Water Corporation

Preliminary Report on Buffer Zone for Subiaco Wastewater Treatment Plant

June 2001

Consulting Environmental Engineers

Buffer Zone for Subiaco Wastewater Treatment Plant

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1 Subiaco Wastewater Treatment Plant

Subiaco Wastewater Treatment Plant (WWTP) commenced operations in 1927 to provide the residents of the CBD and western suburbs of Perth with a sewerage service. At present, the Subiaco plant serves approximately 310,000 persons. The present wastewater flow treated at the plant is 58 million litres per day (58 ML/d).

A modern wastewater treatment plant has several functions:
* Remove detritus and other solid and gritty objects from the wastewater;
* Remove organic solids and convert into useful products for reuse;
* Remove dissolved constituents to meet water quality standards;
* Remove nitrogen and phosphorus to meet environmental objectives;
* Remove pathogens to protect public health; and
* Prepare a reclaimed water stream for subsequent reuse.

A series of physical, biological and chemical processes are used to achieve the performance requirements. More complex processes are being adopted as the requirements for water quality, reclaimed water quality, energy constraints and reuse become progressively more stringent with time. Increased quantities of reclaimed products (solids and effluent) and chemicals are expected to be stored on the site in the future.

In the past, a wastewater treatment plant has been seen as a site for handling the wet wastes from the community. In the future, this function will continue, but with the site also being recognized as a biological/chemical processing plant producing energy, reclaimed effluent and soil conditioning products.

2 The Issue

The issue addressed in this report is to recommend, based on available information and experience with large treatment plants, the buffer zone adjacent to the Subiaco plant which should be maintained. The buffer zone should exclude residential development and similar odour-sensitive land uses. A related aspect is to suggest suitable land uses for the buffer zone.

3 Buffer Zones

The duty of planners is to achieve an efficient and compatible arrangement of land uses taking into account physical constraints and opportunities, social patterns, commercial services, service infrastructure, development paths, environmental sensitivities and economic conditions. Residential areas require higher standards of amenity than industrial or commercial operations. Buffer zones are maintained to protect residents from the effects of land uses that are not compatible with residential areas.

Even with good pollution control technology and practice, there can be accidental or unintended emissions of odour, volatile organics, noise, and chemicals as a result of accidents, new treatment processes, equipment failures, power failures and abnormal weather conditions. These emissions should be anticipated and allowed for as part of land use planning, as well as in the management of the treatment plant.

These episodic or accidental emissions are generally intermittent and originate near ground level. An adequate buffer zone allows the emissions to dissipate without significant adverse effects on sensitive land uses. The buffer zone is not, of course, an alternative to 'best practice' operation of a sewerage system, including responsible management of the sewage collection system, treatment system, reuse operations and disposal systems. The buffer zone is part of 'best practice' land use management, particularly when several non-residential land uses are brought together within a common buffer zone.

The consequences of an inadequate buffer zone are threefold:

1. Nuisance and hazard experienced by residents adjacent to the buffer zone;
2. Additional cost experienced to ratepayers for sewerage operations; and
3. Additional energy consumption by sewerage system.

Buffer zones are a practical and widely adopted solution to a real planning issue. For example, buffer zones are recognized for:

* Airports;
* Refineries;
* Quarries and mining;
* Animal feedlots;
* Noxious industries;
* Pharmaceutical manufacture;
* Organic chemical industries: and
* Sewage treatment plants.

3.1 WA Buffer Zone Policy

The EPA of WA issued in July 1997 a draft policy for buffer distances "*Policies, Guidelines and Criteria for Environmental Impact Assessment (Industrial-Residential Buffer Areas Separation Distances"*. The guidelines propose buffer distances depending on the size of the treatment plant and the type of treatment used. For the Subiaco plant, (more than 100,000 person capacity) the recommended buffer distance would be 1000 m.

While the fixed buffer distance is defined as a guide, the policy suggests that wind patterns and topography also be taken into account when setting buffer distances.

3.2 ACT Buffer Zone Policy

The ACT provides a 1000 m radius buffer zone for the major sewage treatment plant in Canberra (this plant is of similar size to the Subiaco WWTP). This equates to a buffer distance of approximately 600 m from the boundary of the plant. The size of the buffer zone reflects the sophisticated treatment processes required at the site to achieve the specified effluent quality and reclaimed water quality, the need for occasional storage of wastewater on the site to avoid overflows into the Murrumbidgee River and the emphasis placed on achieving 100 per cent reuse on farming land of phosphorus, which may involve storage of sludge products on the site.

3.3 NSW Buffer Zone Policy

In NSW, guidelines for buffer zones surrounding sewage treatment plants are set out in the Department of Planning Circular E3 dated March 1989.

The definition of a buffer zone is "an area of land or water in proximity to a treatment plant which together with pollution control measures reduces odour, noise, visibility and other adverse environmental impacts to more acceptable levels". The E3 guidelines recommend that buffer zones have a width of at least 400 m from the boundary of treatment plants and a greater width downwind of plants.

The NSW EPA issued a *Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW* in January 2001. The draft policy notes that odours are the largest source of air pollution complaints to the NSW EPA. Odour problems generally arise when urban development encroaches on existing agricultural or industrial areas, when an odour-generating industry is inappropriately located near residential development or when an existing industry changes technology or operations, resulting in increased odours.

3.4 VIC Buffer Zone Policy

The Victorian guidelines for buffer zones for sewage treatment plants are set out in EPA Bulletin AQ2/86 issued in 1990. The EPA bulletin excludes the following land uses from a buffer zone *"Residential areas (whether occupied or not), hospitals, schools, caravan parks and other similar uses involving the presence of individual people for extended periods, except in the course of their employment or for recreation"*. The width of a buffer zone in the EPA guidelines is 400 m for a biological treatment plant serving up to 50,000 persons.

For larger facilities, the buffer zone is set on a case by case basis, and would generally be greater than 400 m. The site-specific designation of the buffer zone for a large treatment plant takes into account topography, waste loading, plant capacity, and treatment methods and reuse systems. Draft guidelines to refine buffer zones in Victoria suggest that in some circumstances the buffer zone may be increased up to 40 per cent in the downwind direction and decreased by 15 per cent in the upwind direction.

4 Sewage Odour Problems

Every treatment plant releases odour at times. Best management practices to minimise the impacts of odours involve the following:

1. Management of collection system to minimise odours;
2. Management of treatment plant to minimise odours;
3. Collection and scrubbing of odourous gases; and
4. Provision of buffer zone appropriate for particular site and plant.

4.1 Odour Generation In Perth Sewers

Management of the sewage collection system to minimise odours is constrained by the following conditions which are specific to Perth:

1. Large residential blocks and dispersed suburban development, which results in long sewers and a high risk of odour generation;
2. Flat terrain and high groundwater, which requires multiple pumping stations and a longer travel time for sewage to the treatment plant;
3. Warm climate, which results in warm sewage with a greater rate of biological activity and hence a greater odour generation rate.

Experience has shown that in warm climates the production of hydrogen sulphide in sewage can only be avoided if the sewage reaches the treatment plant within about 4 hours. The travel times in the Subiaco catchment are much longer than 4 hours, with average travel times being in the range of 6 to 10 hours, while the maximum travel time is 15 hours.

This combination of local circumstances means that sewage from the Subiaco catchment is very odourous by the time it arrives at the treatment plant. The Water Corporation has management practices to minimise odour release from the collection sewers (oxygen injection at various locations in the sewers) and also to control odour release at the Subiaco treatment plant (addition of high dose of chlorine at the WWTP, covered inlet, chemical scrubber for collected air, covers over primary effluent channel, biofilter for air collected from above primary effluent channel).

Nonetheless, it must be recognized that sewage processed at the Subiaco plant is very odourous when it arrives at the plant, and that this leads to emission of odours throughout the plant.

Measurement of odourous gas release at the Subiaco WWTP on a continuous basis shows that there is a diurnal variation in hydrogen sulphide and volatile organic emissions, with peak emissions at the inlet occurring at around 7 am and then again around noon. Due to the residence time of sewage in the treatment processes, peak emissions from the secondary area would occur in late afternoon and evening, while peak emissions from the sludge processing area may occur in early morning and at night. The sources and composition of the odour therefore vary throughout the day.

4.2 Odour Measurement and Detection

The strength of an odour is measured in terms of odour units (OU) which is the number of times an odourous gas must be diluted with odour-free air so that it is just detectable by 50 per cent of an odour panel. An equivalent unit for measuring odour is ODU, which stands for Odour Dilution Units.

Different methods of collection of odourous gases ('static hood' or 'wind tunnel') and different methods of exposure of the testing panel ('sniffers') to odourous gases ('free choice' or 'forced choice') give different results, as would be expected. Provided the sampling and sniffing procedures are known, it is possible to convert the results from one odour system to another odour system. For example, 10 OU (free choice) = 4 OU (forced choice).

Air with an odour strength of 20 OU would be recognised as odourous. However by the time the gas has been diluted with 20 volumes of ambient air (in the olfactometer or in nature) the odour strength (theoretically) would be reduced to 1 OU, which is the threshold of detection.

In practice there are a number of complications in the measurement and management of odours. The principal complications are as follows:

1. The perception by residents of odours from treatment plants is their olfactory response to many different odourous substances;
2. Some odourous substances mask or cancel the effect of other odourous substances. On the other hand, some odorous substances can have a compounding or intensifying effect in terms of odour perception;
3. The response to the strength of odour is not linear;
4. Some individuals are particularly sensitive to odour. Furthermore, the sensitivity of a community to odour increases with prolonged exposure ('learning') and if the source of odour is visible.
5. The odour emission rate from each treatment process varies substantially from hour to hour and day to day;
6. The microclimate, including near-ground level winds and mixing rates, has a substantial influence on the areas affected by odours;
7. It is not possible to measure an odour strength of less than about 10 OU. Hence all predictions of lower odour levels are extrapolations.

Because of these complications it is unwise to treat the predictions of odour dispersion models as if they have a high level of certainty. Model predictions must always be correlated to 'complaints' with the latter being taken as the real level of community annoyance. After each major change in odour emission rates, a new calibration of an odour model to complaints will be required.

The goal is to have no complaints from the community about odour from the treatment plant. To achieve this goal, it is necessary to build in a high level of odour control at the plant, use rigorous operating procedures, reduce changes in treatment processes to a minimum and maintain a buffer zone of adequate size.

5 Experience Around Perth Treatment Plants

As explained above, the objective of an odour management program is to minimise the number of valid odour complaints, and the effects of odour nuisance on residents.

5.1 Odour Complaints for Subiaco WWTP

The locations of recent complaints from residents concerning odour from the Subiaco WWTP are plotted in Figure 1. The complaints are relatively frequent (2 to 4 per week) and occur throughout the year. Most of the complaints come from the residential area of Floreat, which extends from 600 m to 2000 m north of the plant. An increasing number of complaints are being received from Mt Claremont, 700 to 1000 m southwest.

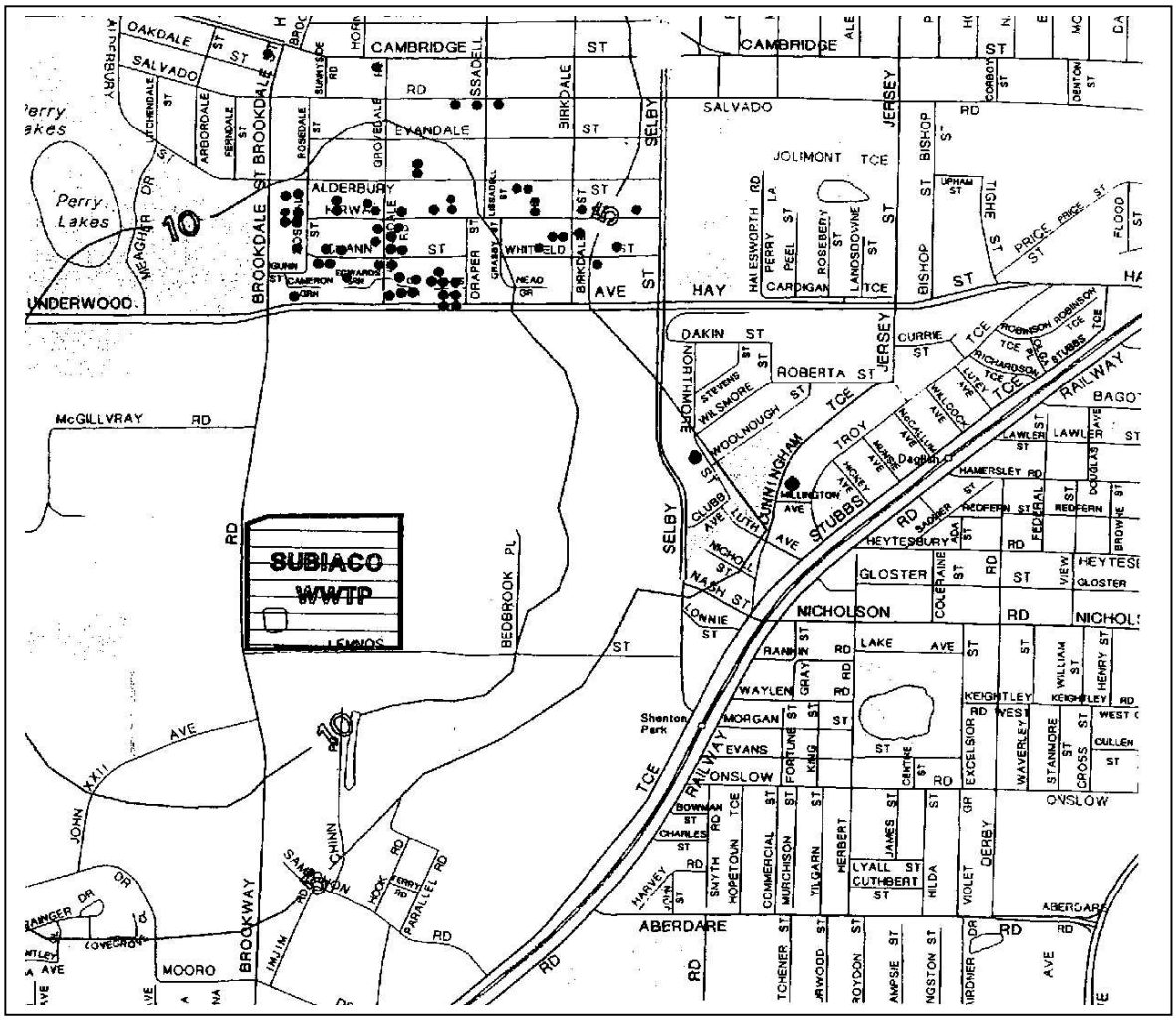


Figure 1. Records of Recent Odour Complaints Around Subiaco WWTP

The complaints record shows that annoying levels of odour consistently extend up to 1800 m from the Subiaco WWTP. Figure 2 shows the distance from the Subiaco treatment plant of each of the 240 complaints received in 1999/2000. The majority of complaints come from residents at 700 m to 1200 m from the plant, with a smaller number of complaints from a distance of 1300 m to 1800 m. There are few complaints from within the 100 m to 600 m distance, as there are few residents in this zone (this is the existing buffer zone which contains a refuse station, sporting ovals and research laboratories).

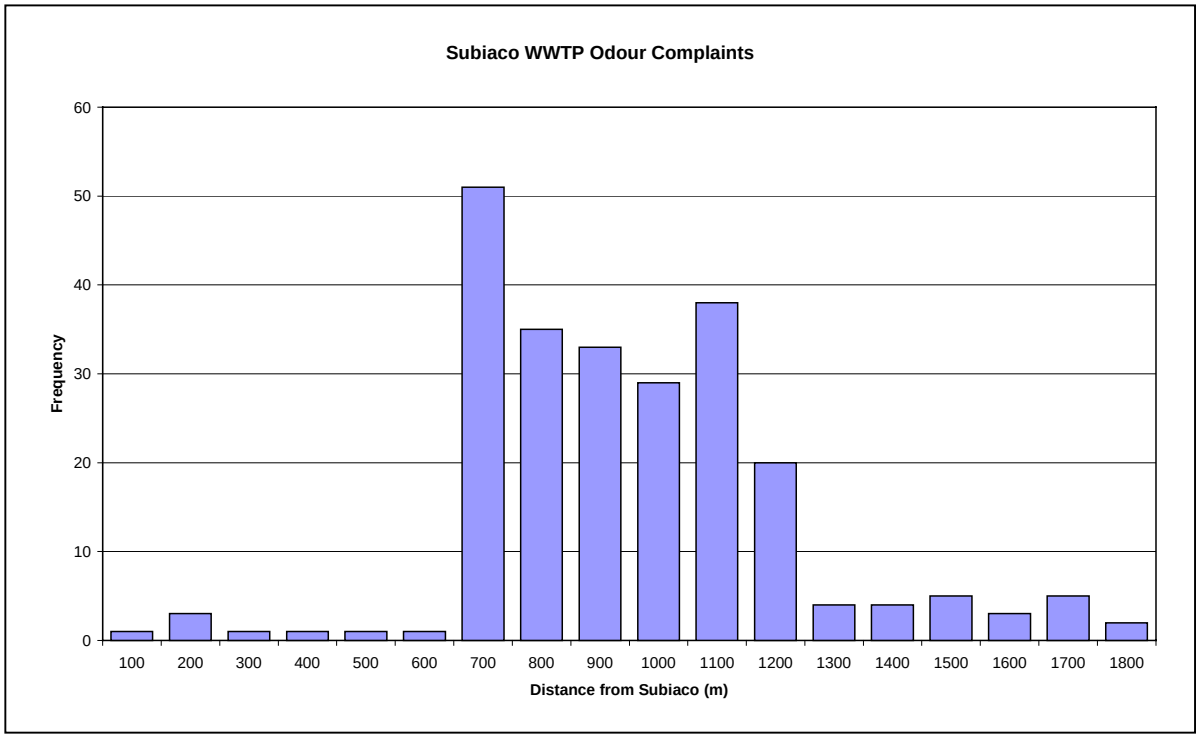


Figure 2. Odour Complaints as a Function of Distance From Subiaco WWTP

5.2 Odour Concerns for Beenyup WWTP

A survey of the perceptions of residents in the region of the Beenyup WWTP was conducted recently and the results are summarised in Figure 3. Problems with odours extended up to 1700 m east and 1800 m west of the plant, with very frequent odour problems from within 1200 m of the plant.

Subiaco and Beenyup are similar plants in terms of catchment size and treatment processes and both show a similar distribution of complaints over distance (taking into account the pattern of residential areas around the two plants). The odour complaints evidence does not show that conditions around Subiaco are markedly better or markedly worse than around Beenyup.

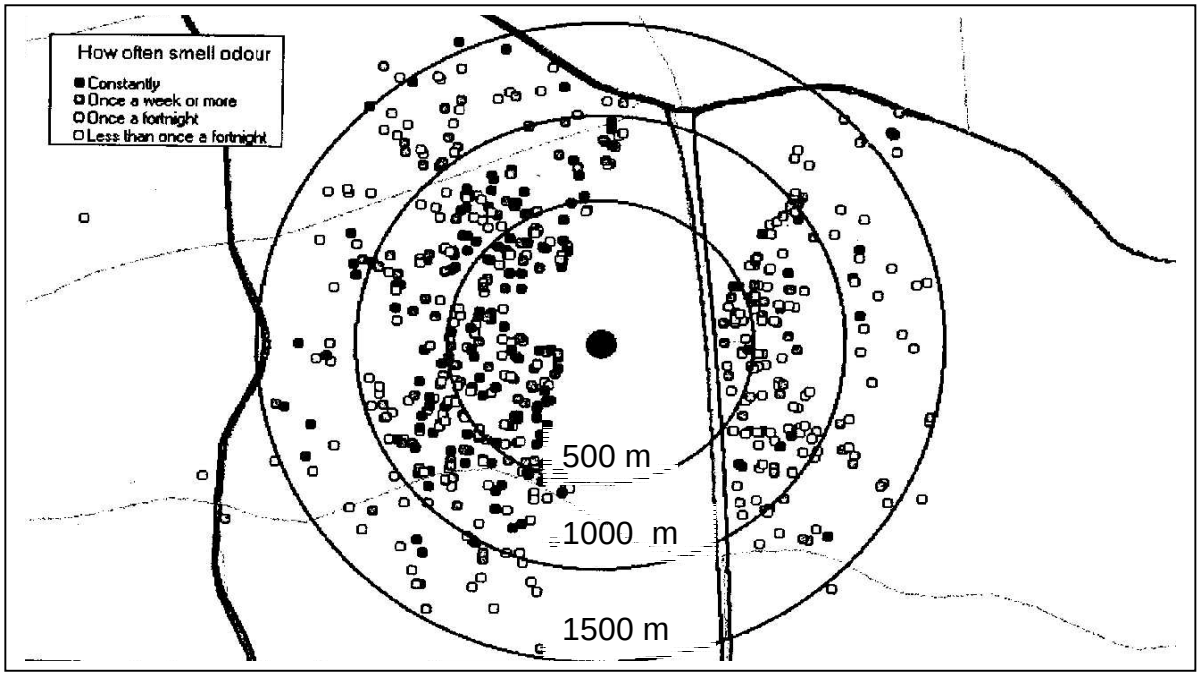


Figure 3. Perception of Odour Problems in Beenyup WWTP Region.

5.3 Interpretation of Odour Complaint Records

Odour complaints are an indication of the actual degree of community annoyance; in general, the number of people annoyed by odour is much greater than the number recording complaints. There are a high number of odour complaints from both treatment plants. The odour complaints evidence from both plants clearly shows that it would not be reasonable or acceptable to locate new residences within the zone of 100 to 600 north or northeast of the Subiaco WWTP. This would allow new residents to move into a zone of odour suffering.

A second conclusion reached from the Subiaco complaints record is that the Water Corporation will struggle to eliminate odour complaints outside the 600 m buffer zone around the Subiaco WWTP. At present complaints are received from residents living up to 1800 m from the plant boundary, and it will require a substantial reduction in odour emissions to eliminate complaints from residents outside the 600 m buffer zone distance.

A third conclusion is that there are recorded complaints from all sectors of the compass around the two plants in which there are residences. This indicates that winds of low speeds, which cause conditions with reduced odour dispersion and hence odour problems, occur at times in every direction from the treatment plants. While low speed winds more commonly come from the east sector, leading to a greater frequency of odour complaints from Beenyup residents west of the plants, ALL sectors of the compass have complaints and therefore must have occurrences of low speed winds.

6 Measured Wind Conditions

Wind speed and direction are measured and recorded at Subiaco WWTP but the wind speed records are kept only for the last 14 days. One year wind records for various sites were available from the Bureau of Meteorology; the records for sites at Swanbourne (between Subiaco and the coast) and Perth Airport (well inland of Subiaco) were used. In addition, the wind file for Kwinana (used in earlier odour modelling for the Subiaco plant) also was obtained and checked.

6.1 Frequency of Low Wind Speed Conditions

As noted earlier, winds of low speeds cause conditions with reduced odour dispersion and hence correspond to odour problems. In the Meteorological Bureau files, winds of very low speed (less than 1 km/hour) are recorded as 'calm'.

The frequency of calm conditions recorded at Perth airport (13 to 26 per cent of mornings) is much higher than at Swanbourne (1 to 2 per cent of mornings). To some extent, this may reflect differences in wind measuring equipment; however it is normal for calm conditions to be recorded more frequently at an inland site than on the coast. Subiaco is close to but somewhat inland from Swanbourne, and thus the proportion of calm conditions at Subiaco would be intermediate between Swanbourne and Perth Airport.

Calm winds do not have an associated direction. To establish the direction pattern of low speed winds, the frequency distribution of 1 to 10 km/hr winds was examined. Tables 1 and 2 show the frequency of these low speed winds as recorded by the Bureau of Meteorology at Swanbourne and Perth Airport, respectively, for each of the eight wind direction segments.

Table 1. Monthly Distribution of Low Speed Winds at Swanbourne (1993/2001)

Month	N	NE	E	SE	S	SW	W	NW
January			1	1	2		1	
February			1	2	1			
March		1	1	2	2	1	1	
April		1	3	2	2	1	1	1
May	1	1	4	2	2	1	1	1
June	1	3	4	2	1	1	1	1
July	1	1	3	2	1	1	1	
August	1	2	3	2	1	1	1	1
September	1	1	3	3	1	1	1	
October			2	2	1	1		
November		1	1	2	2	1	1	
December			1	1	1	1		
Average	**<0.5**	**1.4**	**2.2**	**1.9**	**1.4**	**<1**	**<1**	**<0.5**

Table 2. Monthly Distribution of Low Speed Winds at Perth Airport (1944/2001)

Month	N	NE	E	SE	S	SW	W	NW
January	1	1	3	2	6	4	1	
February	1	2	4	3	5	4	1	1
March	1	2	4	3	5	4	2	1
April	3	4	5	3	5	4	2	1
May	4	9	5	2	3	3	2	1
June	6	11	5	1	2	2	2	1
July	5	10	4	1	3	2	2	1
August	5	9	4	1	3	3	2	2
September	4	6	3	2	5	3	2	1
October	2	4	3	2	6	4	2	1
November	1	2	2	2	6	4	2	1
December	1	1	2	2	6	4	1	1
Average	**2.8**	**5.0**	**3.6**	**2.0**	**4.6**	**3.4**	**1.8**	**1.0**

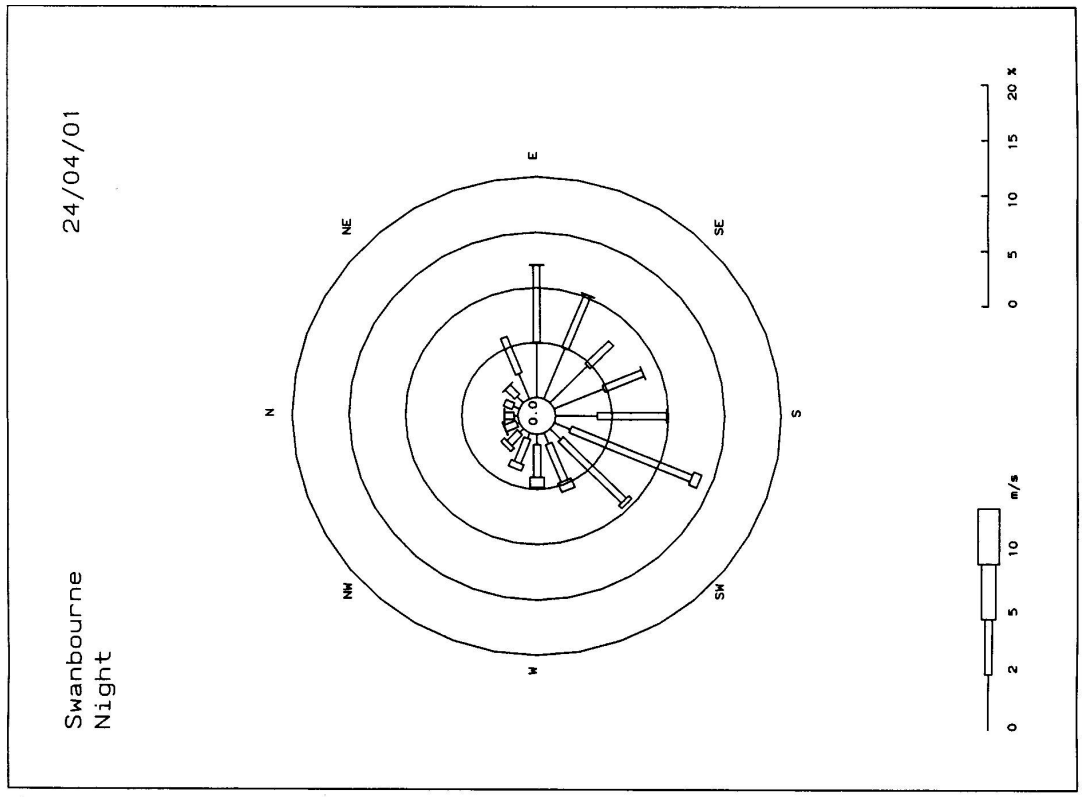
The wind records show that low speed winds are recorded at both Swanbourne and Perth Airport for all segments of the compass. Thus the widespread distribution of low speed winds reflect the complaints record; all sectors of the compass have occurrences of low speed winds and all sectors of the compass (with residences) have complaints.

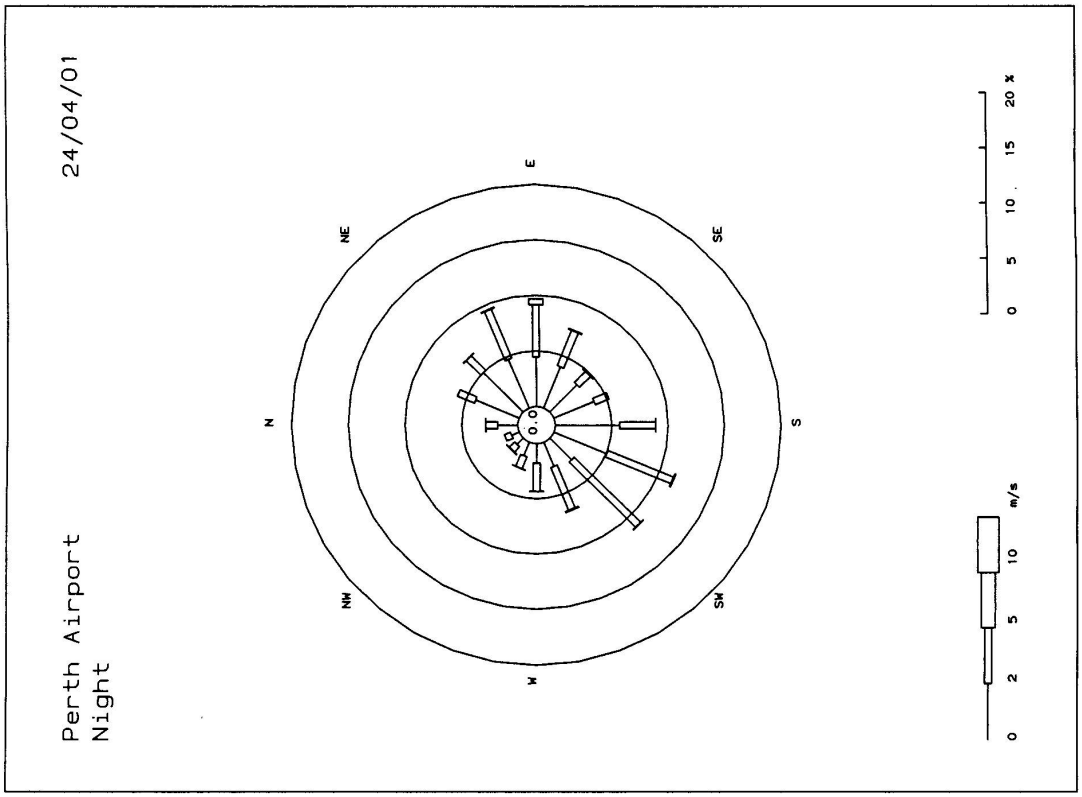
Low speed winds (and odour complaints) occur more commonly at night than during the day. Figures 4 and 5 show the wind roses for night conditions (7 pm to 7 am) for both Swanbourne and Perth Airport sites. The wind roses show that low speed winds and hence odour problems can occur in all segments of the compass (but with fewer complaints to the south of the plants)

At Swanbourne, low speed winds (less than 2 m/s or 7 km/hr) occur for less than 0.5 per cent of hours from the north, but from 1 to 5 per cent of hours from the southwest, south, southeast and east directions.

At Perth airport, low speed winds occur for less than 0.5 per cent of hours from the northwest, but from 1 to 6 per cent of hours from the west, southwest, south, southeast, east and northeast directions.

The distribution of low speed winds in the wind roses confirm the pattern of odour complaints around Subiaco and Beenyup plants.





Figures 4 and 5. Wind Roses for Night Conditions (7 pm to 7 am) for Swanbourne and Perth Airport

6.2 Wind Directions at Subiaco WWTP

As noted above, wind direction is recorded at Subiaco WWTP but not wind speed. The station is now being upgraded by the Water Corporation so that both wind speed and wind direction at 30 minute intervals are stored. A new low level (6 m elevation) wind monitor is also being installed to record winds near the level of the odour plumes.

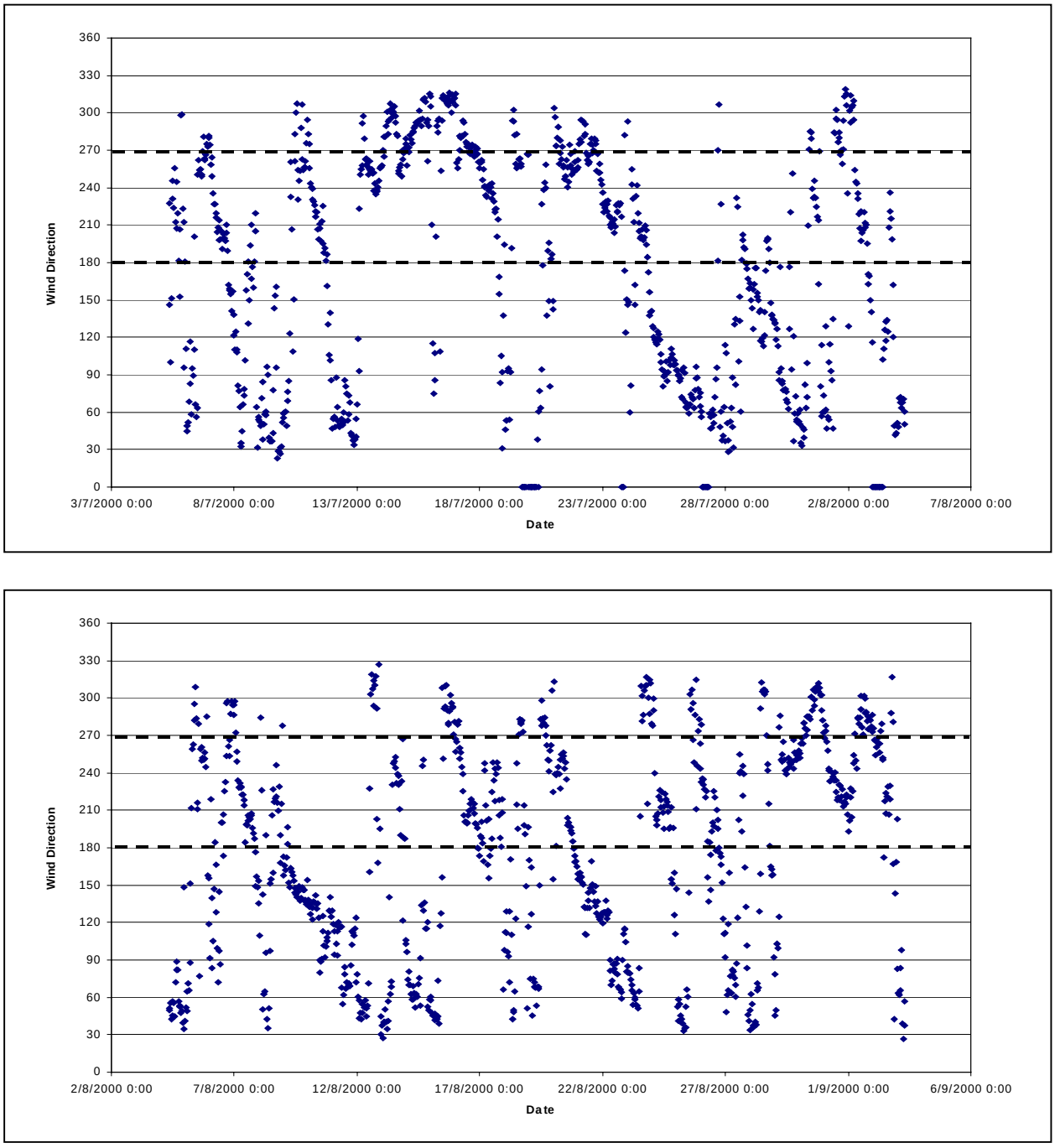


Figure 6. Wind Directions at Subiaco in July 2000 (Upper Graph) and August 2000 (Lower Graph)

The records of wind direction at Subiaco WWTP over the last 12 months were obtained and inspected. July and August were typical months and are reproduced in Figure 6. The Subiaco WWTP wind direction records show that there are a significant number of hours in which winds blow across the plant and carry odour to the land to the north and northeast (winds from 180 to 270 degrees, see Figure 6).

The wind pattern at Subiaco features periods of relatively weak winds which rotate in direction over several days from northwest through south to northeast (see Figure 6). These wind patterns expose large zones around the plant to odours over a period of several hours. This finding reinforces the need to use site-specific wind records in evaluating odour nuisance and odour control measures.

There may be only six to ten such events per year, but they are likely to be associated with significant odour nuisance. The 99.9 percentile odour calculation (8 hours per year limit) would include such events; however the 99.5 percentile odour calculation (44 hours per year limit) may miss these events.

6.3 Comparison of Kwinana, Swanbourne and Perth Airport

Low evening and night time wind speeds accompanied by average to high odour emission rates are the cause of high odour levels in the area surrounding the treatment plants, and thus of odour complaints. The number of the events of low speed winds is an indication of the potential for episodes of high odour levels. Table 3 lists the number of low wind speed events in the wind files prepared for odour modelling based on recorded wind speeds at Perth Airport, Swanbourne and Kwinana (Hope Valley). The table clearly shows that low speed winds of 0.5 m/s or less are seldom recorded at Kwinana whereas these speeds are common at Swanbourne and frequent at Perth Airport.

Table 3. Number of Hours with Low Speed Winds

Wind speed Range	**Number of hours per year**		
	Perth airport	**Swanbourne**	**Kwinana**
0 to 0.5 m/s	298 hours	152 hours	20 hours
0.5 to 1 m/s	411 hours	244 hours	83 hours

The Kwinana wind file underestimates low wind speed conditions at Subiaco WWTP. In addition, if the 99.5 percentile limit is adopted as the odour criterion, then **no** 0.5 m/s events will be considered using the Kwinana wind file (as there are less than 44 hours per year of these speeds) whereas 0.5 m/s will be the governing 99.5 percentile wind speed using the Swanbourne and Perth airport wind files. Use of the 99.9 percentile frequency limit in modelling provides a greater degree of confidence that the peak odour conditions experienced by residents are predicted.

It is considered that the Swanbourne file provides a more representative description of near-ground winds at Subiaco.

7 Odour Objective

Experience at other major treatment plants in Australia has shown that there are no complaints outside the 99.9 percentile 2 to 3 OU contour (free choice odour method) predicted by an odour dispersion model using conservative odour emission rates. This would correspond to about 5 OU using the forced choice measurement method.

The WA EPA Draft Guidance Statement on assessment of Odour Impacts (Statement No 47 issued in April 2000) has defined an odour limit of 2 OU (CEN or forced choice method).

The Guidance Statement advises that:
"The EPA deems that the appropriate averaging time for odour impact assessment is one hour, and the corresponding percentile compliance is 99.9 %".

The Guidance Statement also requires that odour impact assessments shall include a "**reasonable worst case assessment of odour emissions**".

This is a conservative odour guideline which when implemented would result in minimal odour nuisance. The use of 99.9 percentile compliance is justified unless the local wind conditions or the absence of complaints shows that a more lenient criterion is justified.

Comparison of 99.9 % and 99.5 % Limits

The 99.9 percentile limit means that odours can exceed the defined limit of 2 OU for only 8 hours per year in each direction from the treatment plant. For the wind conditions at Subiaco, this means that, in the region surrounding the plant, the odour level could exceed 2 OU for up to 100 hours per year, although only 8 hours per year at any particular location. Using the Swanbourne wind file, if the 99.9 percentile odour level is 2 OU, the maximum odour level should not be more than about 4 OU. This level is below the level of odour complaint for all except the most sensitive residents.

On the other hand, the more lenient 99.5 percentile limit would mean that odours could exceed the defined limit of 2 OU for 44 hours per year in each direction from the treatment plant. For the wind conditions at Subiaco, this means that, in the region surrounding the plant, the odour level could exceed 2 OU for up to 500 hours per year, although limited to 44 hours per year at any particular location. Using the Swanbourne wind file, if the 99.5 percentile odour level is 2 OU, the maximum odour level could be about 12 OU. This is within the level of odour complaint from most residents.

Subiaco happens to be a site for which there is a large difference between the 99.5 and the 99.9 percentile odour prediction. In such cases, the conservative decision is to use the 99.9 percentile limit unless there are reasons (eg, no complaints) to adopt a more lenient approach.

8 Odour Modelling

8.1 Odour Model

Odour modelling for this assessment has been carried out using the following procedure:

- Ausplume Model version 5.1 as issued by the Victorian EPA;
- 1-hour averaging time and CEN odours, as defined by the WA EPA;
- Odour emission rates based on measurements and assessments as described below;
- Ground-following winds with no significant influence of terrain;
- Four meteorological files (Swanbourne, Perth Airport, Kwinana and Low-Wind Speed);
- WWTP geometry from plans of the site; and
- Other model parameters (eg, roughness) to best suit the Subiaco WWTP area.

8.2 Odour Modelling Scenarios

Odour contours have been predicted and plotted for three scenarios or combinations of emissions:

1. Emission rates as measured by CH2MHill in 1999 and used in their December 2000 odour modelling report;
2. Emission rates developed by CEE to represent reasonable worst case conditions in 2001, based on a site inspection, previous measured data, reports by CH2MHill and experience at other comparable plants; and
3. Expected (target) rates developed by CEE to represent reasonable worst case conditions in 2004, based on advice from URS and the Water Corporation on the proposed $22 million odour control plan, a site inspection, previous measured data, reports by CH2MHill and experience at other comparable plants.

9 Odour Emission Rates

Table 4 summarises the odour emission rates for the three scenarios. For modelling, the larger area sources (eg, anoxic tanks or clarifiers) have been represented as multiple sources to preserve the actual spatial distribution of the emissions.

Table 4 also lists the odour emission rates measured at various times in 1996/2000 for various processes by CH2MHill. It can be seen that there is a considerable variation in odour emission rates from time to time. For example, the odour emission from the inlet scrubber was measured as 48900 OU/s on one occasion and 63500 OU/s on the second occasion, a difference of 30 per cent. Similarly, measurements of odour emissions per unit area of the secondary clarifiers ranged from 1.4 to 5.2 OU/m^2/s.

Table 4. Estimates of Odour Emissions for Three Scenarios

Odour Source	Odour Unit	Measurements	Odour Emission rate, OU/s		
			CH2MH 1999	CEE 2001	Target 2004
Inlet air chemical scrubber	OU/ m3	48900 63500	105,656	20,000	2,500
Pretreatment building	-	-	-	5,000	2,500
Screenings bin	OU	54 131	-	200	200
Grit bin	-	-	-	200	200
Raw wastewater channel	SOER	85 94	21,360	21,600	2,500
Primary sedimentation tanks	SOER	42,55 59,69	85,576	91,680	3,000
Future primary air scrubber	-	-	-	-	3,000
Anoxic secondary tanks	SOER	19,54 65,122	63,480	63,480	3,500
Future secondary air scrubber	-	-	-	-	3,000
Aeration tanks	SOER	1, 4, 4, 5, 6, 7, 12, 13	27,264	34,080	3,410
Mixed liquor Channel	-	-	-	2,190	2,190
Secondary clarifiers	SOER	1.4, 1.7, 3.6, 5.2	11,664	14,000	14,000
Soilbed filter for primary effl. Channel	-	-	-	500	250
Secondary sludge processing bld (DAF)	OU/ m3	410 5860	1476	5,000	2,500
OFS sludge drying building	-	-	-	18,000	3,600
Main door OFS building	-	-	-	4,000	1,400
OFS process building	-	-	-	2,000	2,000
OFS discharge stack	OU/ m3	30000, 42100, 44000	136,000	20,000	8,000
Biosolids storage (proposed future)	-	-	-	-	6,000
Return sludge pits	-	-	-	3,000	3,000
TOTAL ODOUR FLUX	**OU/s**	**-**	**452,476**	**304,930**	**66,570**

The total odour emission rate for Scenario 1 (CH2MH 1999) is 452,476 OU/s, which corresponds to the total odour emission rate used in the CH2MH reports of August 2000 and December 2000. Note that this odour emission rate is largely based on the **average** of the odour emission measurements.

It also reflects the odour emission situation following closure of the sludge digesters (recognized as a major source of odours in the mid-1990's) and installation of the new oil-from-sludge process (intended to produce useful sludge byproducts and replace the digesters).

The total odour emission rate for Scenario 2 (CEE 2001) is 304,930 OU/s. This is a 33 per cent reduction from the 1999 odour emission level as a result of improved controls on the scrubber treating odourous air from the inlet sewers and the oil-from-sludge process. However a small increase in odour emissions has been adopted for the primary sedimentation tanks, the aeration tanks and the secondary clarifiers, based on the **75 percentile** measured odour emission rate.

Some additional sources which were not included in the 1999 model have been included. Note that all sources may not emit at the peak odour rate at the same time; however the hour-by-hour emission rate is a refinement which will need to be examined in more detail at a later stage.

The total odour emission rate for Scenario 3 (Target 2004) is 66,570 OU/s. This is predicted odour emission level in the year 2004 assuming that the $22 million odour control plan works as expected, with additional controls and odour reductions from most of the existing sources. Allowance has been made for a future on-site storage of biosolids pellets but not for additional aeration tanks or clarifiers to cater for future growth in the catchment.

The predicted total odour emission rate for Scenario 3 of 66,570 OU/s represents a further 78 % reduction in odour emissions from 2001. As before, not all sources will emit at the peak odour rate at the same time; however the hour-by-hour emission rate is a refinement which will need to be examined in more detail at a later stage.

The odour emission rates adopted for this report are generally similar to those derived by CH2MH but with some additional sources and changes in emission rates, based on more recent information.

Modern treatment plants include many return and recycling flows. Thus upsets in one process can quickly lead to problems in other processes. For example, an upset in the sludge dewatering process can lead to odourous liquids being transferred back to the primary tanks and then flowing through the rest of the plant. Thus in the event of a plant upset, it is possible for most treatment processes to be emitting odours at a high rate.

Figure 7 illustrates the change in the predicted total odour emission over time. It can be seen that there has been an estimated 30 per cent reduction in emission between 1999 and 2001. The proposed 2004 odour emission rate following the upgrading should reduce odour emissions by a further 78 per cent, to approximately one-fifth of the year 2001 levels. Odour contours should decrease in proportion to the reduction in odour emission rate.

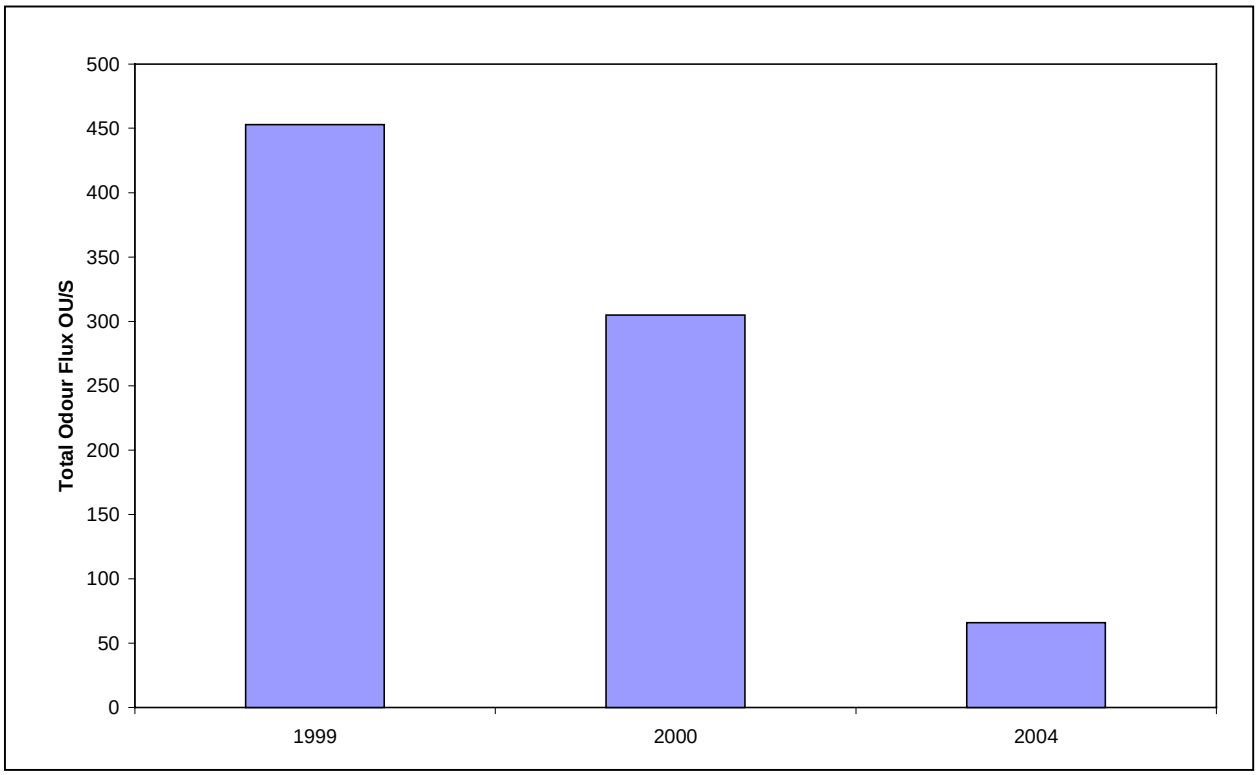


Figure 7. Predicted Total Odour Emission Rate

10 Predicted Odour Contours

A total of 17 odour model runs have been completed to establish the probable extent of odour impact around the Subiaco WWTP under various assumed emission and wind conditions. Plots of the odour contours for each run are given in Appendix A. The contours are plotted on an abbreviated AMG coordinate grid; for convenience in reference, a photo of the WWTP and northern buffer zone to the same scale also are shown on the contour plans.

Figure 8 shows the most likely odour contours in the area surrounding the plant following completion of the proposed upgrade based on the modelling done for this assessment. Odours are predicted at the 99.9 percentile level using the Swanbourne meteorological wind file and the year 2004 target emissions listed in Table 4.

The highest odour contour is 15 OU along the northern boundary of the plant. The 10 OU contour encircles that plant at a distance of about 500 m out from the plant boundary. Along Underwood avenue, the predicted odour level is 5 to 8 OU. The 5 OU contour extends into Floreat. This prediction strongly supports the need for a buffer zone.

The position of the 5 OU contour in Floreat indicates a need for refinement of the odour control plans to further reduce odours in this residential area. Further more detailed modelling has demonstrated that by moving the proposed sludge stockpiles and scrubbers to the south of the treatment plant site, and increasing the height of the scrubber stacks, it would be possible to reduce the extent of the 5 OU contour to the north to Underwood Avenue. These changes may have process implications and need to be examined by the design team before they are implemented.

The seventeen model runs and their rationale are as follows:

<u>Predictions of Odours in 1999 Using Various Wind Files</u>

1. CH2MH 1999 Emissions and Kwinana Winds
2. CH2MH 1999 Emissions and Low Winds
3. CH2MH 1999 Emissions and Swanbourne Winds
4. CH2MH 1999 Emissions and Perth Winds

<u>Predictions of Odours in 2001 Using Various Wind Files</u>

5. CEE 2001 Emissions and Kwinana Winds
6. CEE 2001 Emissions and Low Winds
7. CEE 2001 Emissions and Swanbourne Winds
8. CEE 2001 Emissions and Perth Winds

<u>Predictions of Odours in 2004 Using Various Wind Files</u>

9. Target Emissions and Kwinana Winds
10. Target Emissions and Low Wind File
11. Target Emissions and Swanbourne Winds
12. Target Emissions and Perth Winds

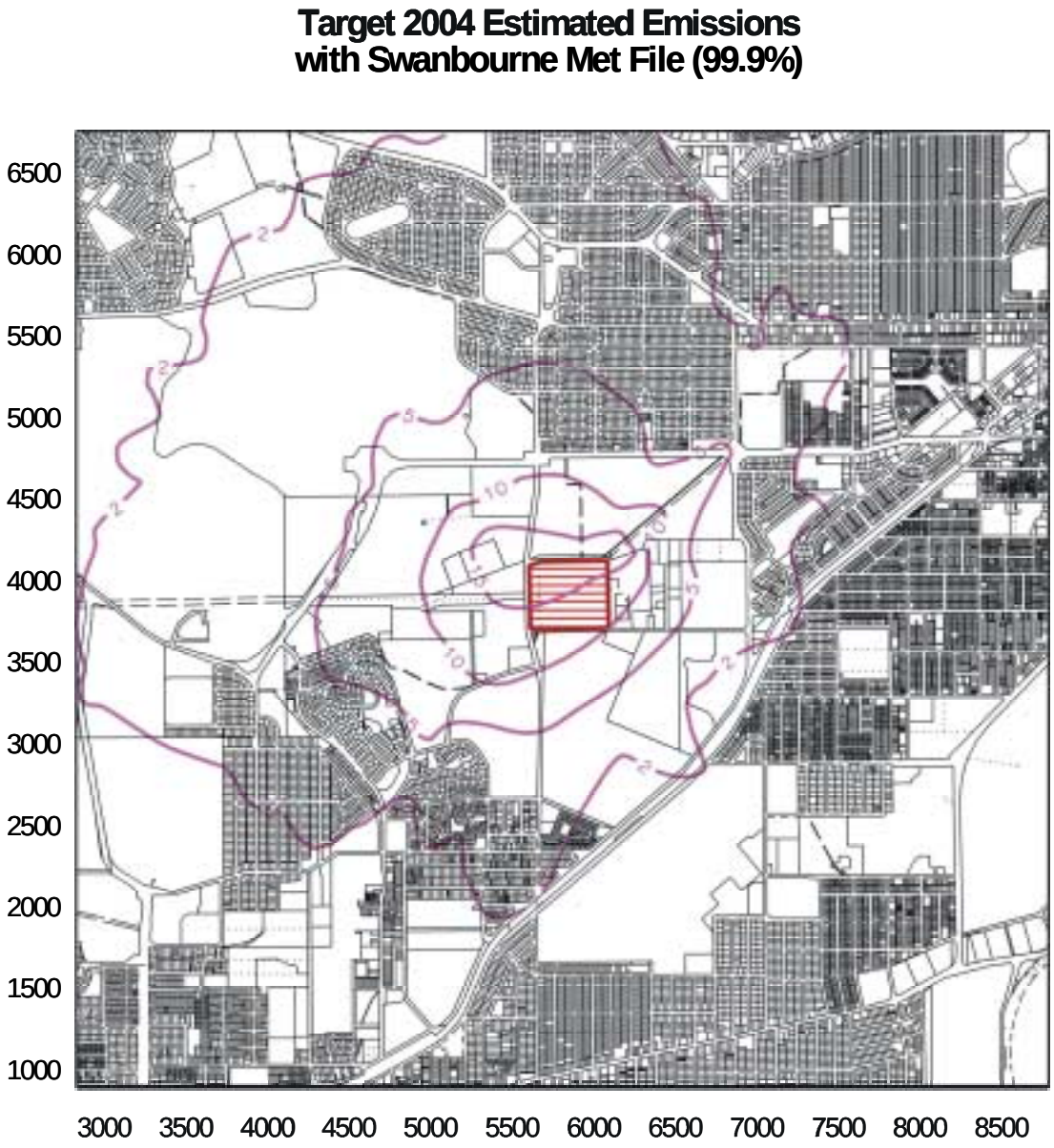


Figure 8. CEE Predictions of Odour Contours for 2004

The four wind files used in the odour modelling were the two Meteorological Bureau files (Swanbourne and Perth airport), the Kwinana file (used in previous Subiaco odour modelling) and a low-wind file (used to check the highest expected odour level in calm wind conditions). This wind file provides a reasonably conservative base case and indicates the maximum possible extent of odour impact. A smaller extent of impact can occur due to local wind or topographic features, but normally specific evidence would be needed to provide a reason for adopting a less conservative prediction.

Examination of Effect of Percentile Limit on Predicted Odours Using Kwinana Wind File

13. Target Emissions and Kwinana Winds (Maximum)
14. Target Emissions and Kwinana Winds (99.9%)
15. Target Emissions and Kwinana Winds (99.5%)
16. Target Emissions and Kwinana Winds (99.0%)
17. Target Emissions and Kwinana Winds (95.0%)

Table 5 summarises the predicted odour level in 1999, 2001 and 2004, for the four wind files examined, at two road intersections to the north and northwest of the Subiaco WWTP:

- West Underwood Avenue (Brockdale Road and Underwood Avenue)
- East Underwood Avenue (Selby Street and Underwood Avenue).

The predictions in Table 5 are discussed below.

Table 5. Peak Concentrations along Underwood Avenue

Receptor Location	**CH2MH 1999 Estimated Emissions**			
	Low Wind	Perth	Swanbourne	Kwinana
West Underwood Avenue	80	80	52	28
East Underwood Avenue	50	40	28	12
	CEE 2001 Estimated Emissions			
	Low Wind	Perth	Swanbourne	Kwinana
West Underwood Avenue	70	70	40	20
East Underwood Avenue	40	30	20	10
	Target 2004 Estimated Emissions			
	Low Wind	Perth	Swanbourne	Kwinana
West Underwood Avenue	12	12	8	4
East Underwood Avenue	9	8	5	2

CH2MH 1999 Estimated Emissions

The predicted odour levels with the CH2MH 1999 emission rates are very high for all four wind files used. The highest concentrations occur with the low-wind file, as would be expected, as it comprises 0.5 m/s winds in all directions with low ambient mixing (Class F stability).

The low-wind and Perth Airport wind files provide similar results, in terms of odour contours, because the Perth wind file contains many low speed winds and therefore mimics the low-wind file.

The Swanbourne wind file has fewer low speed winds and therefore predicts lower odour levels (at the 99.9 % frequency) the Perth airport file, while the Kwinana wind file contains even fewer low speed winds and therefore predicts even lower odour levels (at the 99.9 % frequency).

The CH2MH 1999 emissions were measured at a time of very large odour emissions from the inlet scrubber and the oil-from-sludge plant. The odour levels at Underwood Avenue are predicted to range from 28 OU to 80 OU. These odour levels correspond to a high level of nuisance and complaint, which is what is shown in the complain record. Nuisance odour possibly extended at times for 3 km north and 2 km east from the plant.

CEE 2001 Emissions

The predicted odour levels with the CEE 2001 emission rates are still high for all four wind files used. The low-wind and Perth Airport wind files predict 30 to 70 OU at Underwood Avenue. With the Swanbourne wind file the predicted odour level would be 20 to 40 OU, still well into the range of nuisance and complaint, which corresponds to the existing high number of complaints.

Target 2004 Emissions

The predicted odour levels with the Target 2004 emission rates are much lower. The low-wind and Perth Airport wind files predict 8 to 12 OU at Underwood Avenue, still likely to cause an occasional minor nuisance. With the Swanbourne wind file the predicted odour level would be 5 to 8 OU, which would be just perceptible, and possibly cause complaints only from sensitive residents (see Figure 8).

As explained above, further more detailed modelling has demonstrated that by changing the arrangement of process units, it would be possible to reduce the extent of the 5 OU contour to the north to Underwood Avenue. These changes are recommended for consideration by the Water Corporation.

It is of interest to note that the Kwinana wind file predicts 2 to 4 OU at Underwood Avenue, which is much less than the other wind files. This is a result of the small number of low wind speed hours in the Kwinana file. There is no reason to consider the Kwinana wind file more appropriate for the Subiaco WWTP than the Swanbourne wind file. Hence the Kwinana predictions are considered to be too low.

The odour modelling carried out by CEE confirms the predictions of CH2MH that the 5 OU contour will be close to the boundary of the WWTP IF all the odour controls work as effectively as predicted, the Kwinana winds also occur at Subiaco and there is no expansion or new treatment processes introduced at the plant. Unfortunately these assumptions are not realistic.

Based on the work to date, it is considered that the proposed expenditure of $22 million on odour control will reduce odour levels in the land to the north and northeast of the plant to 5 to 10 OU on a 99.9 percentile basis.

11 Assessment of Predictions

The WA EPA Draft Guidance Statement on assessment of Odour Impacts (Statement No 47 issued in April 2000) defines an odour limit of 2 OU (CEN or forced choice method) to be met 99.9 % of the time with a 1-hour averaging period. The predicted odour level depends on the percentile compliance required, particularly for the Kwinana wind file.

Table 6 summarizes the predicted odour level at the two Underwood Avenue intersections to the north and northwest of the Subiaco WWTP for six model situations:

1. 100 % predicted level for Kwinana wind file;
2. 99.9 % predicted level for Kwinana wind file;
3. 99.5 % predicted level for Kwinana wind file;
4. 99.0 % predicted level for Kwinana wind file;
5. 95.0 % predicted level for Kwinana wind file;
6. 100 % predicted level for low-wind file.

Table 6. Peak Percentile Concentrations along Underwood Avenue with Kwinana Met File

Receptor Location	**Target 2004 Estimated Emissions**					
	100 %	99.9 %	99.5 %	99.0%	95.0%	**Low Wind**
West Underwood Avenue	10	4	2	2	1	**12**
East Underwood Avenue	4	2	1	1	1	**9**

It can be seen that changing the percentile compliance from 99.9 % to 99.5 % reduces the predicted odour level by a factor of two. This is a particular result of the Kwinana wind file, which has few low speed winds. In comparison, the Perth wind file predicts much the same 99.9 % and 99.5 % odour levels.

The 99.5 % odour levels are only a small fraction of the predicted maximum odours for the Kwinana wind file and the low-wind file. Thus they are considered to be incorrect.

In deciding what are the likely future levels of odour on the buffer zone between the Subiaco WWTP and Underwood Avenue the following factors need to be considered:

- Local wind data are not available, with the best estimate being somewhere between the Swanbourne and Perth Airport wind files.
- Emission rates are still mostly estimates and need to be confirmed by measurement;
- Even when large tanks are covered, part of the covers will be open or removed for regular maintenance each week day and all of the covers will be removed for maintenance on a few days per year.
- Reasonable allowance must be made for changes in process technology and the pressure to reduce chlorine use and reduce energy consumption.
- Allowance must be made for the expected number of low speed near-ground wind events at the Subiaco plant.
- The hour-by-hour variation and peak day odour emission need to be considered further.
- There will be increasing production and storage of useful byproducts on the site, to maximise waste reuse.

For the land north and northeast of the Subiaco WWTP, it is considered that for the foreseeable future the 99.9 % odour level will be 5 to 10 OU along Underwood Avenue, at the northern boundary of the land, and 20 to 30 OU at the boundary at the Subiaco treatment plant (after the proposed upgrade has been completed). These levels are above the acceptable levels for residential development.

12 Previous Predictions

It is appropriate to relate the odour predictions of CH2MHill and Chester Consulting to those developed in this study.

The 1999/2000 CH2MHill study was designed to establish the major odour sources and to relate complaints to odour contours. The difficulties inherent in this work are illustrated by the measured increase on odour emission between 1996 and 1999 (from 279,201 OU/s to 452,476 OU/s) over a period in which the apparent major source of odours in 1996 (the sludge digesters) were closed.

The CH2MHill study recommended that the 5 OU, 99.5 % frequency, 3-minute average criterion be used as the basis for the development of an odour buffer zone around the plant, with an additional 'safety margin' of 100 m to the north, east and west, and 200 m to the south. The CH2MHill findings are considered reasonable as a basis for engineering design but not as a basis for defining a planning buffer zone, for the following reasons:

1. The odour model used average and not worst case emissions;
2. The odour model did not include all existing sources of odour;
3. The odour model did not allow for covers being open during routine maintenance or for known new odour sources;
4. The Kwinana wind file was used; however it is not representative of the Subiaco site and is inherently non-conservative as it has few hours of low speed winds;
5. The 99.5 % frequency allows 44 hours per year of high odours (or, for example, 11 events each of 4 hours per year) which is too many events given the wind conditions which cause odour complaints near the Subiaco WWTP;
6. The interpretation assumed that complaints are related in a linear fashion with odour which is yet to be demonstrated for the site;
7. Neither the Subiaco WWTP nor the Beenyup WWTP (both treating septic sewage) have been able to operate to date without regular complaints from beyond a 1000 m buffer distance. Hence there is no evidence that a buffer distance much smaller than 600 m is feasible in the foreseeable future.

The December 2000 report by Chester Consulting recommends a much more extensive and costly odour control program than that proposed by CH2MHill, stating that "All uncovered wastewater treatment processes should be covered". Chemical scrubbers also are recommended. The Chester report concludes that "It can confidently be predicted if the odour control works are installed as described and performance continually monitored and improved, odour contours will be reduced and if necessary, the installation of an activated carbon polishing plant would reduce the 5 ODU contour to the boundary of the plant." This prediction is made without an odour emission inventory or an odour model, and is speculation rather than a prediction.

Proposals for Upgrading Odour Management at Subiaco WWTP

The proposals made by Chester Consulting (2000) for management of odours at Subiaco WWTP are as follows:

- Install microclimate weather station (being implemented);
- Scrubber for head of works (implemented);
- Cover all uncovered treatment processes (planned for primary sedimentation, anoxic and aeration tanks, but not for secondary clarifiers, being considered for future biosolids stockpiles)
- Oil from sludge air to be scrubbed (equivalent odour control implemented);
- Use activated carbon scrubbers (being considered).

The proposals made by Air Water Noise Consultants (2001) for management of odours at Subiaco WWTP are as follows:

- Automate inlet chlorine dosing (dosing now automated by time and flow rate);
- Examine effectiveness of existing scrubber systems (being done);
- Upgrade effectiveness of inlet scrubber and biofilter (being done);
- Collect more samples to assess odour emissions (being done);
- Investigate and upgrade odour control in oil from sludge process (being done);
- Provide odour control systems (covers and scrubbers) for major odour sources (being implemented).

It can be seen that the odour management plan by the Water Corporation is addressing the proposals suggested by these consultants. Further refinement of the design of the Subiaco odour management system is underway. The resulting system should provide effective odour control.

13 Best Practice Management

For the Subiaco WWTP, it is considered that a buffer zone to Underwood Avenue is essential for the foreseeable future, even with 'best practice' management of odours, recognizing the likely environmental pressures on plant performance and operations in the future.

14 Other Needs for Buffer Zones

A buffer zone protects a treatment plant from the encroachment of inappropriate land uses, and also protects residents from the risks of living close to a treatment plant. The risks encompass odour nuisance and several other possible circumstances:

1. **Flammable or dangerous liquids in sewer.** The Subiaco plant is at the downstream end of all the sewers in the CBD and southwestern Perth. Thus there is a potential for accidental spills or illegal discharges of dangerous liquids. The Water Corporation has evacuation procedures to protect the employees in the event of such circumstances; these procedures need to be complemented by a buffer zone, which prevents people from living close to the plant.

2. **Dangerous chemicals stored at the plant.** The Subiaco plant uses, with full authorization and safety precautions, a range of chemicals which are classed as hazardous materials to achieve the desired removal and processing of nutrients, wastes and sludge. A preliminary hazard analysis would indicate that a potential hazard exists and that the appropriate planning response is to provide a buffer zone around the areas of chemical storage and use.

3. **Consequences of chlorine leak.** Chlorine is a dense gas which is used to disinfect reclaimed water so it can be transported to reuse sites without regrowth of bacteria. In the event of a leak, the chlorine plume could be potentially injurious to health. It is acknowledged that there has not ever been a chlorine leak. However prudent planning would provide a buffer zone to ensure minimal risk to personnel in the event of a leak.

4. **Visual impact.** A sewage treatment plant has a large area of tanks, storages, processing facilities and stockpile that should not form part of the visual outlook of a residential or commercial zone.

5. **Noise.** A large sewage treatment plant uses a range of large pumps, blowers and other mechanical equipment to treat sewage and manufacture products for reuse. Acoustic shielding is provided as a matter of course, but a buffer zone provides protection against noise and vibration.

15 Recommendations

In terms of efficient resource use, the Subiaco WWTP represents a source of reclaimed water and biosolids. Planning should encourage land uses within the buffer zone that can use these resources for the benefit of the community, and reduce the discharge of effluent to the ocean.

The Subiaco plant requires a buffer zone, which extends to Underwood Avenue to the north and to the existing educational land uses to the east. The sporting grounds to the west and northwest, and the army base to the south provide reasonably compatible land uses and hence a buffer zone in other directions.

The recommended buffer zone for the Subiaco plant would not exclude any existing land use within the proposed buffer zone, but would exclude rezoning and development to any of the following land uses:

* Residential Dwelling Houses and any other form of accommodation;
* Restaurants;
* Entertainment, Accommodation and Leisure.

Compatible land uses within the buffer zone are being developed as a separate exercise by the Water Corporation. Examples of suitable land uses are as follows:

* Horticulture using reclaimed effluent;
* Nature reserve;
* Plantation forestry;
* Agriculture;
* Scenic buffer.

In terms of efficient land use, further consideration should be given to using the land within the buffer zone for activities, which make economic use of reclaimed effluent and biosolids.

Recommended Buffer Zone for Subiaco WWTP

The shape of a buffer zone in a developed urban area must reflect an appreciation of the adjacent existing land uses, potential future land uses which can be integrated with the buffer zone, cadastral boundaries and the skilled interpretation of the odour predictions. Based on these considerations, a buffer zone for Subiaco WWTP recommended for consideration by planning authorities is shown in Figure 9.

The recommended buffer zone excludes existing developed residential areas north of Underwood Avenue and to the southwest of the plant. The northern boundary of the buffer zone extends along Underwood Avenue. The eastern and southern boundaries follow a combination of the 5 OU contour and cadastral boundaries. The western boundary excludes the existing residential areas but includes the existing sporting ovals, and generally follows the 5 OU contour predicted in this assessment.

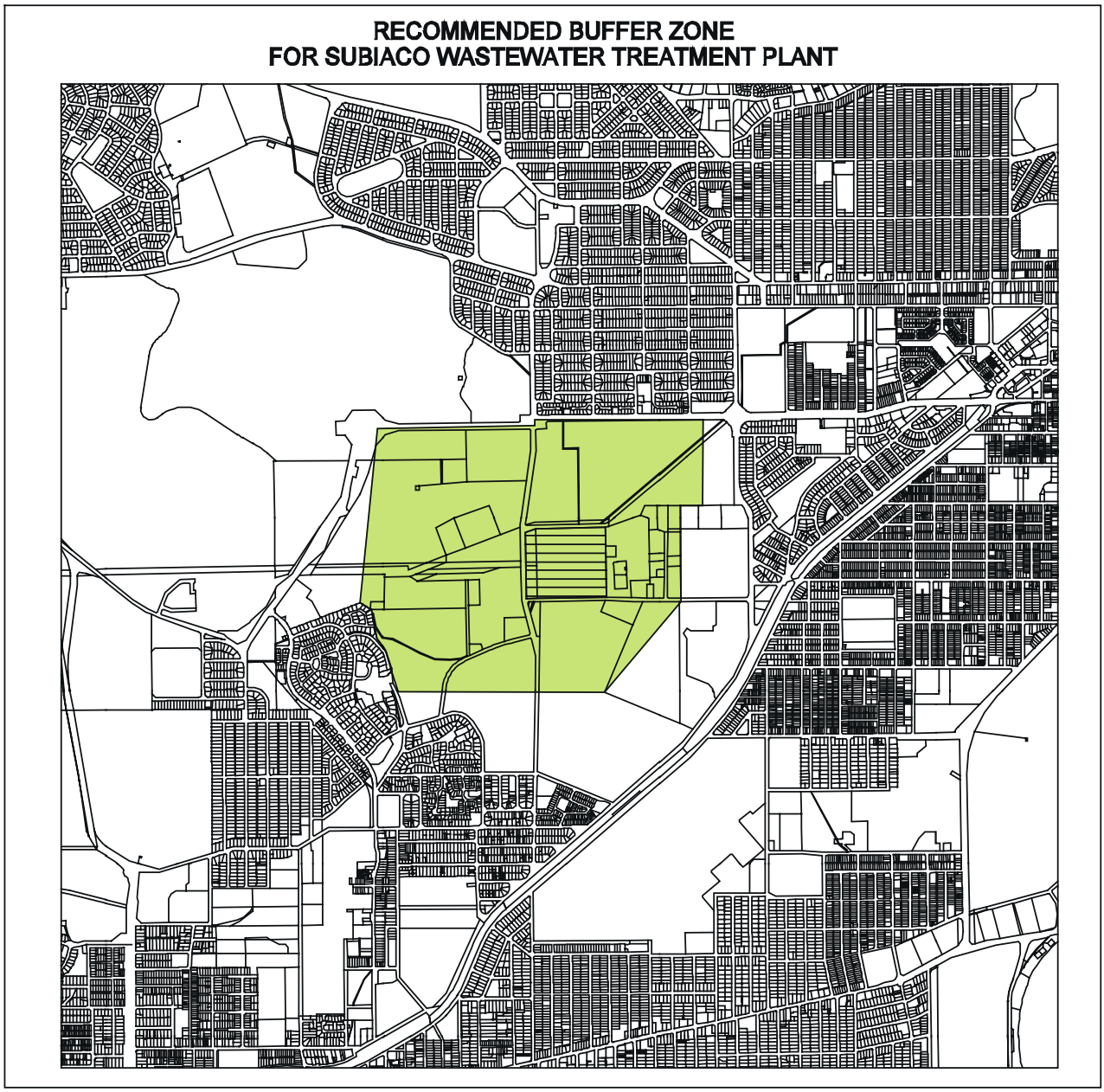


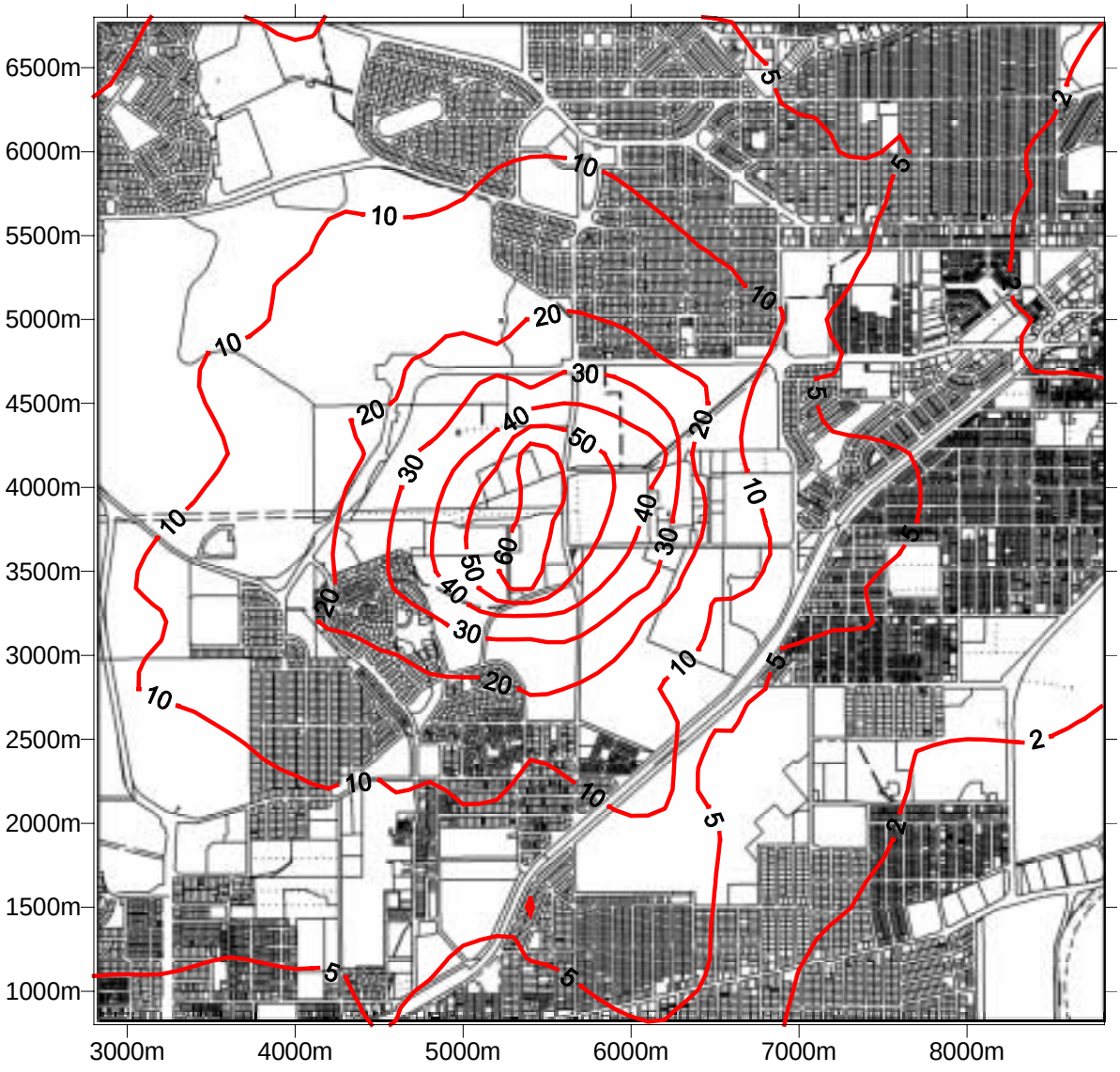
Figure 9. Recommended Buffer Zone for Subiaco WWTP

16 Appendices

PREDICTED ODOUR CONTOURS FOR

CH2MH EMISSIONS AND KWINANA WINDS

CH2MH 1999 Estimated Emissions with Kwinana Met File (99.9%)

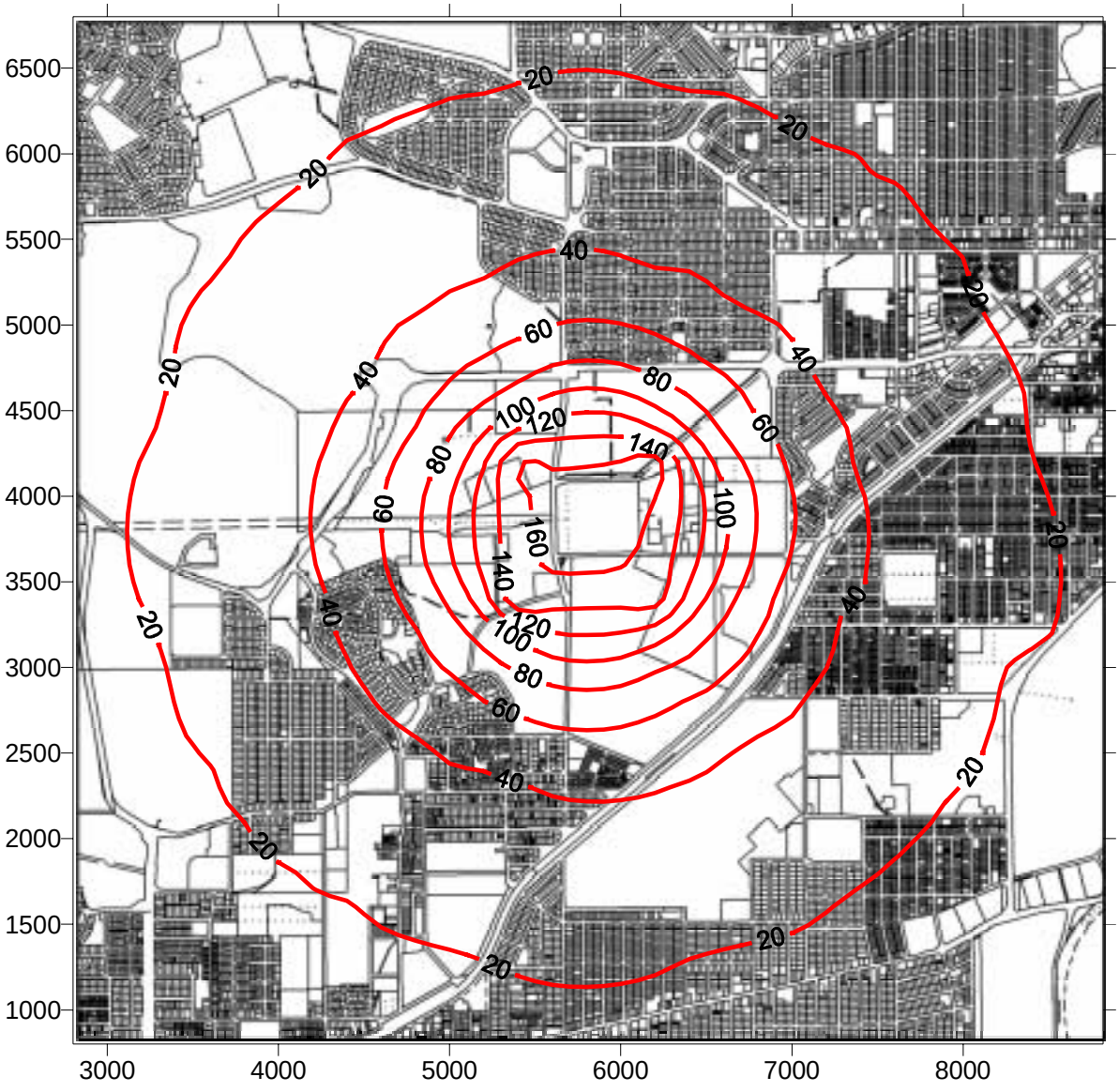


Conc. (Odour_Units); 1 hour avg.

PREDICTED ODOUR CONTOURS FOR

CH2MH EMISSIONS AND LOW WINDS

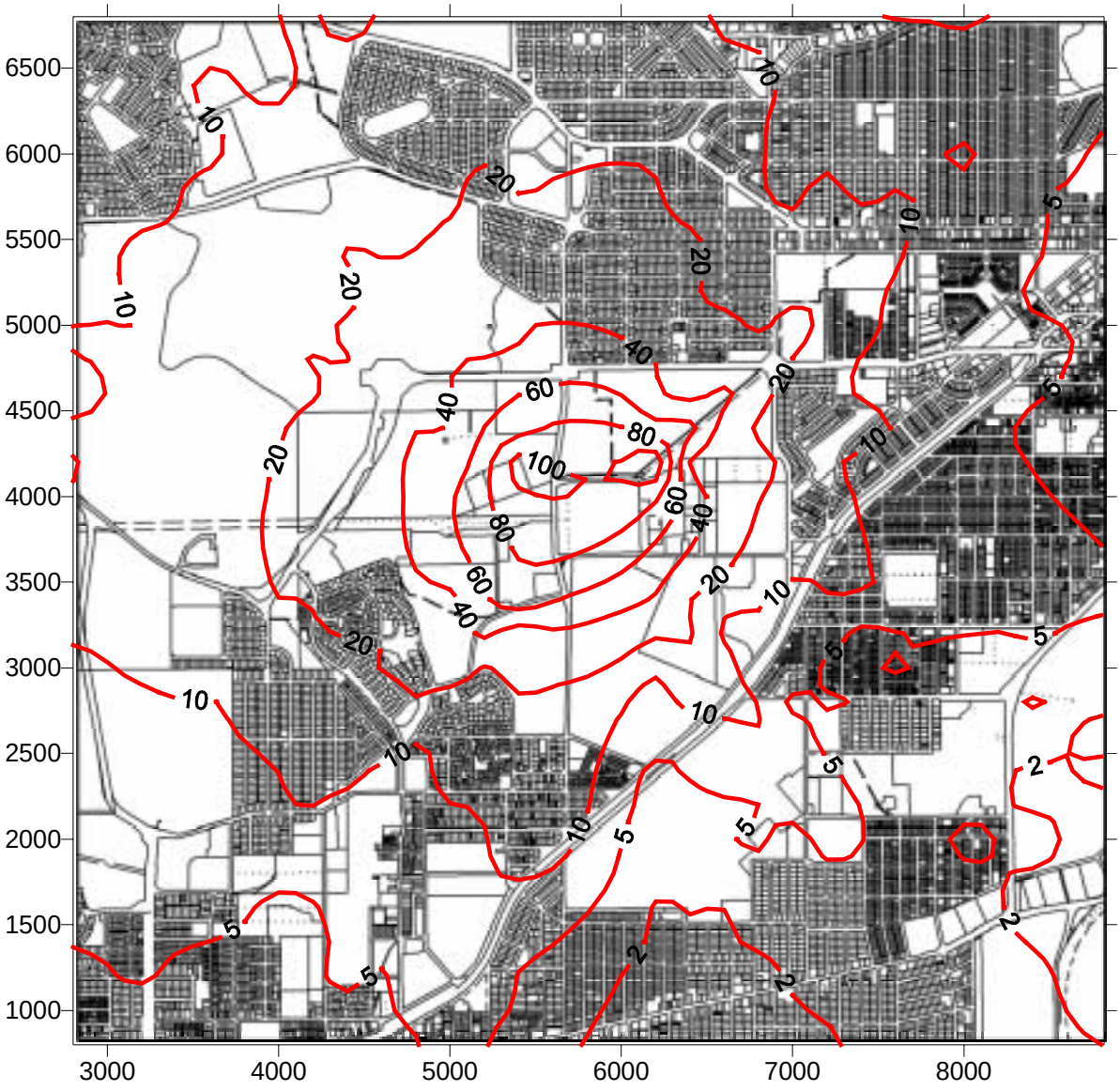
CH2MH 1999 Estimated Emissions with Low Wind Met Files (99.9%)



PREDICTED ODOUR CONTOURS FOR

CH2MH EMISSIONS AND SWANBOURNE WINDS

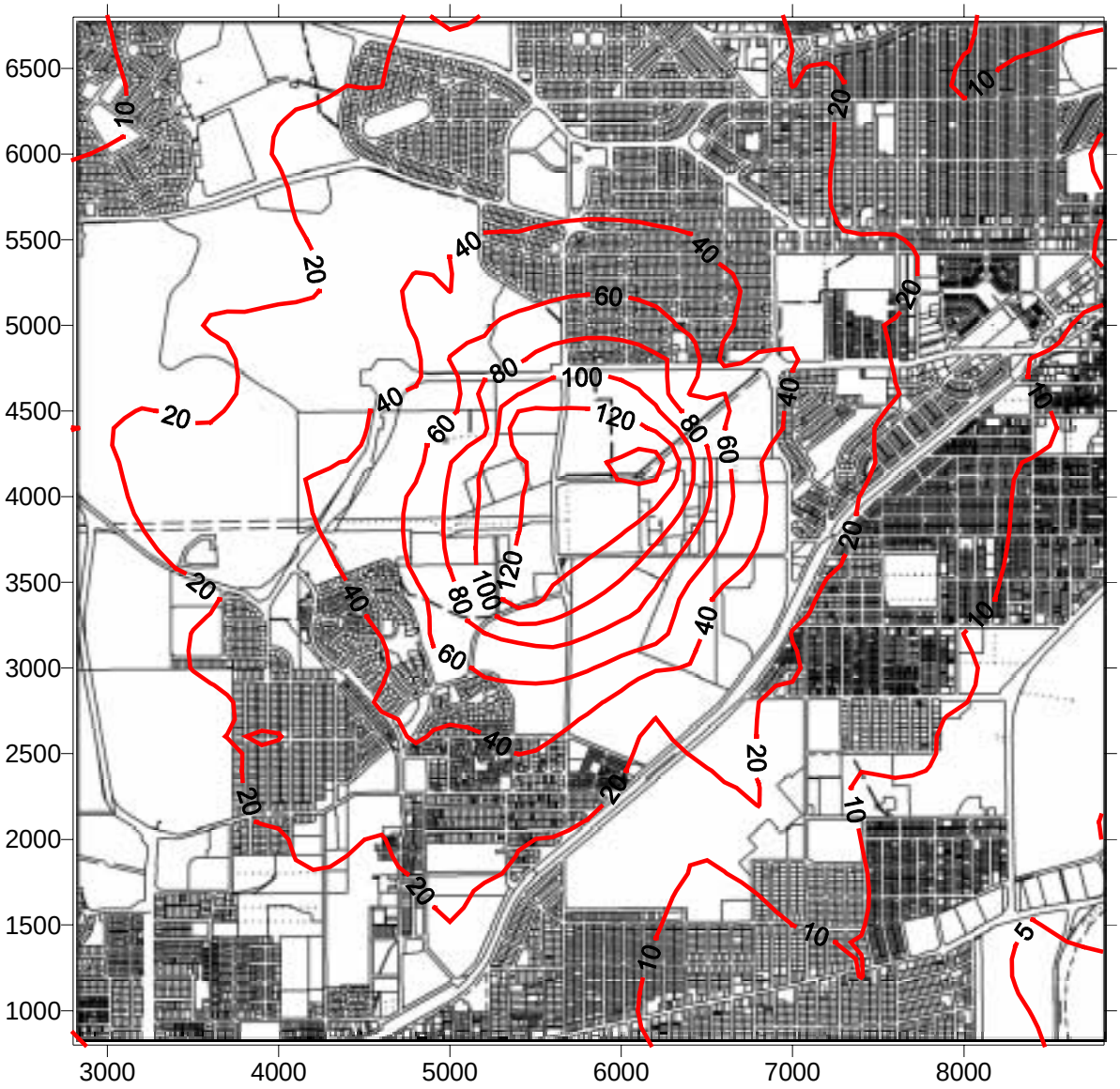
CH2MH 1999 Estimated Emissions with Swanbourne Met File (99.9%)



PREDICTED ODOUR CONTOURS FOR

CH2MH EMISSIONS AND PERTH WINDS

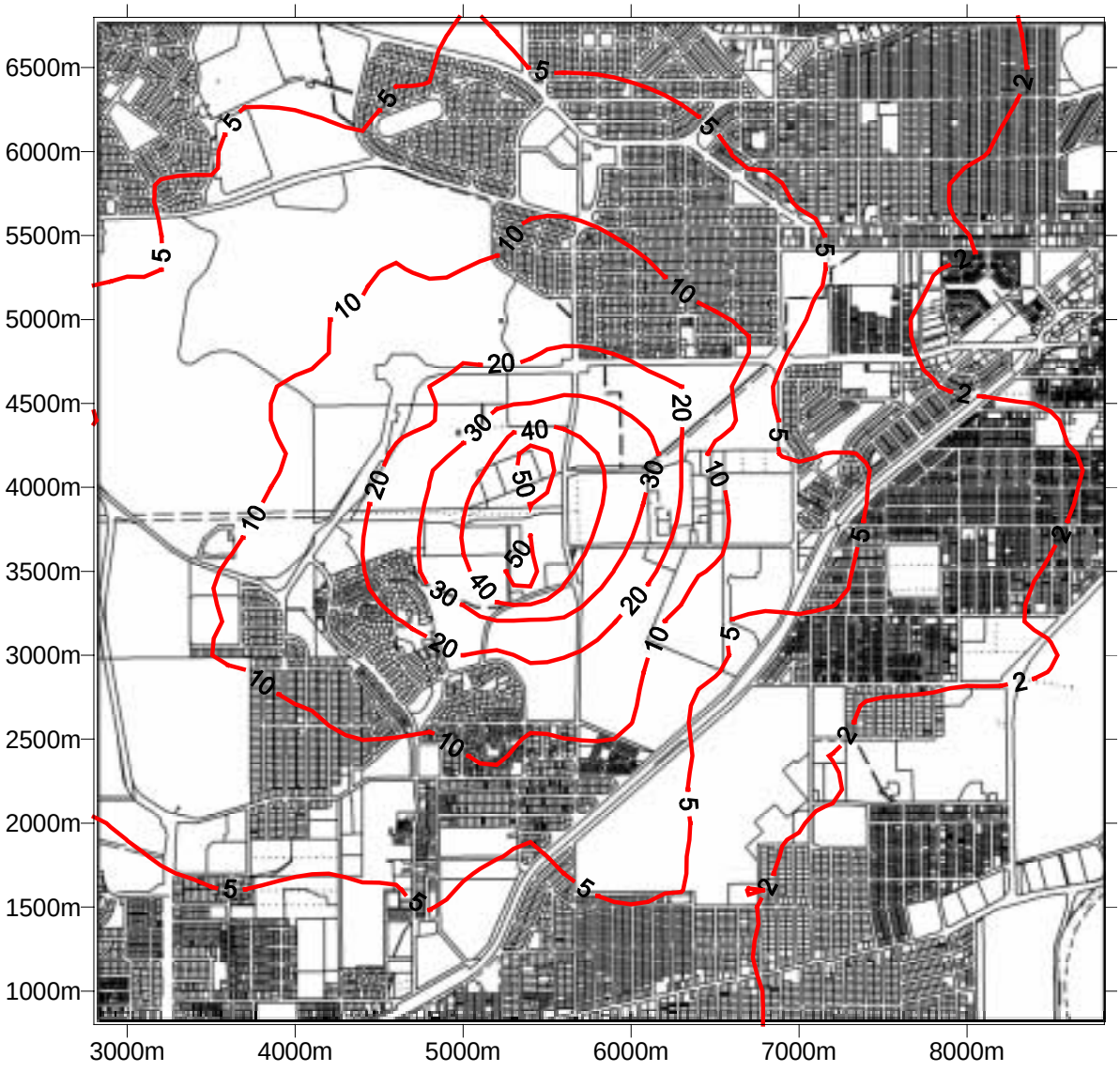
CH2MH 1999 Estimated Emissions with Perth Wind File (99.9%)



PREDICTED ODOUR CONTOURS FOR

CEE 2001 EMISSIONS AND KWINANA WINDS

CEE 2001 Estimated Emissions with Kwinana Met File (99.9%)



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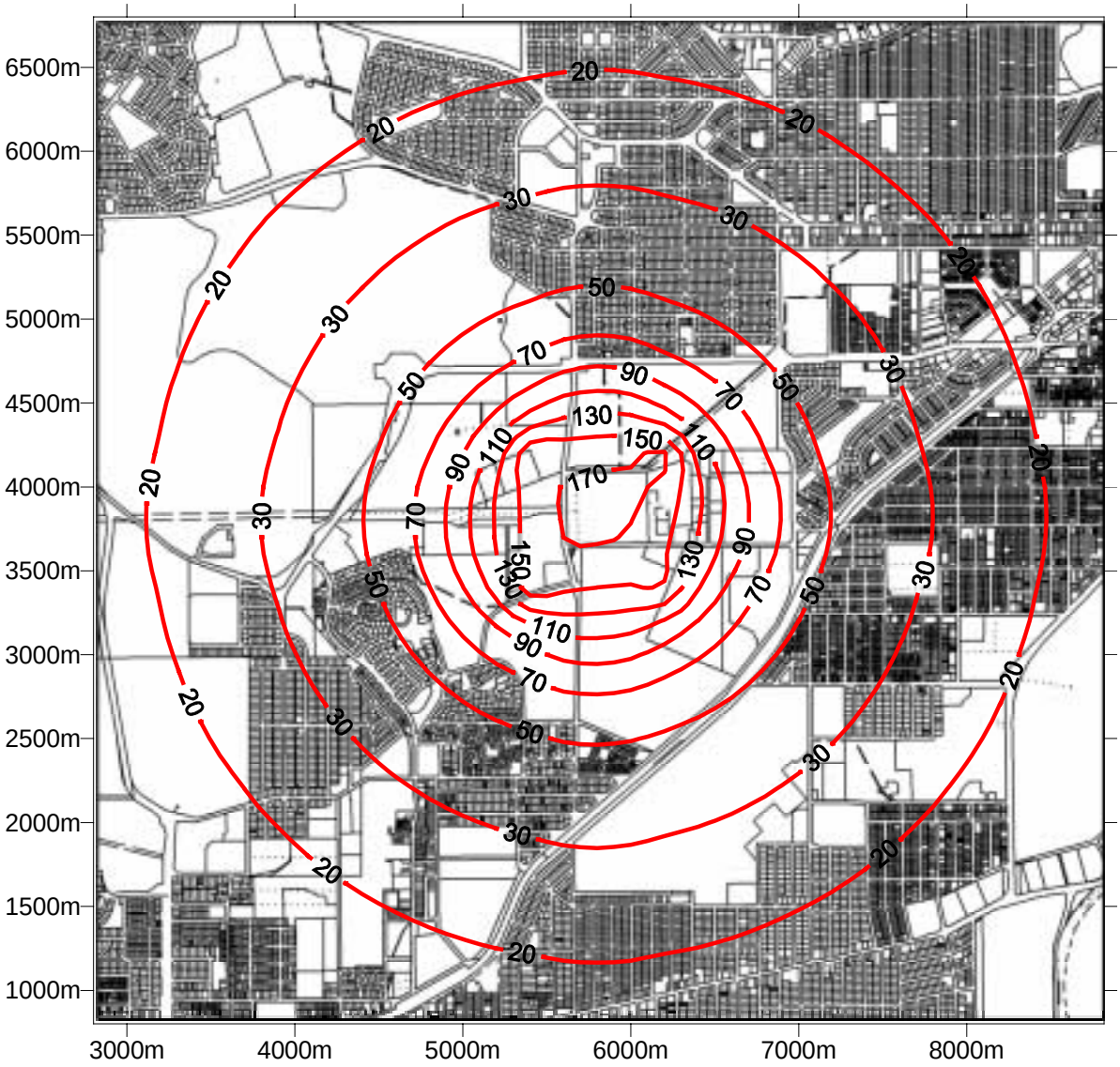
PREDICTED ODOUR CONTOURS FOR

CEE 2001 EMISSIONS AND LOW WINDS

CEE 2001 Estimated Emissions with Low Wind Met File (99.9%)

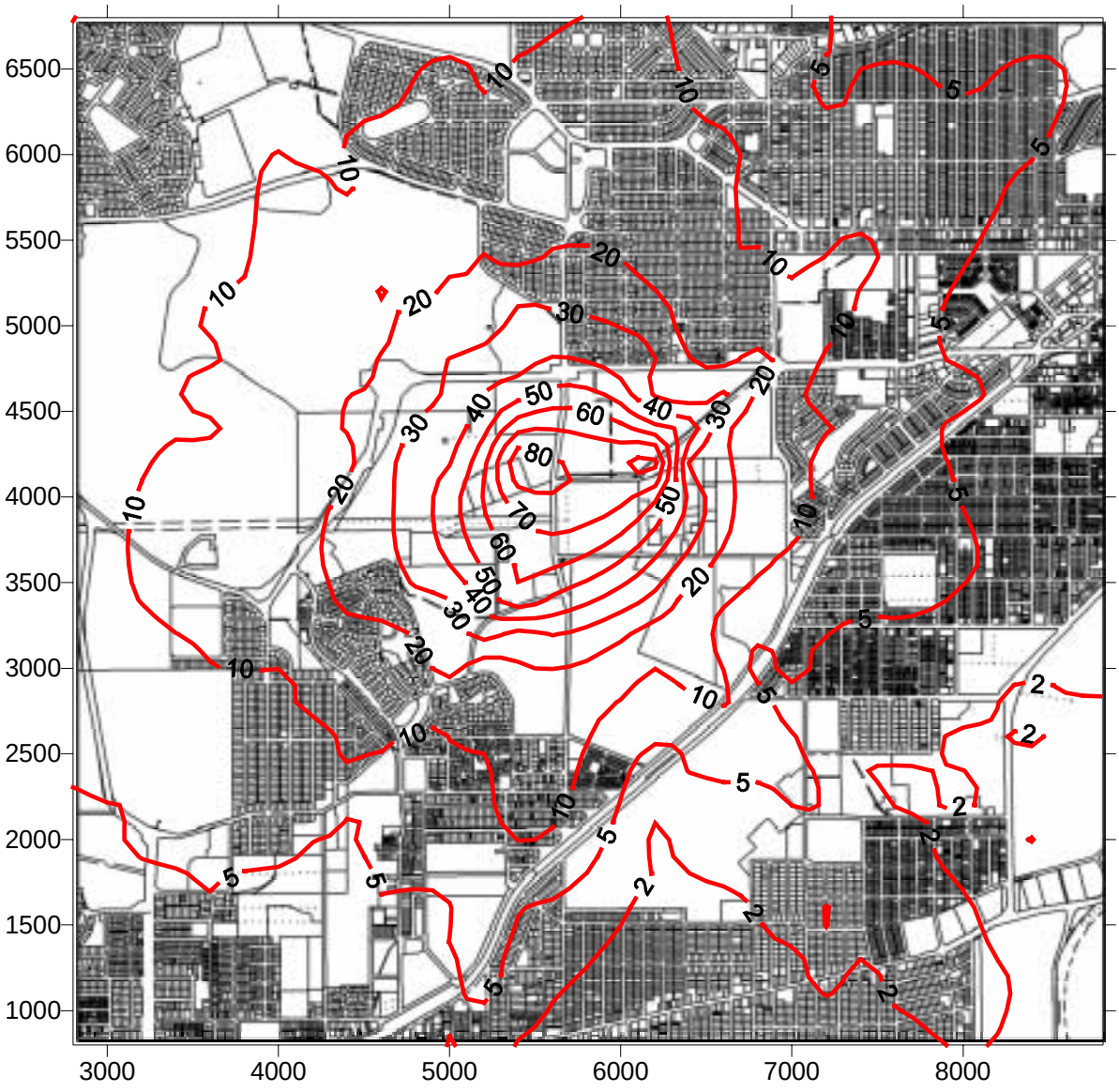


Conc. (Odour_Units); 1 hour avg.

PREDICTED ODOUR CONTOURS FOR

CEE 2001 EMISSIONS AND SWANBOURNE WINDS

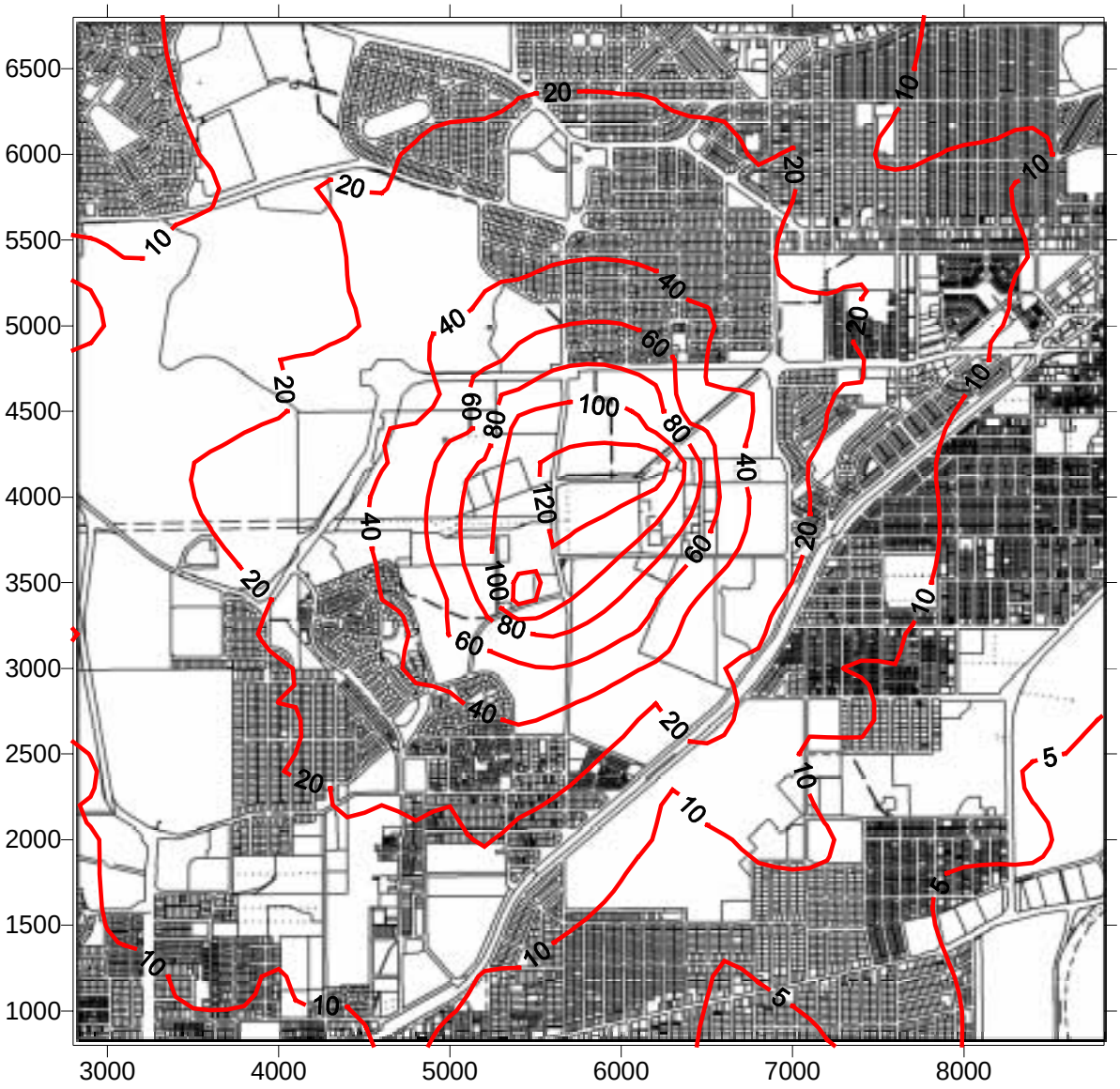
CEE 2001 Estimated Emission with Swanbourne Met File (99.9%)



PREDICTED ODOUR CONTOURS FOR

CEE 2001 EMISSIONS AND PERTH WINDS

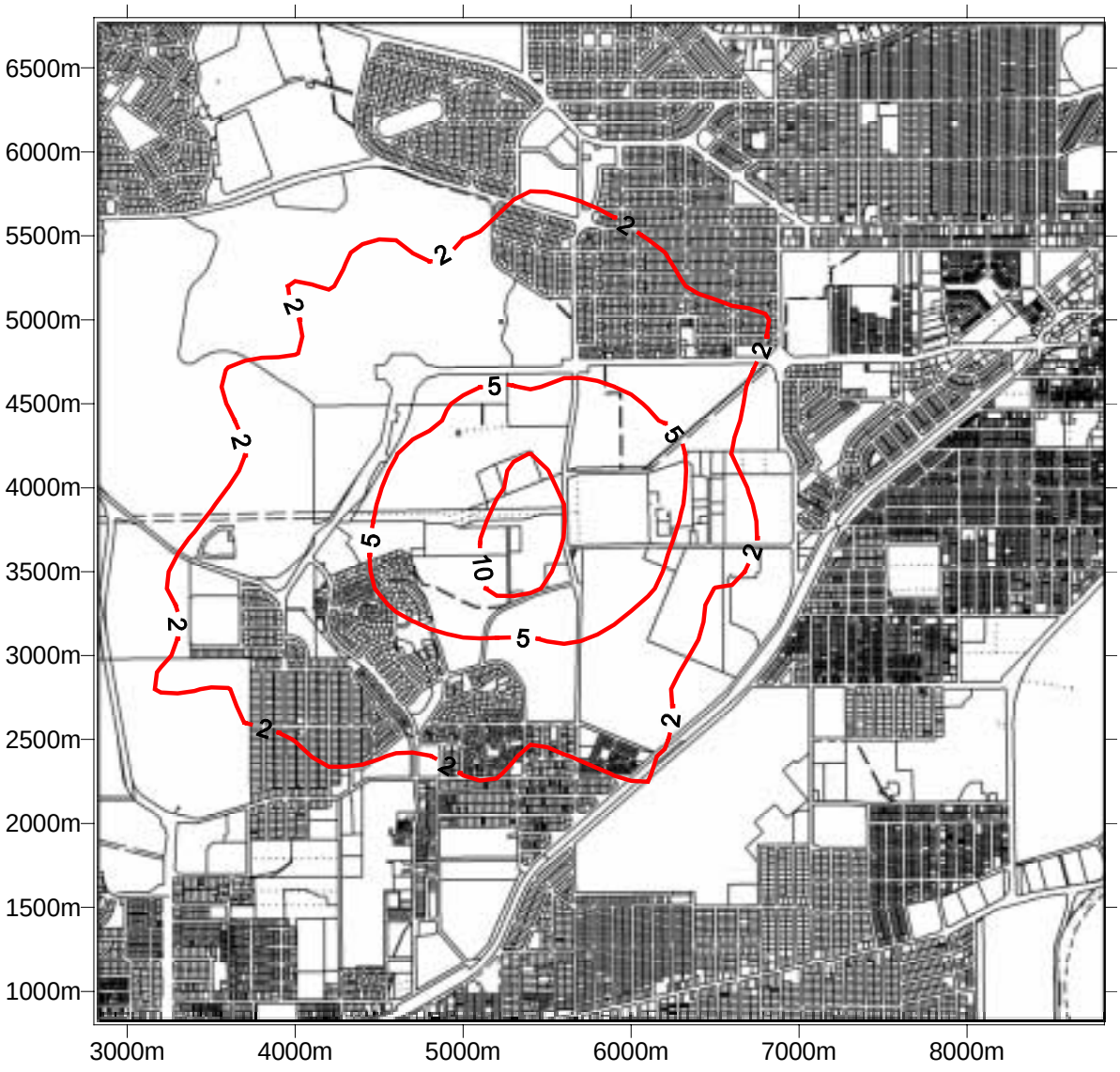
CEE 2001 Estimated Emissions with Perth Met File (99.9%)



PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS

Target 2004 Estimated Emissions with Kwinana Met File (99.9%)



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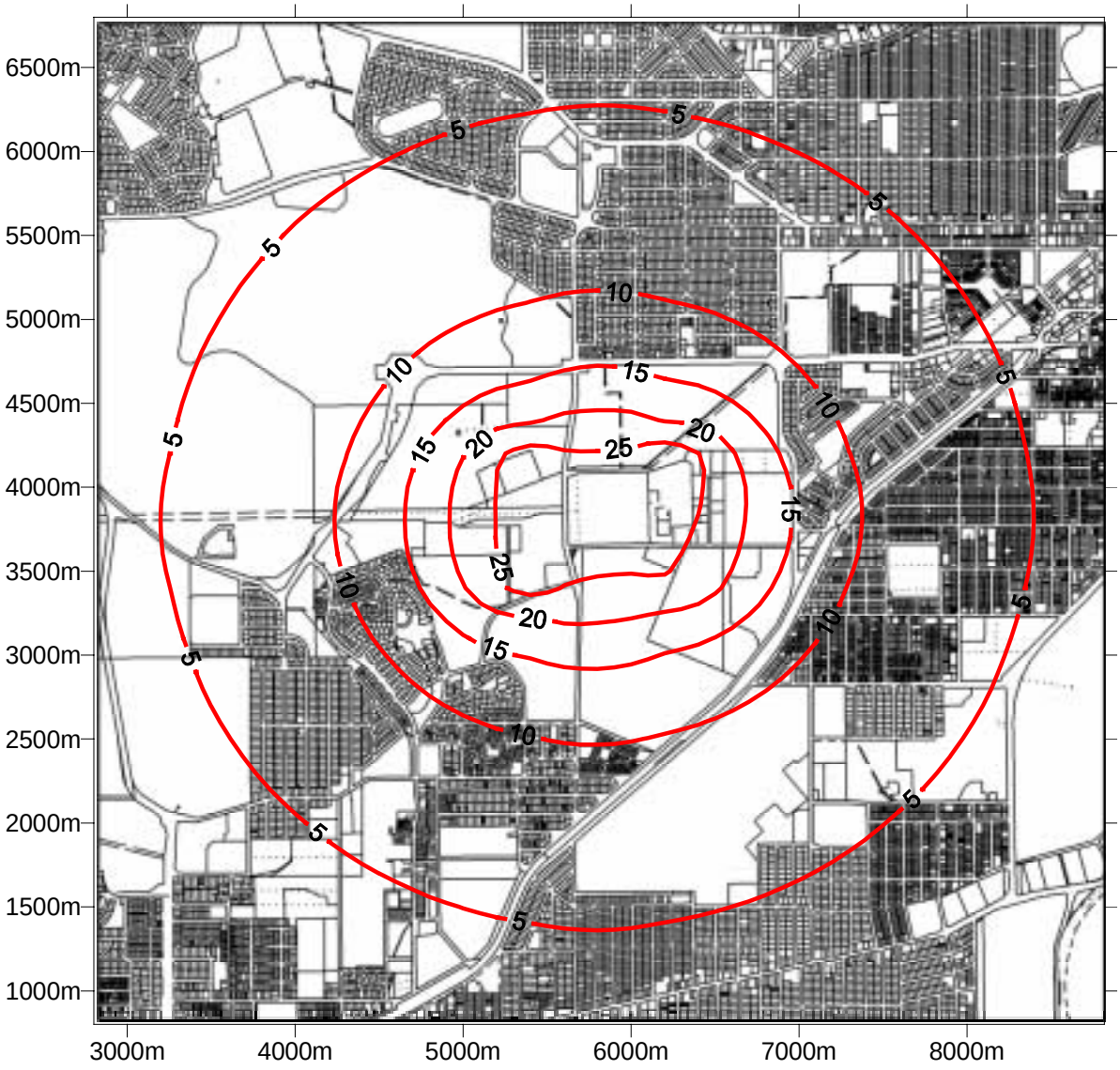
PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND LOW WIND FILE

Target 2004 Estimated Emissions with Low Wind Met File

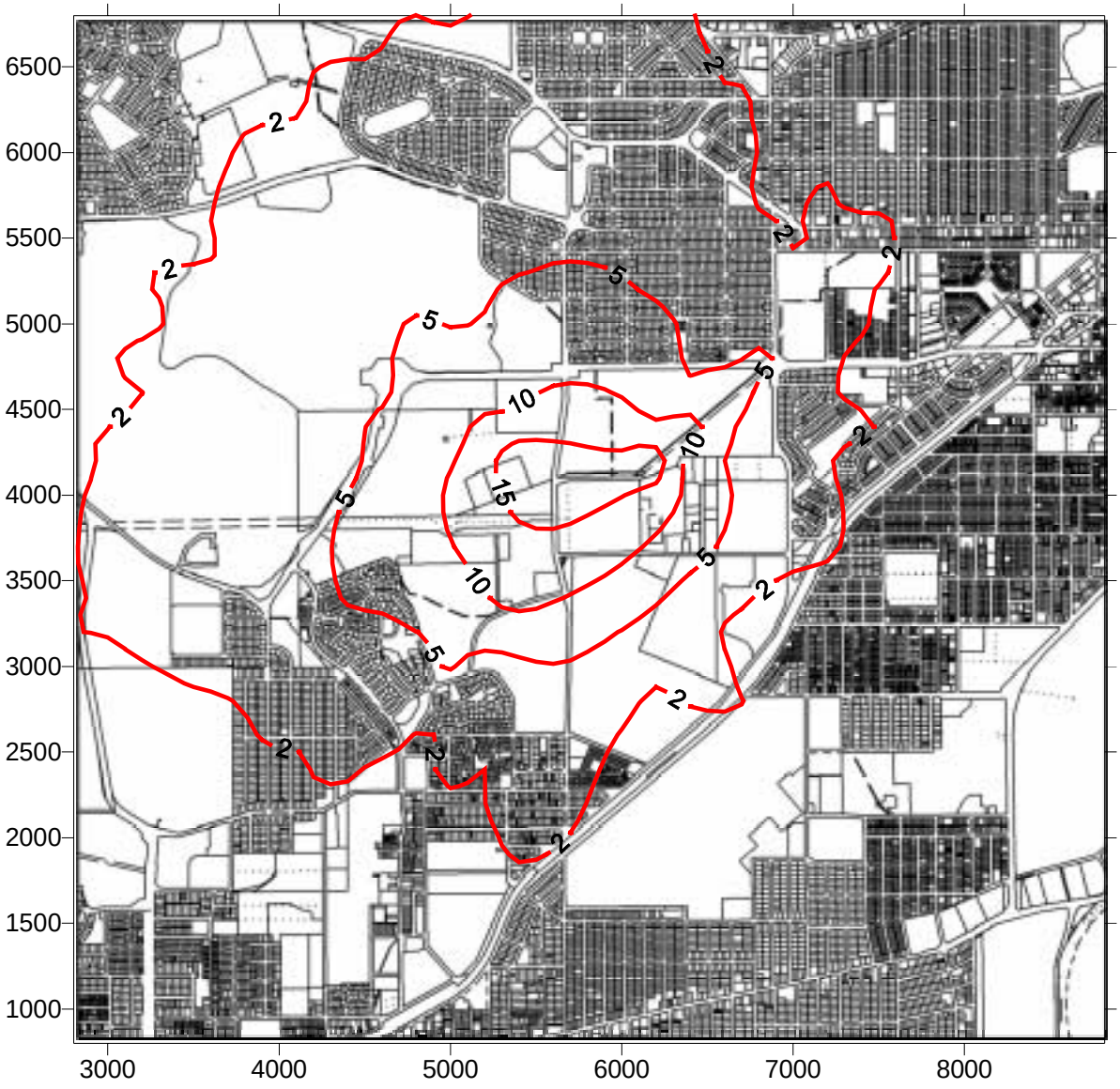


Conc. (Odour_Units); 1 hour avg.

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND SWANBOURNE WINDS

Target 2004 Estimated Emissions with Swanbourne Met File (99.9%)



PREDICTED ODOUR CONTOURS FOR

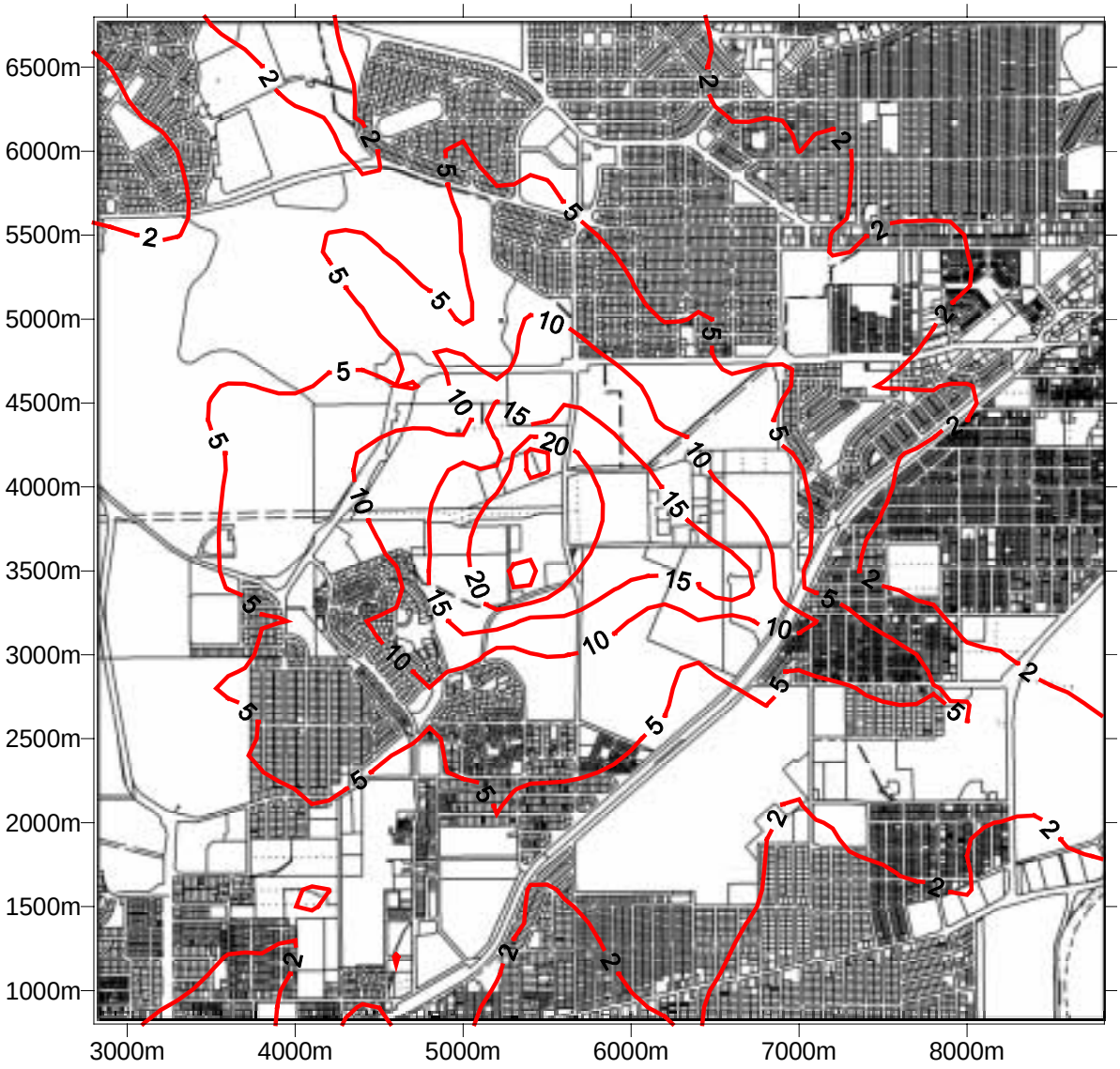
TARGET EMISSIONS AND PERTH WINDS

Target 2004 Estimated Emissions with Perth Met File (99.9%)

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS (MAXIMUM)

Target 2004 Estimated Emissions with Kwinana Met File (Maximum)

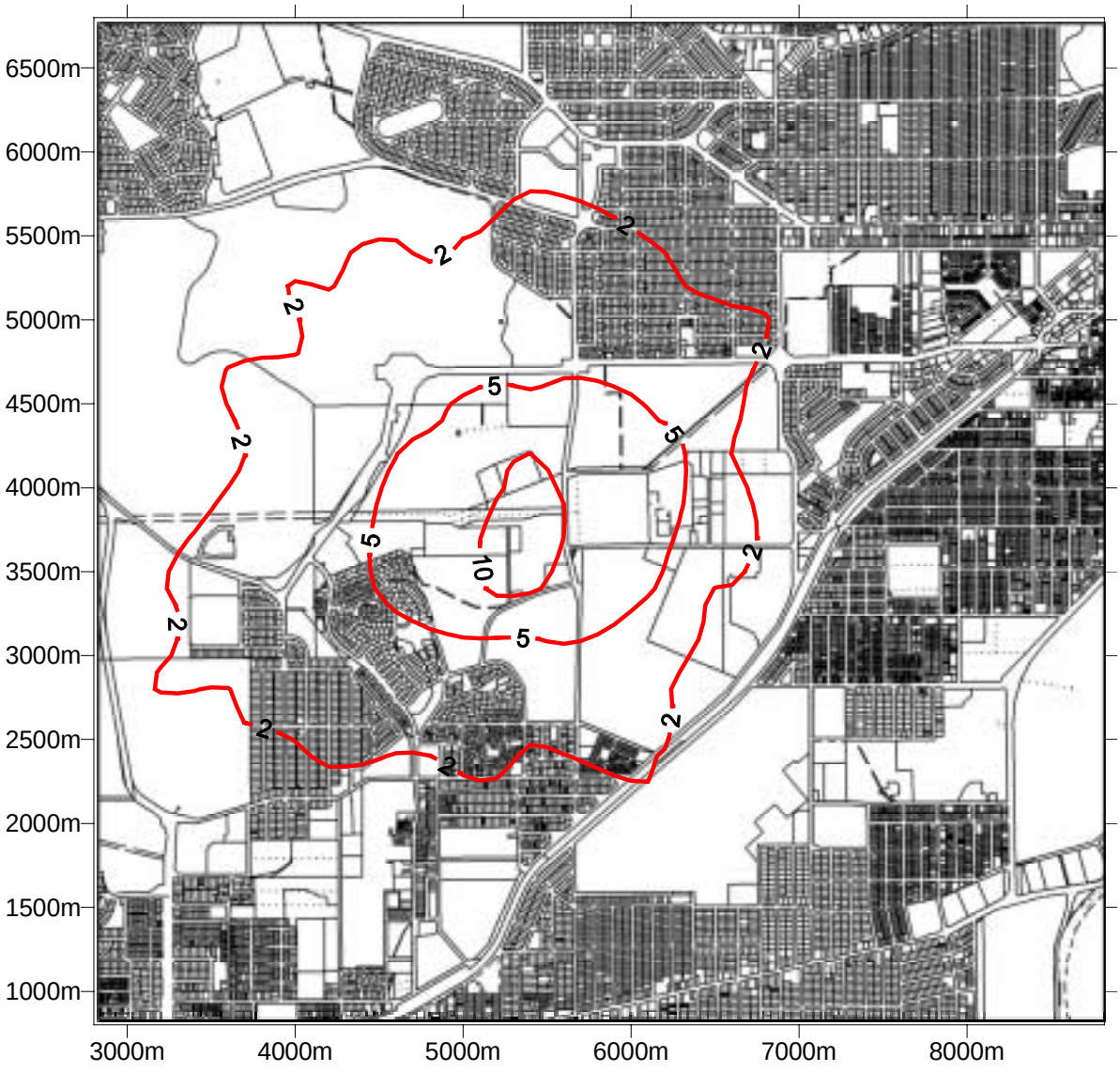


Conc. (Odour_Units); maximum avg.

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS (99.9%)

Target 2004 Estimated Emissions with Kwinana Met File (99.9%)

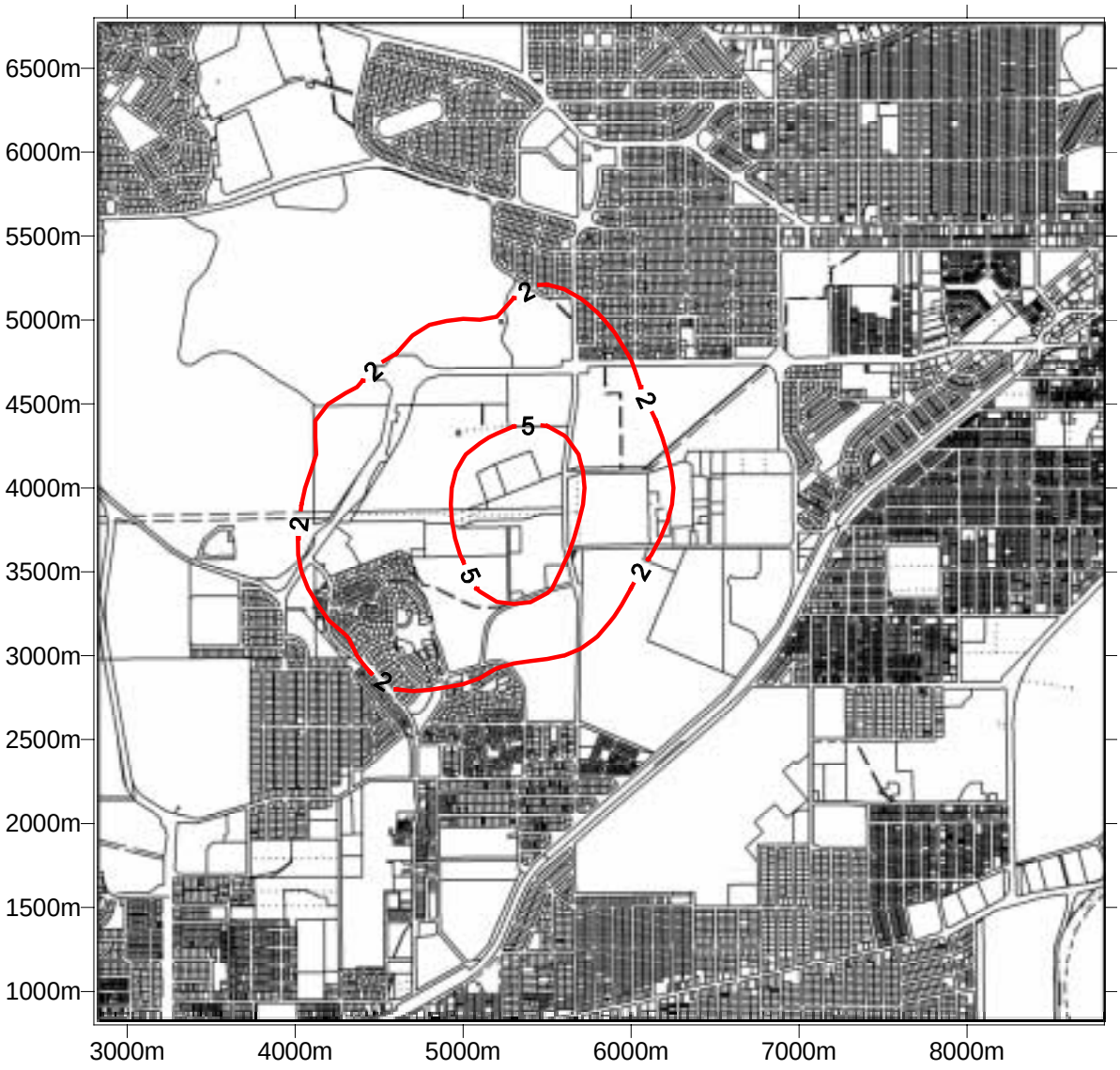


Conc. (Odour_Units); 1 hour avg.

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS (99.5%)

Target 2004 Estimated Emissions with Kwinana Met File (99.5%)

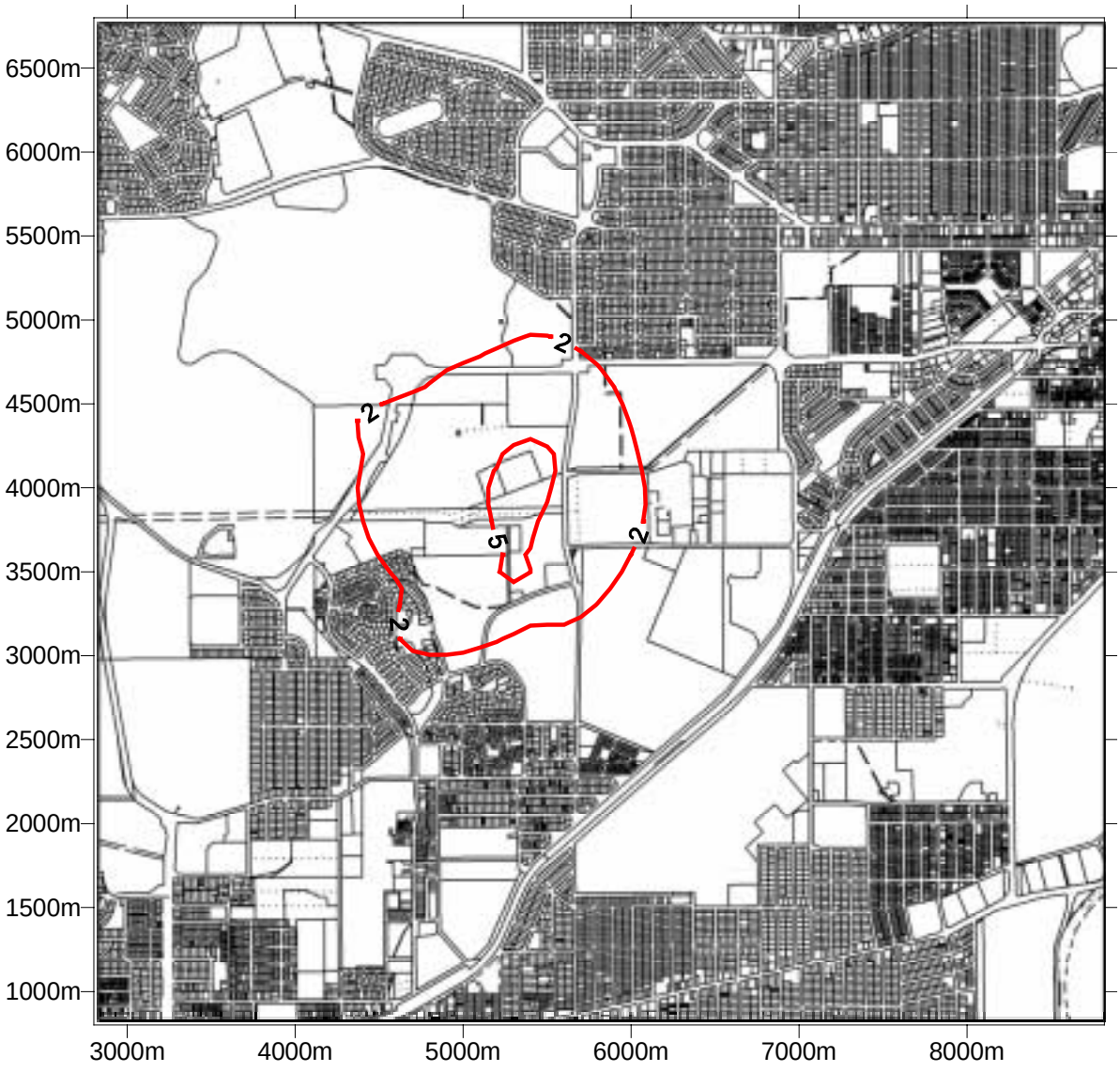


Conc. (Odour_Units); 99.5% avg.

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS (99.0%)

Target 2004 Estimated Emission with Kwinana Met File (99.0%)

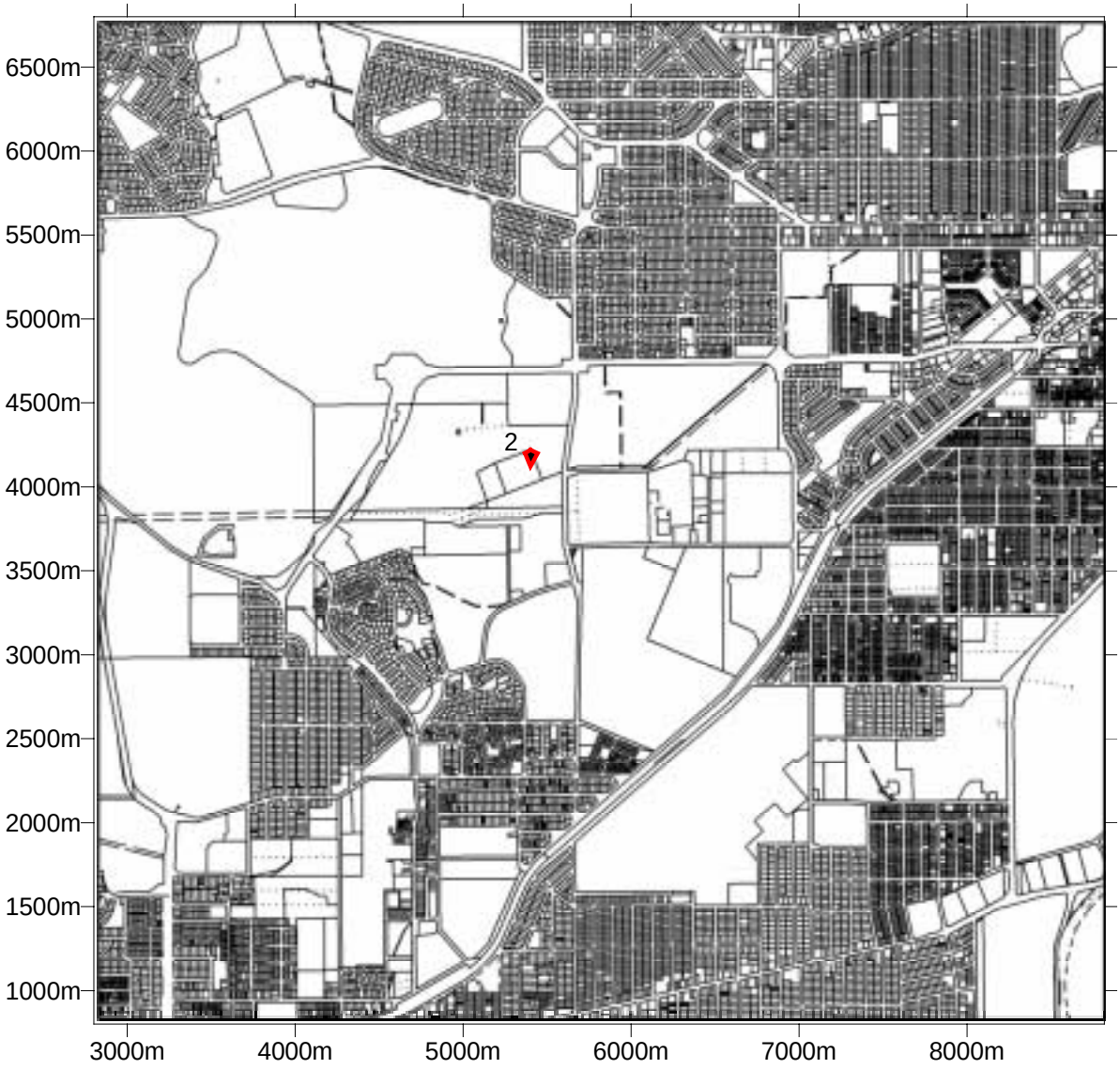


Conc. (Odour_Units); 99.0% avg.

PREDICTED ODOUR CONTOURS FOR

TARGET EMISSIONS AND KWINANA WINDS (95.0%)

Target 2004 Estimated Emissions with Kwinana Met File (95.0%)



Conc. (Odour_Units); 95.0% avg.