# Intermediate or Screening Dispersion Modelling Tools 6

## 6.1 TESTING CAR AND AEOLIUS IN ABERDEEN

Aberdeen City Council was asked to establish a kerbside air quality monitoring station and to "model and assess levels of CO, NOx and $PM_{10}$ at the kerbside at an automatic monitoring station using a range of models and screening methods". The screening methods selected were:

- *CAR International*
- *AEOLIUS*

CAR and AEOLIUS were selected because they are both relatively straightforward to use and input data are readily available. They are specifically designed for the assessment of traffic pollution in congested locations and are inexpensive to purchase.

CAR is a Dutch model, developed by TNO and RIVM. It can model the pollutant concentrations due to a single road and can take urban background into account. It includes the pollutants CO, $NO_2$, benzene and "black smoke" and produces average concentrations and 98th percentile of hourly average concentrations. The modelling period is user-specified and period-specific wind speeds can be used if desired. The model includes two vehicle types, light and heavy duty and the user can specify emissions factors. The model can take road type into account and the user is required to select one of four traffic speed types and five road layout types.

AEOLIUS is a simple street canyon model developed by the UK Meteorological Office. The program calculates hourly average concentrations of pollutants within a street canyon at the roadside.

The input data for CAR are listed in Table 6.1. The emissions factors used by Aberdeen are similar to fleet-weighted factors that would be derived from the DETR emissions factor database (http://www.environment.detr.gov.uk/airq/aqinfo.htm) , which was not available on-line when Aberdeen carried out their work. The monthly results for CAR International are summarised and compared with roadside measurements in Table 6.2. Although the modelled and measured periods are not strictly comparable, the model clearly underpredicts the concentrations of all three pollutants.

Input data for AEOLIUS is given in Table 6.3. The diurnal variation in traffic flow is illustrated in Figure 6.1. AEOLIUS predicts hourly mean concentrations and an example of the hourly prediction for $NO_2$ are shown in Figure 6.2, together with the measured hourly concentrations. Like CAR International, AEOLIUS appears to underpredict concentrations at this site.

As both models underpredict, the Aberdeen data suggest they are not useful as conservative screening tools for Stage 2 review data assessments. They are not included in the Department's pollutant specific guidance (DETR *et al.*, 1998b) which only refers to the Highways Agency's Design Manual for Roads and Bridges (DMRB).

## 6.2 INTERCOMPARISON OF SMALL SCALE DISPERSION MODELS IN LONDON

A similar study to that in Aberdeen was carried out by the 33 Authorities in the London First Phase area. Concentrations of CO and NOx estimated by a range of models of varying complexity were compared with measurements alongside the Mile End Road in Tower Hamlets. This road runs approximately east-west and

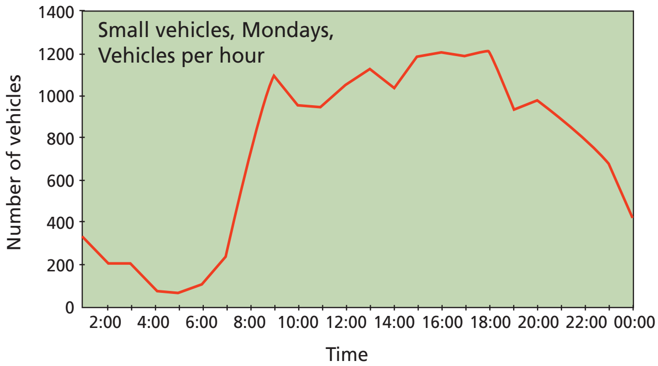


Figure 6.1. Diurnal variation in traffic flow at Union Street, Aberdeen.

**TABLE 6.1. INPUT DATA FOR CAR MODEL FOR UNION STREET, ABERDEEN**

| | | | | | |
|---|---|---|---|---|---|
| City Diameter | 9.6 km | | | | |
| Percentage trucks and buses | 12 % | | | | |
| Number of vehicles | 20105 per day | | | | |
| Distance to road axis | 8 m | | | | |
| Road type | 3b | Bldgs situated at a distance from the road axis of 1.5 times the height of the bldgs | | | |
| Speed type | Vc | Represents average city speed traffic | | | |
| Tree factor | 1 | No trees either side | | | |
| Emissions Factors (g/km/vehicle) | | $PM_{10}$ | NOx | CO | |
| Light duty | | 0.045 | 1.65 | 10.64 | |
| Heavy duty | | 1.03 | 10.98 | 4.21 | |
| Background Concentrations ($\mu gm^{-3}$) | | 0 | 13 | 250 | |
| wind speed (knots) | | March | April | May | June |
| | | 5.74 | 4.8 | 4.35 | 5.07 |

**TABLE 6.2 CAR INTERNATIONAL RESULTS FOR UNION STREET, ABERDEEN**

| | $NO_2$ (ppb) | | CO (ppm) | | $PM_{10}$ ($\mu gm^{-3}$) |
|---|---|---|---|---|---|
| | average 1 hour | 98th percentile | average 8 hour | 98th percentile | average monthly |
| March | 18.6 | 51 | 0.72 | 2.33 | 13.9 |
| April | 20.2 | 54 | 0.82 | 2.60 | 15.8 |
| May | 19.5 | 52 | 0.76 | 2.42 | 14.6 |
| June | 17.6 | 48 | 0.65 | 2.12 | 12.5 |
| Measured values March to September | 36 | 110 | 1.3 | 3.5 (1 hour) | 23 |

**TABLE 6.3 INPUT DATA FOR AEOLIUS**

| | |
|---|---|
| Emissions factor for small vehicles (g/km/vehicle) | 1.65 |
| Emissions factor for large vehicles (g/km/vehicle) | 10.98 |
| Compass bearing to receptor (degrees) | 0 (street runs east-west) |
| Width of street (m) | 16 |
| Average height of street buildings (m) | 20 |
| Surface roughness length (m) | 0.6 |

carries around 35,000 vehicles per day. The results from the American CALINE 4 model and UK-ADMS were compared in some detail for two three day periods, 20 to 22 May 1996 and 29 October to 1 November 1995. For the former period there was a large diurnal variation in stability with wind speeds in the range 2 to 5 m $sec^{-1}$ from the west to south-west. For the latter period stability was neutral to stable with wind speeds between 1 and 3 m $sec^{-1}$. The wind direction varied from northerly to easterly to westerly over the three days.

Background concentrations were taken from a nearby monitoring site and the exercise was aimed at assessing the use of models to estimate the increase of concentrations at the roadside. For these particular periods, ADMS results were better correlated with the measurements than those of CALINE 4. For example, for NOx between 29 October to 1 November, regression of ADMS-modelled hourly mean concentrations against the measurements gave a correlation coefficient, R of 0.61 and a gradient of 0.80. The equivalent statistics for CALINE 4 were 0.38 and 0.67.

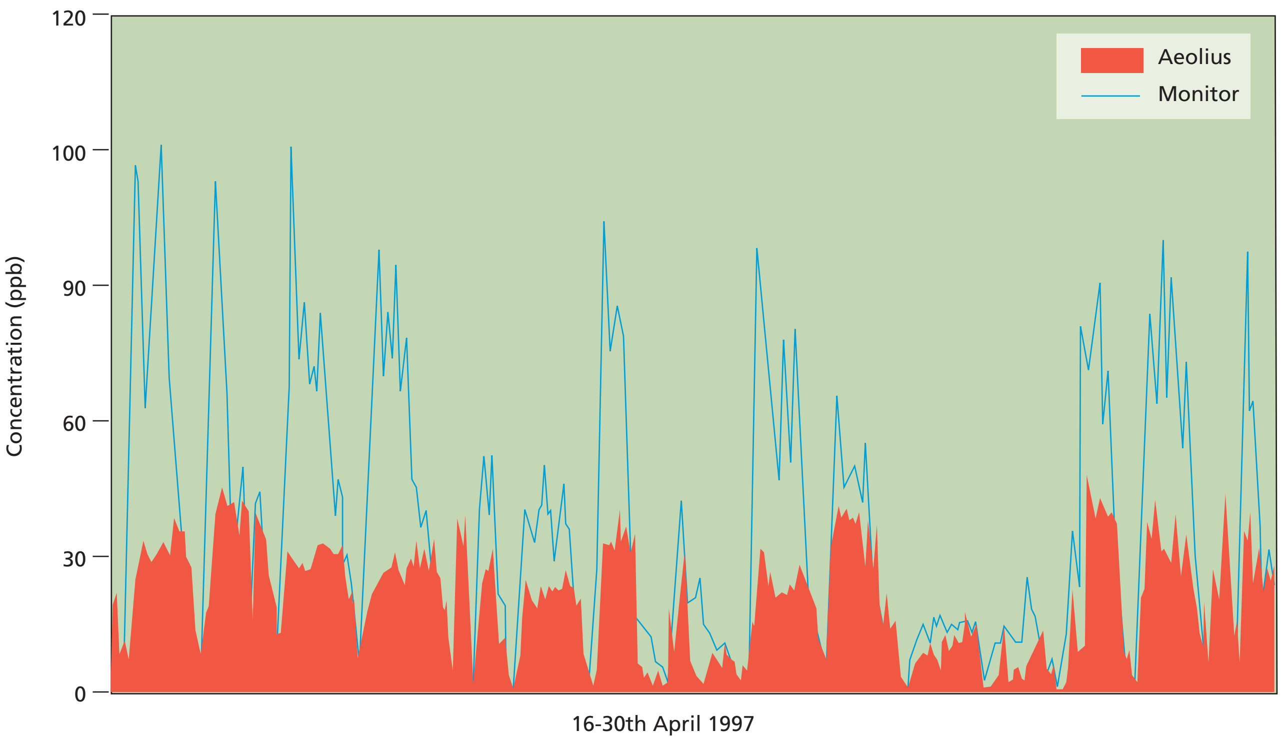


Figure 6.2. Hourly mean concentration of $NO_2$ (ppb) at Union Street, Aberdeen, predicted by AEOLIUS and measured.

## 6.3 DERIVATION OF A SCREENING TOOL FOR STREET CANYONS

Cambridge City Council has prepared a look-up table to aid the assessment of street canyons. They created two tables for each pollutant:

Table A relating street height and width to a "critical" emission for the pollutant and
Table B relating "critical" emission and peak-hour traffic flow to minimum required traffic speed (to avoid exceeding that "critical" emission).

For Table A, they used AEOLIUS and assumed that the wind direction was parallel to the road and that the wind speed was 2 m $sec^{-1}$. For Table B they used the emissions data in the 1984 version of DMRB. An example of the Cambridge lookup table is shown in Table 6.4. This table allows the user to estimate the emission of NOx above which the air quality objective for $NO_2$ might be exceeded. Cambridge has assumed that the critical hourly mean NOx concentration is 840 ppb. This is slightly more than the DETR guidance recommendation of 700 ppb, but this guidance was not available to Cambridge at the time. The equivalent light vehicle traffic flow, using the emissions factors derived by Aberdeen are shown in Table 6.5. This illustrates that, for a typical street canyon of 15m x 15m, the critical flow would be about 1,600 vehicles per hour. It should be noted, however, that the AEOLIUS model from which Cambridge have derived their table was shown to under-estimate by Aberdeen.

**TABLE 6.4. AN EXAMPLE TABLE FROM THE CAMBRIDGE STREET CANYON SCREENING TOOL. THIS SHOWS THE "CRITICAL" NOx EMISSION (μg $m^{-1}$ $sec^{-1}$) WITH RESPECT TO AN HOURLY MAXIMUM $NO_2$ CONCENTRATION OF 150 PPB FOR A GIVEN STREET HEIGHT AND WIDTH. THE HEIGHT OF THE STREET IN METRES IS READ FROM THE TOP LINE AND THE WIDTH FROM THE FIRST COLUMN.**

| H | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **W** | | | | | | | | | | | | | | | | | | | | | | | | |
| **7** | 612 | 573 | 542 | 517 | 496 | 479 | 464 | 451 | 439 | 429 | 420 | 412 | 404 | 397 | 391 | 385 | 379 | 374 | 370 | 365 | 361 | 357 | 353 | 350 |
| **8** | 669 | 625 | 591 | 564 | 541 | 522 | 505 | 491 | 478 | 467 | 457 | 448 | 440 | 432 | 425 | 419 | 413 | 407 | 402 | 397 | 392 | 388 | 384 | 380 |
| **9** | 723 | 676 | 639 | 609 | 584 | 564 | 546 | 530 | 516 | 504 | 493 | 483 | 474 | 466 | 458 | 451 | 445 | 439 | 433 | 428 | 423 | 418 | 414 | 410 |
| **10** | 777 | 725 | 685 | 653 | 627 | 604 | 585 | 568 | 553 | 540 | 528 | 517 | 508 | 499 | 491 | 483 | 476 | 470 | 464 | 458 | 453 | 448 | 443 | 438 |
| **11** | 829 | 774 | 731 | 696 | 668 | 644 | 623 | 605 | 589 | 575 | 562 | 551 | 541 | 531 | 522 | 514 | 507 | 500 | 493 | 487 | 482 | 476 | 471 | 466 |
| **12** | 881 | 822 | 776 | 739 | 708 | 683 | 661 | 641 | 624 | 609 | 596 | 584 | 573 | 563 | 553 | 545 | 537 | 529 | 523 | 516 | 510 | 504 | 499 | 494 |
| **13** | 931 | 869 | 820 | 781 | 748 | 721 | 697 | 677 | 659 | 643 | 629 | 616 | 604 | 594 | 584 | 575 | 566 | 559 | 551 | 544 | 538 | 532 | 526 | 521 |
| **14** | 981 | 915 | 863 | 822 | 787 | 759 | 734 | 712 | 693 | 677 | 661 | 648 | 636 | 624 | 614 | 604 | 595 | 587 | 579 | 572 | 565 | 559 | 553 | 547 |
| **15** | 1031 | 961 | 906 | 862 | 826 | 796 | 770 | 747 | 727 | 709 | 694 | 679 | 666 | 654 | 643 | 633 | 624 | 615 | 607 | 600 | 592 | 586 | 579 | 573 |
| **16** | 1080 | 1006 | 948 | 902 | 864 | 832 | 805 | 781 | 760 | 742 | 725 | 710 | 697 | 684 | 673 | 662 | 652 | 643 | 635 | 627 | 619 | 612 | 606 | 599 |
| **17** | 1128 | 1050 | 990 | 942 | 902 | 869 | 840 | 815 | 793 | 774 | 757 | 741 | 727 | 714 | 702 | 690 | 680 | 671 | 662 | 653 | 646 | 638 | 631 | 625 |
| **18** | 1176 | 1095 | 1032 | 981 | 940 | 905 | 875 | 849 | 826 | 806 | 788 | 771 | 756 | 743 | 730 | 719 | 708 | 698 | 689 | 680 | 672 | 664 | 657 | 650 |
| **19** | 1223 | 1138 | 1073 | 1020 | 977 | 940 | 909 | 882 | 858 | 837 | 818 | 801 | 786 | 771 | 758 | 746 | 735 | 725 | 715 | 706 | 698 | 690 | 682 | 675 |
| **20** | 1270 | 1182 | 1114 | 1059 | 1014 | 976 | 943 | 915 | 890 | 868 | 849 | 831 | 815 | 800 | 787 | 774 | 763 | 752 | 742 | 732 | 724 | 715 | 707 | 700 |
| **21** | 1317 | 1225 | 1154 | 1097 | 1050 | 1011 | 977 | 948 | 922 | 899 | 879 | 861 | 844 | 829 | 814 | 802 | 790 | 778 | 768 | 758 | 749 | 740 | 732 | 725 |
| **22** | 1364 | 1268 | 1194 | 1135 | 1087 | 1046 | 1011 | 981 | 954 | 930 | 909 | 890 | 873 | 857 | 842 | 829 | 816 | 805 | 794 | 784 | 774 | 766 | 757 | 749 |
| **23** | 1410 | 1311 | 1234 | 1173 | 1123 | 1081 | 1044 | 1013 | 985 | 961 | 939 | 919 | 901 | 885 | 870 | 856 | 843 | 831 | 820 | 809 | 800 | 790 | 782 | 773 |
| **24** | 1456 | 1353 | 1274 | 1211 | 1159 | 1115 | 1078 | 1045 | 1017 | 991 | 969 | 948 | 930 | 913 | 897 | 883 | 869 | 857 | 846 | 835 | 825 | 815 | 806 | 798 |
| **25** | 1501 | 1395 | 1314 | 1248 | 1195 | 1149 | 1111 | 1077 | 1048 | 1021 | 998 | 977 | 958 | 940 | 924 | 909 | 896 | 883 | 871 | 860 | 850 | 840 | 830 | 822 |
| **26** | 1547 | 1438 | 1353 | 1286 | 1230 | 1183 | 1144 | 1109 | 1078 | 1052 | 1027 | 1006 | 986 | 968 | 951 | 936 | 922 | 909 | 897 | 885 | 874 | 864 | 855 | 846 |
| **27** | 1592 | 1479 | 1392 | 1323 | 1265 | 1217 | 1176 | 1141 | 1109 | 1081 | 1057 | 1034 | 1014 | 995 | 978 | 963 | 948 | 934 | 922 | 910 | 899 | 889 | 879 | 869 |
| **28** | 1637 | 1521 | 1431 | 1360 | 1301 | 1251 | 1209 | 1172 | 1140 | 1111 | 1086 | 1063 | 1042 | 1023 | 1005 | 989 | 974 | 960 | 947 | 935 | 924 | 913 | 903 | 893 |
| **29** | 1682 | 1563 | 1470 | 1396 | 1336 | 1285 | 1241 | 1204 | 1170 | 1141 | 1115 | 1091 | 1069 | 1050 | 1032 | 1015 | 1000 | 985 | 972 | 960 | 948 | 937 | 927 | 917 |
| **30** | 1727 | 1604 | 1509 | 1433 | 1371 | 1318 | 1274 | 1235 | 1201 | 1171 | 1144 | 1119 | 1097 | 1077 | 1058 | 1041 | 1026 | 1011 | 997 | 984 | 972 | 961 | 950 | 940 |

**TABLE 6.5. THE "CRITICAL" LIGHT DUTY VEHICLE TRAFFIC FLOW (THOUSANDS PER HOUR) WITH RESPECT TO AN HOURLY MAXIMUM $NO_2$ CONCENTRATION OF 150 PPB FOR A GIVEN STREET HEIGHT AND WIDTH. THE HEIGHT OF THE STREET IN METRES IS READ FROM THE TOP LINE AND THE WIDTH FROM THE FIRST COLUMN.**

| H | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 1.3 | 1.3 | 1.2 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| 8 | 1.5 | 1.4 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 |
| 9 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 10 | 1.7 | 1.6 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 11 | 1.8 | 1.7 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| 12 | 1.9 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| 13 | 2.0 | 1.9 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 |
| 14 | 2.2 | 2.0 | 1.9 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 |
| 15 | 2.3 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| 16 | 2.4 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 |
| 17 | 2.5 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| 18 | 2.6 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 |
| 19 | 2.7 | 2.5 | 2.4 | 2.2 | 2.1 | 2.1 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 |
| 20 | 2.8 | 2.6 | 2.5 | 2.3 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 |
| 21 | 2.9 | 2.7 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 |
| 22 | 3.0 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 |
| 23 | 3.1 | 2.9 | 2.7 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 |
| 24 | 3.2 | 3.0 | 2.8 | 2.7 | 2.5 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| 25 | 3.3 | 3.1 | 2.9 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 |
| 26 | 3.4 | 3.2 | 3.0 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |
| 27 | 3.5 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 |
| 28 | 3.6 | 3.3 | 3.1 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 |
| 29 | 3.7 | 3.4 | 3.2 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 |
| 30 | 3.8 | 3.5 | 3.3 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 |