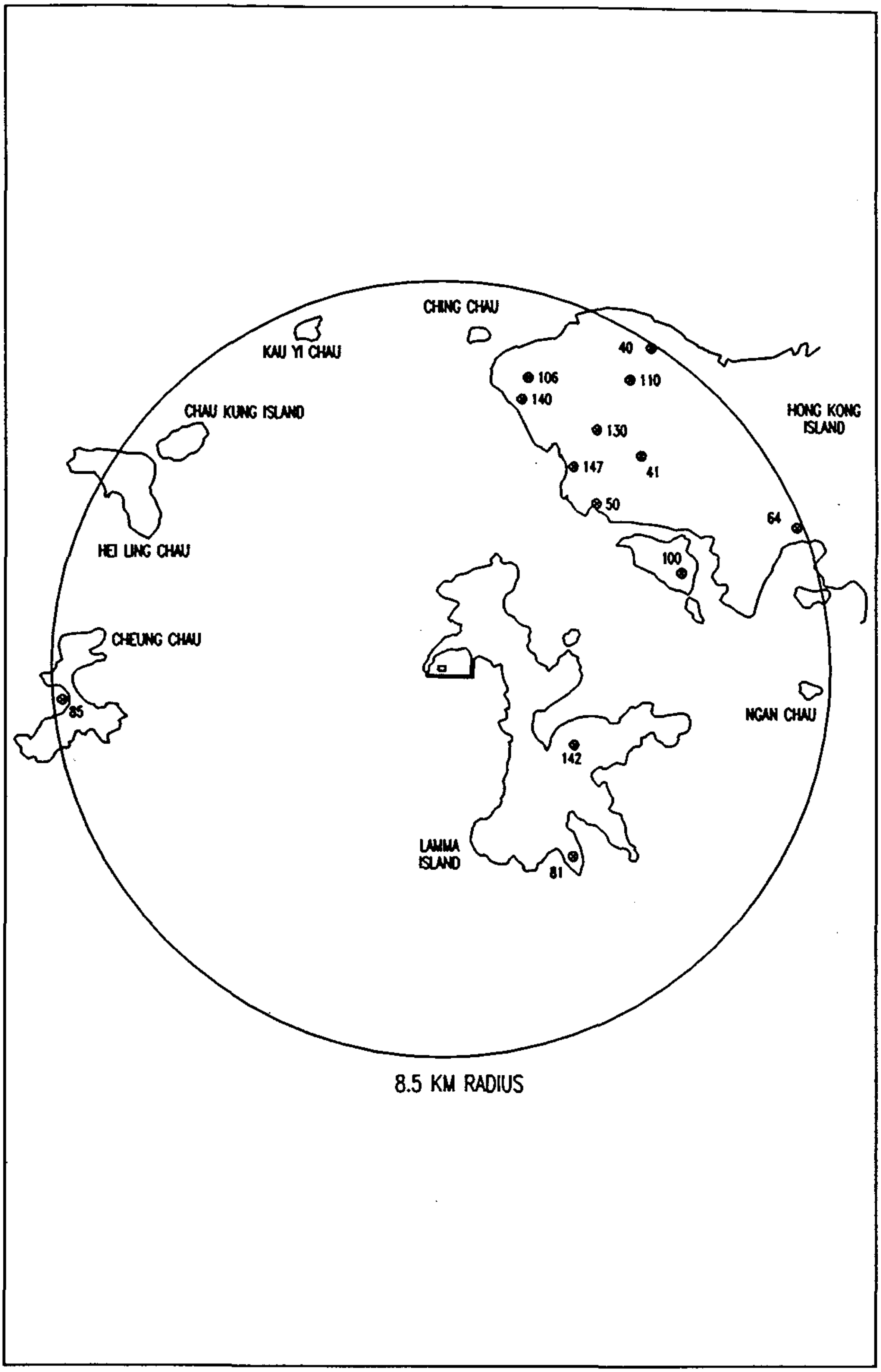

Maximum hourly $NO_2$ concentrations for July 1994 (B1, B2) at ground level

Figure 3.1.23



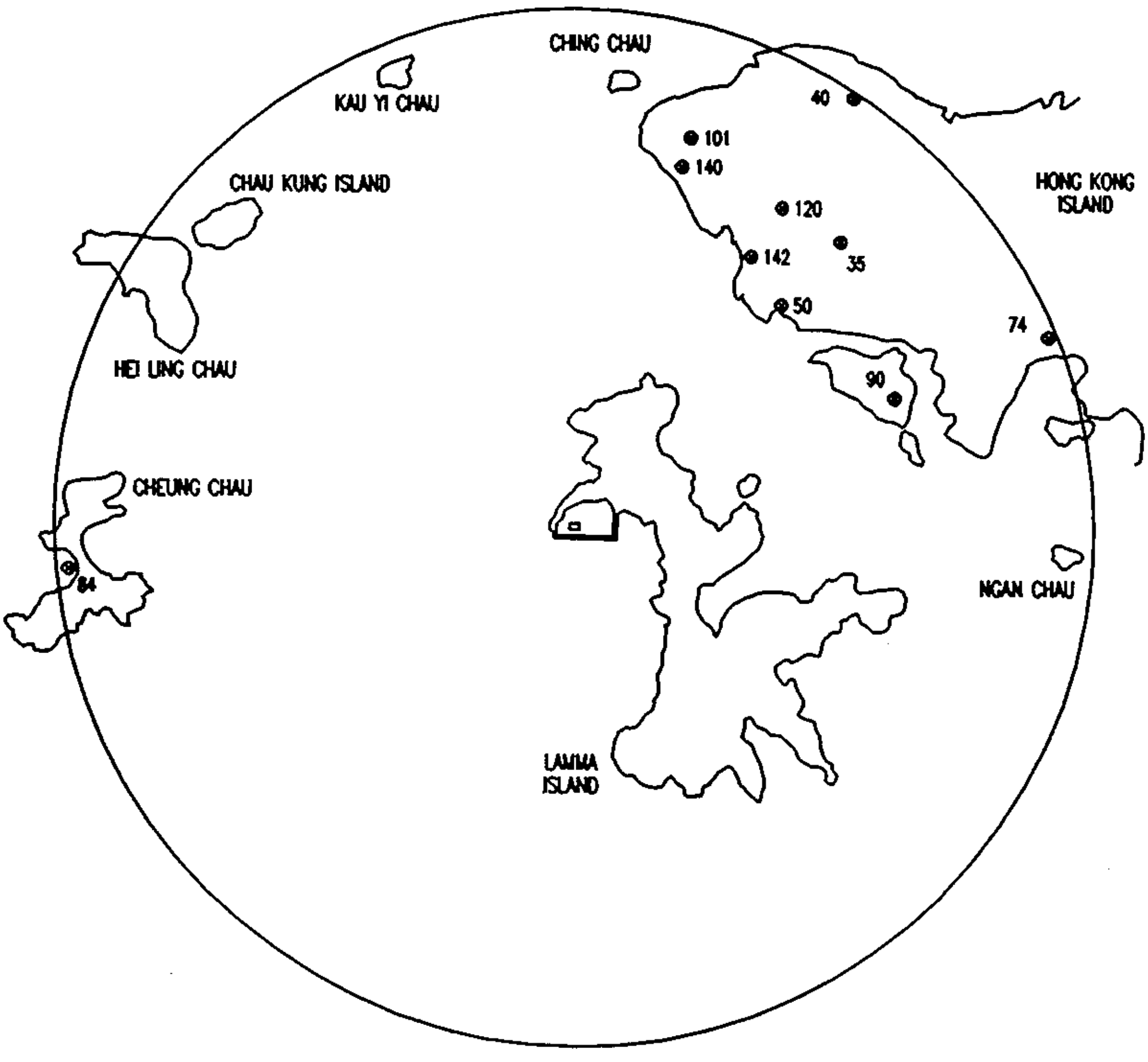

Maximum hourly $NO_2$ concentrations for July 1994 (B1, B2) at 30m

**Figure 3.1.24**



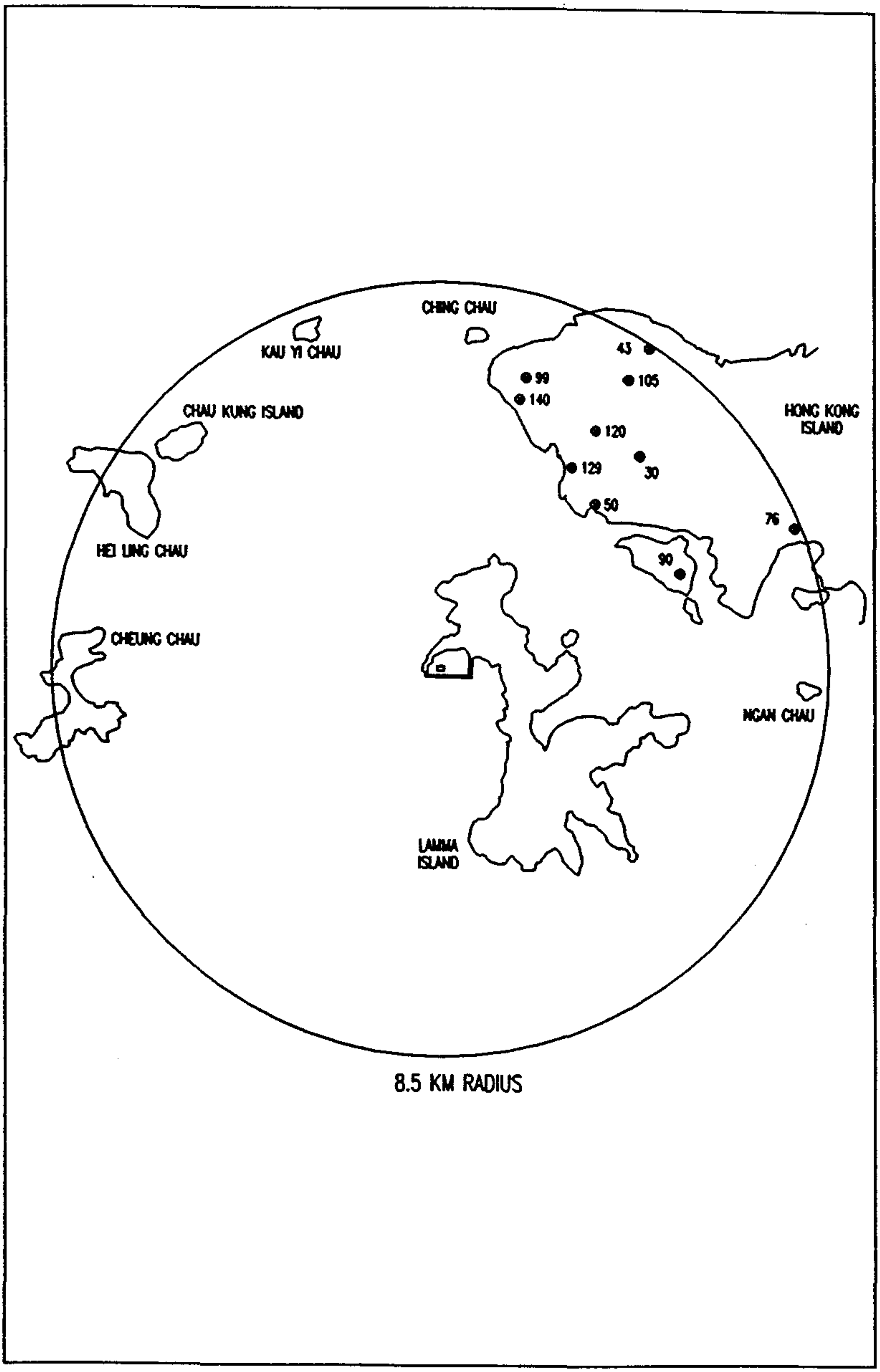

**Maximum hourly $NO_2$ concentrations for July 1994 (B1, B2) at 60m**

Figure 3.1.25



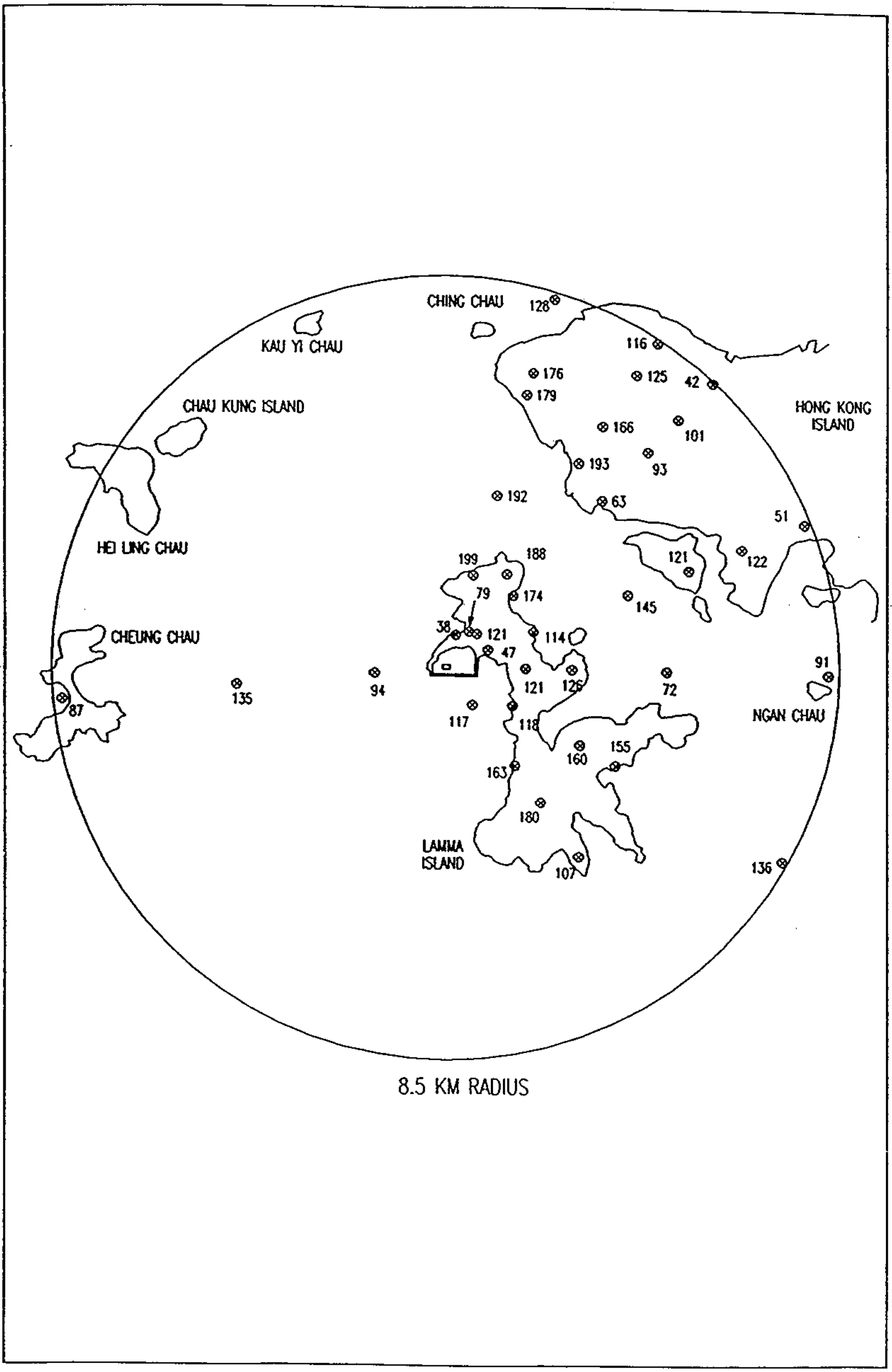

**Maximum hourly $NO_2$ concentrations for July 1994 (B1, B2) at 90m**

Figure 3.1.26



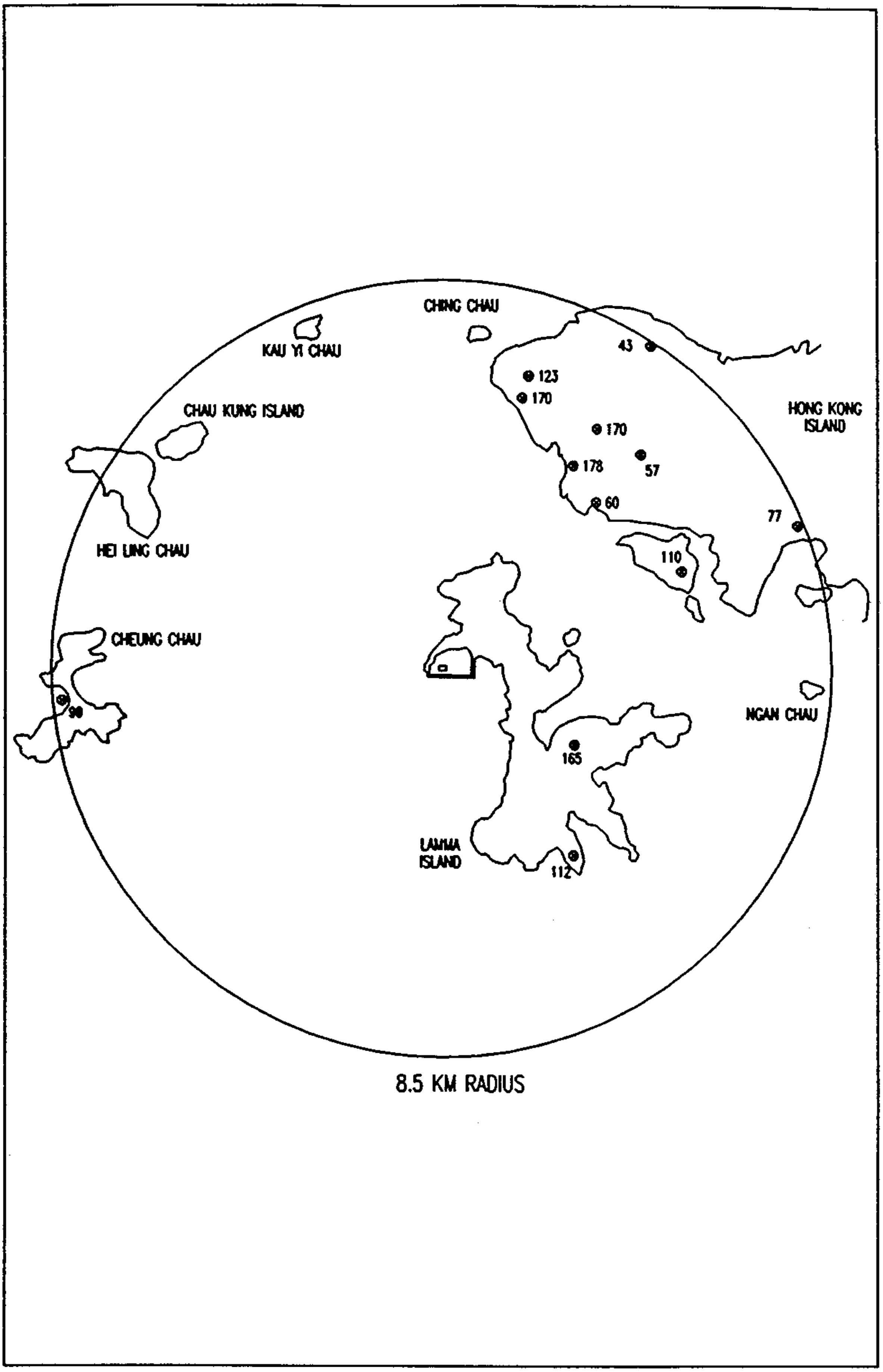

**Maximum hourly $NO_2$ concentrations for July 1994 (B1, B2) at 120m**

Figure 3.1.27



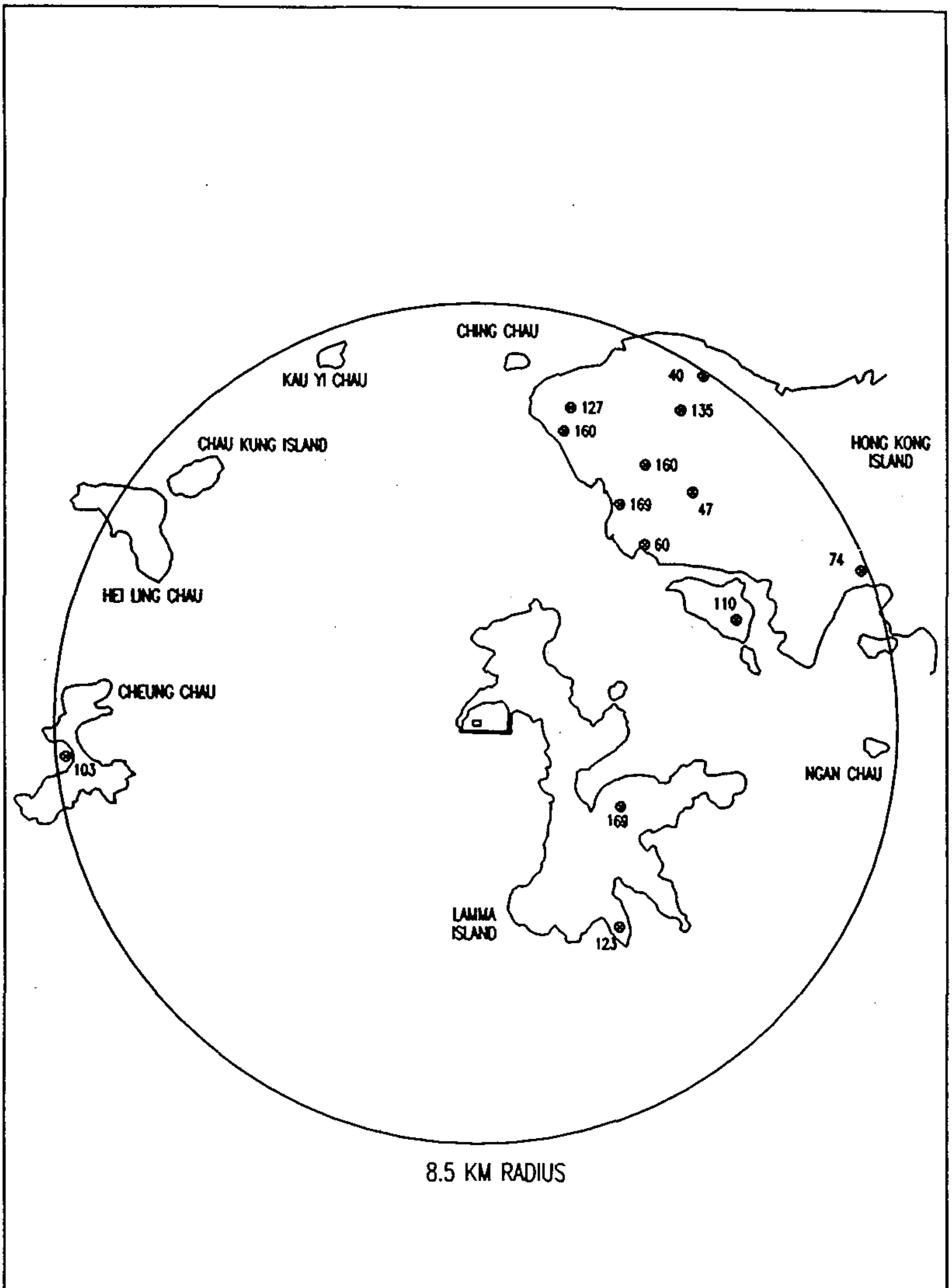

Maximum hourly $NO_2$ concentrations for July 2000 (T1, T4) at ground level

Figure 3.1.28



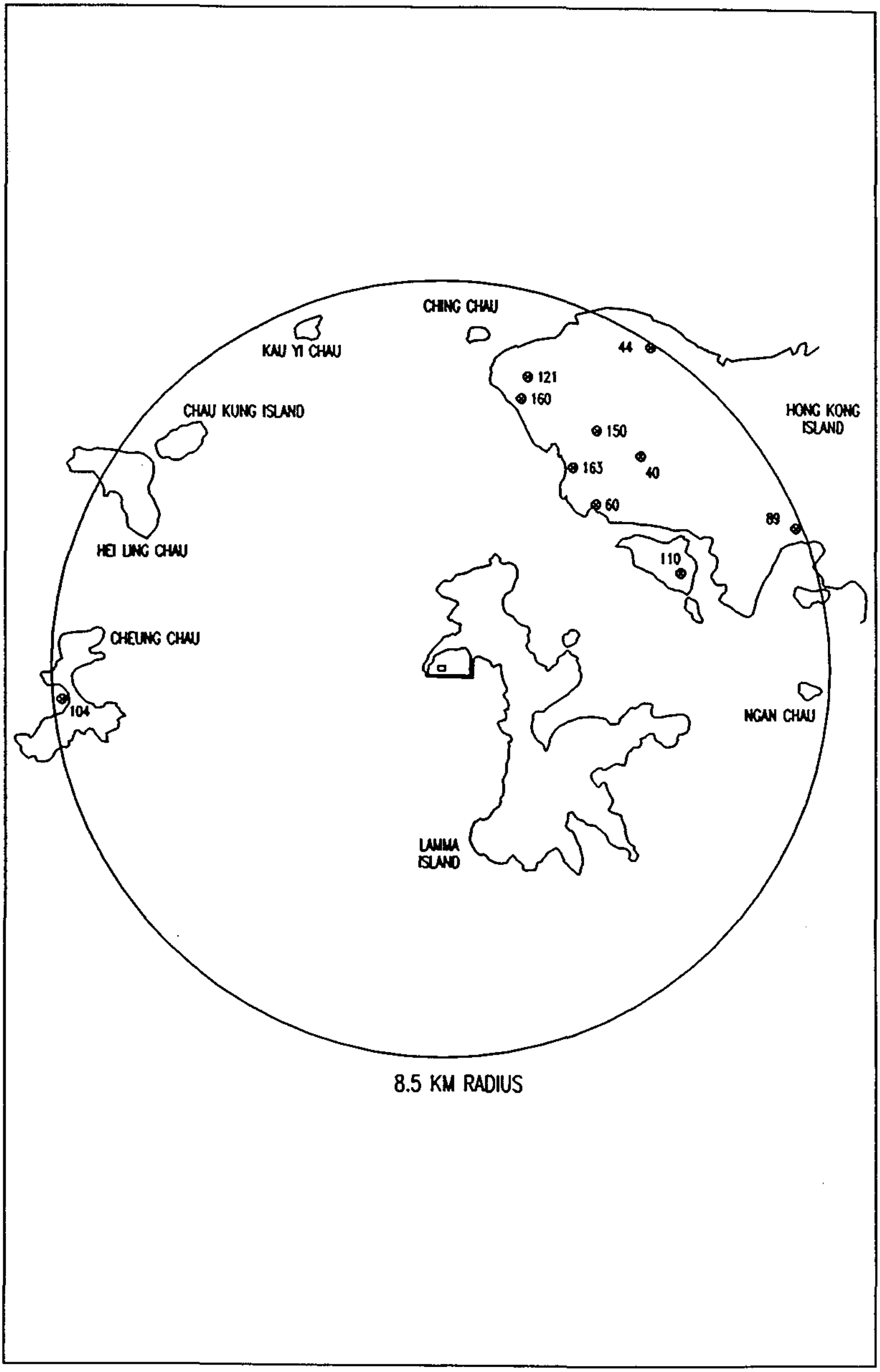

**Maximum hourly $NO_2$ concentrations for July 2000 (T1, T4) at 30m**

**Figure 3.1.29**



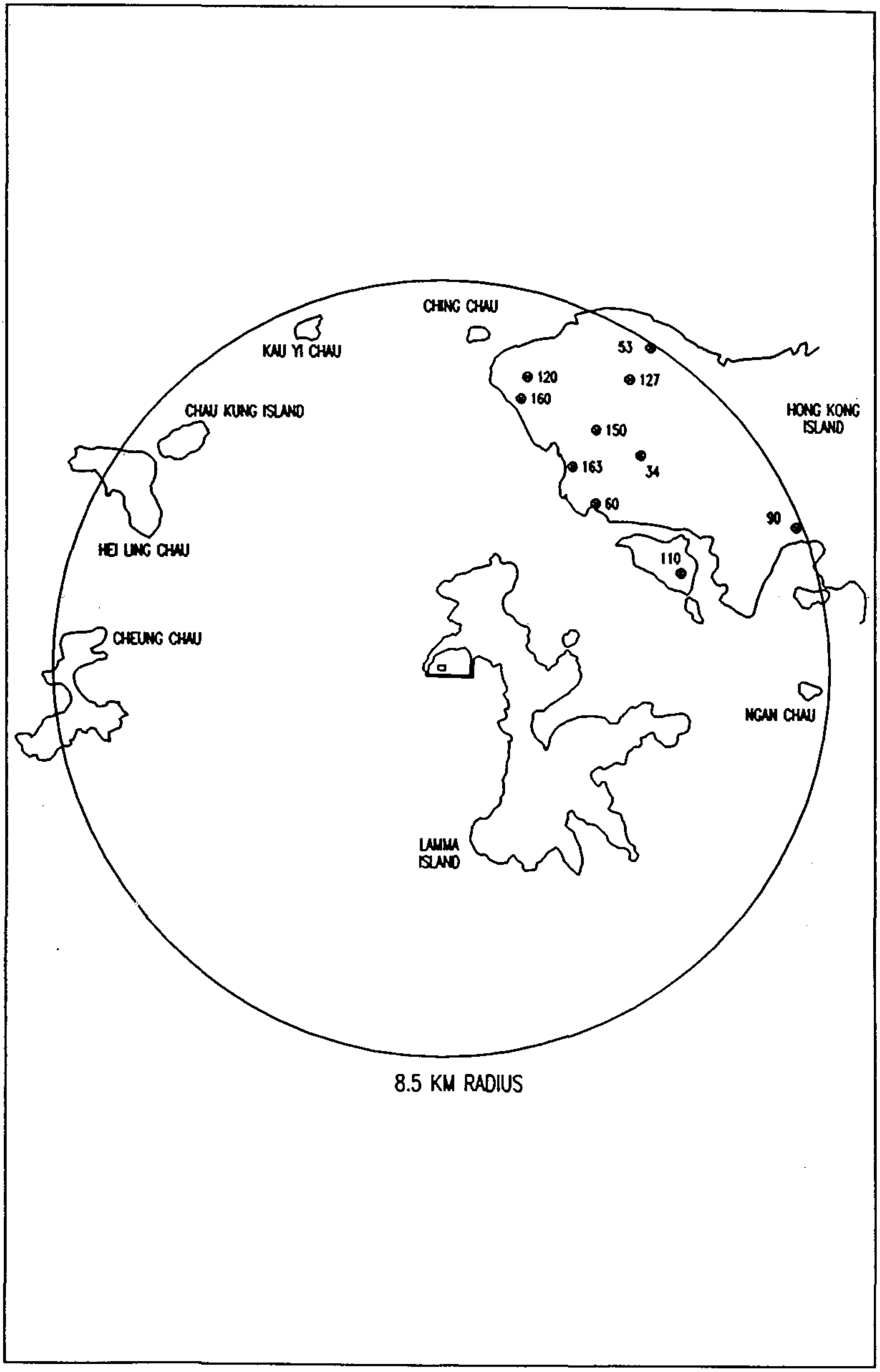

**Maximum hourly $NO_2$ concentrations for July 2000 (T1, T4) at 60m**

Figure 3.1.30




**Maximum hourly $NO_2$ concentrations for July 2000 (T1, T4) at 90m**

**Figure 3.1.31**




**Maximum hourly $NO_2$ concentrations for July 2000 (T1, T4) at 120m**

## APPENDIX A

### Interpolation of Maximum Concentrations at Elevated Positions

In response to a request from EPD, measured vertical concentration profiles were used as a basis for interpolation of the concentration at a number of locations at which only ground level concentrations had been measured.

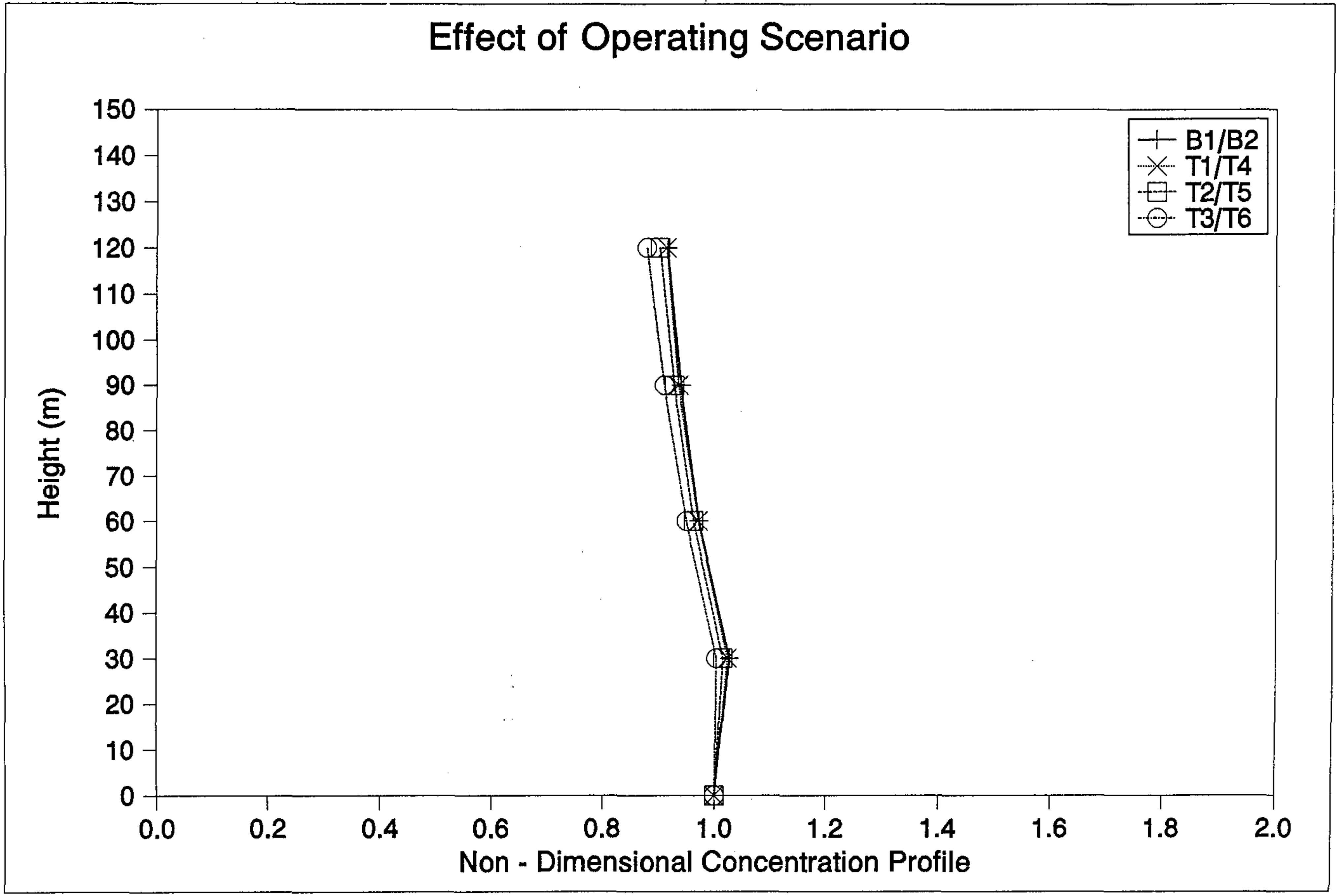
Figure A1 shows the vertical concentration profile for the 4 different operating scenarios non-dimensionalised by the ground level concentration. The profiles are at Sensor 2,3 and the wind speed is 15m/s. It is clear that there is little variation between the concentration profiles for the different conditions. The figure is an illustrative example. The same behaviour was evident at other wind speeds and locations.

On the basis of this conclusion it is necessary to establish the concentration profile for only one operating condition for each location and wind speed, as the same profile could be used for the other conditions.

The interpolated concentration profiles are presented in Figure A2. In the interpolation of the concentration profiles allowance was made for downwind distance and local topography. The measured profiles in Figure A2, are illustrative of similar profiles to those interpolated, but do not form the basis of the interpolation. As a function of downwind distance all measured elevated profiles were converted to a non-dimensional form and used as a reference set for the interpolation. On a judgemental basis profiles measured on terrain dissimilar to the sensor under study, were eliminated in producing the interpolated values.

In terms of absolute values precise downwind distance and topography were automatically included at ground level, as each interpolated profile had a ground level measurement. Using the ground level concentration measurements at the locations of the interpolated non-dimensional concentration profiles, estimates of the elevated concentration could be made.

Due to the nature of the interpolations it is difficult to be systematic in assessing the accuracy of the interpolations. A judgement made from examining the profiles presented in Figure A2 would suggest that the profile for Sensors 1,4, 3,3 and 4,4 are accurate to $\pm 10\%$ and Sensor 2,5 accurate to $\pm 5\%$.



Effect of Operating Scenario
B1/B2
T1/T4
T2/T5
T3/T6
Height (m)
Non - Dimensional Concentration Profile
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0


Figure A1

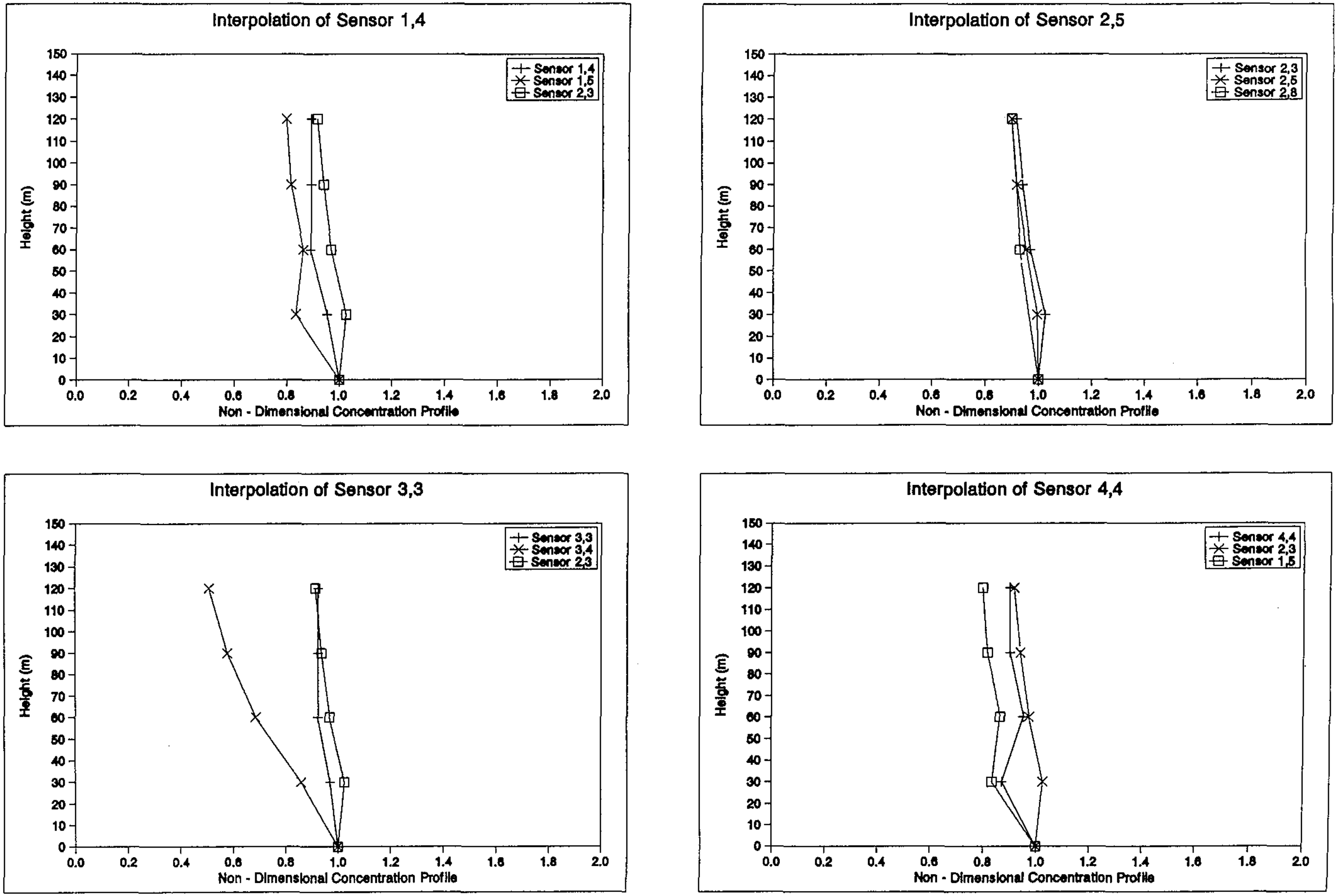

Interpolation of Sensor 1,4
Sensor 1,4
Sensor 1,5
Sensor 2,3
Height (m)
Non - Dimensional Concentration Profile
Interpolation of Sensor 2,5
Sensor 2,3
Sensor 2,5
Sensor 2,8
Height (m)
Non - Dimensional Concentration Profile
Interpolation of Sensor 3,3
Sensor 3,3
Sensor 3,4
Sensor 2,3
Height (m)
Non - Dimensional Concentration Profile
Interpolation of Sensor 4,4
Sensor 4,4
Sensor 2,3
Sensor 1,5
Height (m)
Non - Dimensional Concentration Profile

Figure A2

**APPENDIX B**

**Detailed Response to EPD Comment on Plume Height Versus Downwind Distance**

In the initial calculation of the plume height, the centreline was established by determining the height of the point of maximum concentration within the plume at points downwind of the stack. To establish the plume height more exactly it is possible to manually calculate this from the Briggs formulae as described in the ISCST manual. Three steps are required, first, calculation of the Briggs buoyancy flux parameter 'F', second, determination of whether the plume rise is dominated by momentum or buoyancy and finally, calculation of the final plume rising using the buoyancy flux and the appropriate formula. This calculation is detailed below, with reference to the equations in the ISCST manual. The input information used for the calculation is as follows:

| | | |
|---|---|---|
| Efflux temperature | : | 397°K |
| Efflux velocity | : | 16.13m/s |
| Stack diameter | : | 9.7m |
| Ambient temperature | : | 298°K |
| Wind velocity | : | 2.7m/s (at stack height) |

The Briggs buoyancy flux parameter F is given by:

$$F = g v_s \, d^2 \frac{\Delta T}{4T_s}$$ (equation 2.3 in ISCST Manual)

where $\Delta T = T_s - T_A$

thus $$F = \frac{9.8 \times 16.13 \times 9.7^2 \times 99}{4 \times 397}$$

$$F = 927.2 m^4 \, s^{-3}$$

In neutral conditions the crossover temperature difference to determine whether plume rise is dominated by momentum or buoyancy is found from:

$$(\Delta T)_c = \frac{0.00575 \; T_s \; V_s^{0.6666}}{d^{0.3333}}$$ (equation 2.5 in ISCST Manual)

$$(\Delta T)_c = \frac{0.00575 \times 397 \times 16.13^{0.6666}}{9.7^{0.3333}}$$

$$(\Delta T)_c = 6.8°K$$

Thus buoyancy rise dominates.

To calculate the distance to final rise the following Briggs formula is used.

$x_f = 0.119 \, f^{0.4}$ km (equation 2.7 in ISCST Manual)

$x_f = 0.119 \times 927.2^{0.4}$

$x_f = 1.83$km

To calculate the final plume rise in neutral conditions the following formula is used:

$$H = h' + \frac{38.71 \ F^{0.6}}{u}$$ (equation 2.9 in ISCST Manual)

$$H = 215 + \frac{38.71 \times 927.2^{0.6}}{2.7}$$

$$H = 1079m$$

The calculations indicate agreement with EPD's figure of approximately 2km to the point of final plume rise. However the height of the final plume rise remains as previously calculated.

As an alternative in the calculation of H, the wind speed of 2.7m/s may be replaced by 3.75m/s, which accounts for the wind profile between 10m and 215m.

Then $H = 889m$.

The latter approach is consistent with the wind tunnel measurements and general meteorological practice, where all wind speeds referenced are those at 10m.

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