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Wentworth Club
Water Resources Assessment

Institute of Hydrology
Minster Agriculture Limited
Sir Alexander Gibb & Partners
Institute of Terrestrial Ecology

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WENTWORTH CLUB
WATER RESOURCES ASSESSMENT

List of Contents

	Page
Summary	
1. BACKGROUND	
1.1 Introduction	1
1.2 Scope of Work	1
1.3 Potential Sources of Supply	2
2. FUTURE WATER DEMAND	
2.1 Introduction	3
2.2 Approach and Methodology	4
2.2.1 Irrigation Demand	4
2.2.2 Club House and Facilities	6
2.2.3 Total Water Demand	6
2.3 Irrigation System Cost Estimates	8
2.4 Improvements in Irrigation Water Use	8
3. WATER RESOURCES ASSESSMENT	
3.1 Mains Water Supplies	11
3.2 Surface Water Sources	11
3.2.1 Winter Abstraction from the Bourne River	12
3.2.2 Winter Abstraction from Streams Draining Chobham Common	14
3.3 Groundwater Sources	15
3.3.1 Geology	15
3.3.2 Tertiary Aquifers	16
3.3.3 Upper Chalk Aquifer	17
3.3.4 Lower Greensand Aquifer	20
4. ENVIRONMENTAL IMPACT	
4.1 General	22
4.2 Reasons for Heathland Loss	22
4.3 Survey of Heathland Areas	24
4.4 Environmental Impact of Storage Reservoir Sites	25
4.5 Impact of Surface Abstraction on Downstream Environments	26
4.6 Impact of Spray Irrigation upon Heathland Ecology	27

5. SOURCE DEVELOPMENT COSTS

5.1 General 29
5.2 Mains Water Supplies 31
5.3 Surface Water Supplies 31
5.3.1 Diversion Weirs 32
5.3.2 Reservoir Construction 32
5.4 Retreatment of Club House Supplies 34
5.5 Groundwater Supplies 35
5.5.1 Abstraction Costs 35
5.5.2 Groundwater Abstraction without Reservoir Storage 37
5.5.3 Groundwater Abstraction with Reservoir Storage 38

6. CONCLUSIONS AND RECOMMENDATIONS 45

References

Annex A. Outline Terms of Reference
Annex B. Methodology for Calculating Flow Duration Curves

APPENDIX I : Pumping from Surface Streams
APPENDIX II - A : Estimated Costs - Open Bunded Storage Reservoir
- B : " - Surface Water Abstraction
- C : " - Retreatment of Club House Water
- D : " - Tertiary Groundwater
- E : " - Upper Chalk Groundwater
- F : " - Lower Greensand Groundwater
- G : " - Alternative Groundwater Schemes

APPENDIX III : Chemical Analyses

APPENDIX IV : Environmental Assessment Field Sheets

LIST OF TABLES

1. Wentworth Club Water Demand Estimates
2. Virginia Water: Percent Diversion for Alternative Reservoir Capacities
3. Chobham Common: Percent Diversion for Alternative Reservoir Capacities
4. Geological Succession
5. Yield of Chalk Boreholes
6. Inferred Maximum Yield from Chalk Boreholes
7. Artesian Flow from Lower Greensand Boreholes
8. Surface Reservoir Locations
9. Summary of Hydrochemical Data
10. Comparitive Costs
11. Abstraction without Reservoir Storage Tank
12. Abstraction with Collecting Tank
13. Abstraction with Bunded Reservoir
14. Abstraction with Valley Reservoir
15. Summary of Schemes to meet Target Year Water Demands

LIST OF FIGURES

1. Catchment Boundaries
2. Flow Duration Curve - Virginia Water
3. Flow Duration Curve - Chobham Common
4. Monthly Flow Duration Curves - Virginia Water
5. Monthly Flow Duration Curves - Chobham Common
6. Abstraction Rates and Monthly Flow Duration Percentiles
7. Summary Geology and Tertiary Stratigraphy
8. Depth to Top of Upper Chalk
9. Depth to Top of Lower Greensand
10. Potential Reservoir Sites

Summary

This assessment of the availability and cost of developing alternative sources of irrigation water supplies to reduce the use of mains water has indicated the following:

* The annual irrigation water demands are expected to increase to 210000 m3. This would cost £62500/y at 1990 prices if met from the mains supply. In addition, improvements to the Club House facilities could cost £10000/y in water charges.

* Surface water resources are available. However, as diversion is only permitted during the winter, an investment of between £1.2 to 3.5 million would be required to provide the necessary reservoir storage to meet average to dry year water demands. Retreatment of Club House supplies is not considered to be a viable alternative source.

* The groundwater resources are limited and borehole yields uncertain. Nonetheless, a phased development strategy based on abstraction from both the Tertiary and Chalk aquifers pumping to a collecting tank would appear to be feasible if used in conjunction with supplementary supplies from the mains, the Lower Greensand aquifer, or from a small natural reservoir(s) with a total capacity of 50000 m3. The capital cost of such a scheme would be about £180000 with a recurrent cost of £4000/y for mains supplies in an average year. The same scheme could also provide part of the Club House water requirements. The eventual costs will partly depend upon the required level of reliability of the supply during dry years.

WENTWORTH CLUB
WATER RESOURCES ASSESSMENT

Chapter 1

BACKGROUND

1.1 INTRODUCTION

The Institute of Hydrology (IH) were appointed by Chelsfield plc on behalf of Wentworth Club to undertake an assessment of potential sources of irrigation water supplies within the Wentworth Estate at Virginia Water, Surrey.

Potable mains supplies are used at present to irrigate the three golf courses at Wentworth. The irrigation facilities are being upgraded as part of a programme of improvements. This is expected to result in a tenfold increase in the peak irrigation water demands. Such supplies are costly, less secure during droughts and could have a detrimental effect on the natural heathland vegetation. Consideration is therefore being given to alternative sources of irrigation water supplies to either minimize or replace mains supplies.

1.2 SCOPE OF WORK

The water resources study consists of two phases. Phase 1, which is considered in this report, comprises an assessment of the irrigation water demands; the availability and cost of mains supplies; the availability, cost and any potential environmental hazard of local surface and groundwater supplies; and the preparation of a water development strategy for future demands. Phase 2 comprises assistance in obtaining any necessary permissions to implement the selected strategy. Further details are given in Annex A.

The respective components of the study were carried out by the following organisations:

Water Resources Assessment and Strategy - Institute of Hydrology
Water Demands - Minister Agricultural Ltd
Environmental Impact - Institute of Terrestrial Ecology
Engineering - Sir Alexander Gibb and Partners

1.3 POTENTIAL SOURCES OF SUPPLY

The following alternative sources of supply have been considered:

- Mains supply from the North Surrey Water Company
- Surface water from the River Bourne and/or its tributaries
- Shallow groundwater from the Bagshot Beds or deeper groundwater from the Chalk and/or Lower Greensand aquifers
- Treated wastewater
- Conjunctive use of the above sources.

Each potential source has been examined in relation to the predicted irrigation water requirements and to water quality, environmental impact, economic and engineering considerations.

Chapter 2

FUTURE WATER DEMAND

2.1 INTRODUCTION

This chapter covers the water demand aspects of the study. It focuses on the requirements for irrigation of the various playing surfaces at the Wentworth Club and the supply of water to the various Club facilities. Specific areas to be irrigated are the West (Championship), East and Edinburgh 18 hole courses, a Nine Hole Par 3 course, practice areas and the landscaped park around the Club House and Facilities. Water requirements for the latter cover the kitchens, staff quarters and sporting facilities.

The soils at Sunningdale are, in general, fine loamy sands to medium sandy loams overlying at varying depths a subsoil of clay or gravelly clay. In small and isolated areas, this subsoil appears at the surface. The surface horizon is very shallow and the majority of plant roots are, in general, concentrated in the top 150 mm; about 25% extending to 45 mm. The soils of the greens and tees are man-made and predominantly medium to coarse sands, though on the older West and East courses, many of these are underlain by a man-made clay subsoil, placed to conserve moisture. Rooting depths of the grasses on the tees and greens are generally 150 to 250 mm.

Infiltration rates on the fairways are currently very low, particularly on the slopes, due to compaction of the soil surface and generally poor vegetation cover. Present rates are estimated to be less 0.5 cm/hr, but this should improve once good vegetative cover is restored. Typical infiltration rates for such soils with good vegetative cover are in the order of 2.5 cm/hr. Water holding capacity of the sandy loams will be about 10 cm/m. The small inclusions of clayey soils will have a similar infiltration rate but a higher water holding capacity. Infiltration rates on the greens and tees are relatively fast.

The present state of the fairway vegetation, especially on the West and East Courses, after two dry summers is patchy and poor, although, where remedial treatment (soil coring, slitting, lifting, spot drainage, etc.) has been carried out, improvements are noticeable. This work, together with a fairway irrigation system, should significantly improve and maintain vegetation cover on the fairways.

2.2 APPROACH AND METHODOLOGY

2.2.1 Irrigation Demand

The irrigation requirements of a particular golf course or landscape amenity depend on a number of factors including the amount and distribution of rainfall, daily temperatures, soil water holding capacity and plant rooting depth.

Daily rainfall measurements covering the period 1965 to 1989 were obtained from the records at Blacknest Pumping Station and Virginia Water. Evapotranspiration calculations were made from meteorological data recorded over the same period at Heathrow.

As a scale drawing of the areas to be irrigated was not available, the length of fairways and average size of greens and tees were used to estimate the total surface to be irrigated. This is 62.5 hectares. These estimates are supported by data from other courses with similar characteristics.

Adjustments were made for shaded as opposed to open areas in calculating transpiration rates, and for long versus short cut vegetation. The soil moisture deficit allowable was taken as 40 mm on the fairways and 20 mm on the greens and tees. In selecting the defined level, it has been assumed that the fairway vegetation can withstand a moderate level of stress in the interests of overall reduction in water use, while greens and tees will need to be kept stress free. Assumed application rates are 10 mm, applied once the critical deficit is reached.

For the areas of most valuable grass cover, provision can be made to cover maximum irrigation demand in the driest year. For less important areas, it is seldom sensible or economic to plan for full demand, rather it is standard to take the level in the upper quartile (5th driest in 20 years). The year of maximum requirement (ie driest year) was 1976. The wettest year in the period examined was 1985.

For licence applications, the average monthly demand may be all that is required, but for sizing of pumps and mains, it is necessary to know the short period peak demand. This occurred in June 1976 when a total of 63,100 m3 would have been required to irrigate the 58.4 ha of golfing area at Wentworth. This compares to a total of 91,800 m3 required for an entire average summer.

The peak and annual water requirements are based on the following assumptions:

- Fairways have fine sandy loam soils with a rooting depth of 150 mm and water holding capacity estimated at 10%;

- Fairways will be irrigated by half circle sprinklers, for ecological as well as water conservation reasons, but in some cases full circle or extra sprinklers will be used - 15% extra water allocated;

- Greens and Tees are of free draining coarse sand (the clay layer ignored), with a rooting depth of 200 mm and no water holding capacity;

- Greens and Tees over-through (irrigation outside the target areas) provided by full circle sprinklers or extra sprinklers in surround and carry areas - 40% extra water allocated;

- The irrigation season has been taken as April to October;

- Shade versus open aspect has also been taken into account to improve sensitivity of estimates. Thus shaded parts of the fairways as well as green and tees surrounded by high trees have been allocated 30% less water than those in with an open aspect;

- The landscaped park has been assumed to be a shaded environment, as shrubs and trees will shade the open areas. An additional 20% has been added for over-spray of paths and car parks;

- Irrigation efficiency has been taken as 70% for all calculations as this is about the best the existing system (tees excepted) can do;

- Full advantage should be taken of the capabilities of the Network 8000 controller. Climatic data necessary for computation of evapotranspiration rates, soil, slope, shade, grass length data etc, provided in the programme will assist in maximising the effect of applied water and reduce overall water use;

- Transpiration demand in shaded areas was 30% below that of open areas (resulting in a demand reduction of 30 to 50%);

- While temporary areas of bare soil or poorly vegetative cover have a lower transpiration loss, and the establishment of new grass areas will have a greater irrigation frequency, these temporary influences will not greatly effect long term demand;

- Application rates of 10 mm are applied evenly, though in reality some over-watering is inevitable due to uneven and off-target application, and overlap.

2.2.2 Club House and Facilities

Currently the Club House and facilities use an average of 1750 m3 of water per month. The outdoor swimming pool is filled once a year, and drained in winter. It is intended to increase the facilities offered by including an indoor swimming pool and a jacuzzi. Changes will also be made in the number of rooms available and the catering services.

To estimate the peak water requirements, it has been assumed that there will be a throughput of 100 people per hour through the indoor sports facilities, and a similar number through the golf facilities. Average use has been taken as 70% of this figure. The water demands of the catering services and the rate of new water input to the swimming pool and jacuzzi are not yet known.

The future peak daily demand is estimated to be 108 m3 and the average daily demand 83 m3. These estimates can be improved with better knowledge of how the new facilities are used, but the proportion of the overall water demand of the Club will not change greatly as this demand is relatively small in comparison to the irrigation requirement.

2.2.3 Total Water Demand

The total quantity of water required by the Wentworth Club is summarised in Table 1. This table gives the calculated average and peak requirements as well as a target water demand figure. This latter figure is derived by assuming full irrigation of greens and tees in the driest year, and applications to the fairways based on the 5th driest in 20 years (upper quartile). This calculation is deemed to give the optimum priority water requirement for the Club. Water demands based on an 80% irrigation efficiency are also included in Table 1.

Table 1 Wentworth Club Water Demand Estimates

	Water Demand m^3 70% efficiency	80% efficiency
Irrigation		
Average Year - Peak Daily	1600	1400
Targeted Area - Peak Daily	2500	2200
Driest Year - Peak Daily*	3750	3300
Average Year - Annual	158000	138000
Targeted Area - Annual	240000	210000
Driest Year - Annual*	434000	388000

* Driest year was 1976

Club House and Facilities	
Average Year - Peak Daily	85
Peak Year (1976) - Daily	110
Average Year - Annual	30000
Peak Year (1976) - Annual	40000

Domestic daily times 365 = annual; irrigation daily x 105 to 122 = annual.

	Club House demand as percentage of irrigation demand	Potential re-use as percentage of irrigation demand
Average Year - Peak Daily	5	6
Peak Year (1976) - Daily	3	3
Average Year - Annual	19	23
Peak Year (1976) - Annual	9	9

Potential re-use (m^3)	Average Daily	Peak Daily	Average Year	Peak Year
Recycled (90%)	75	95	27000	35600
Rain-runoff*	25	15	9000	5700
Total	100	110	36000	41300

Note: [1] Run-off from 6400 sq. m. roof space plus same area of car park.

2.3 IRRIGATION SYSTEM COST ESTIMATES

Estimated budget costs (irrigation equipment, assorted pipework, controllers and cable, pumps only) are as follows:

East Course	£600,000
Edinburgh Course	£350,000
Nine Hole Par 3	£120,000
Practice Areas	£ 50,000
Landscape Areas	£150,000
Total budget estimate	£1,270,000

The budget costs for future irrigation systems and extensions given above assume that :

- all equipment installed will be new (ie existing equipment on the East Course and the 9 hole Par 3 course will not be used);
- the Edinburgh Course will have fairway, surround and carry area sprinklers added;
- the practice greens will have full irrigation while the driving range will have limited coverage;
- landscape areas will have full irrigation;
- all systems will be connected to the Network 8000 controller.

2.4 IMPROVEMENTS IN IRRIGATION WATER USE

To reduce overall water use and to maintain the natural vegetation at Wentworth, irrigation should be directed at the playing surface only, and part circle sprinklers used to reduce wastage and to limit the effect of over-spray onto surrounding trees, heather or other features. Green surrounds and carry areas should only be watered to enhance "grow-back", and, in the case of the West Course, to improve visual effect for TV coverage.

For planning purposes, water quantities should be based on the targeted priority area figures. Greater advantage should be taken of the sophistication of the Network 8000 controller, inputting soil, slope, shade, and grass length data together with critical climatic information, to maximise water use efficiency.

In years of high demand various water management techniques could be applied, such as reducing the water applied to some areas (ie the Nine Hole Par 3 Course) in favour of other areas.

Improving the soils on the fairways could also reduce water demand. This is taking place at present, but more could be done. The use of soil additives which improve the water holding capacity, would increase the irrigation interval and number of irrigations and thus potentially reduce the overall water requirement. The practice of adding soil conditioners is becoming increasingly popular in the USA, but so far as is known, has not yet been tried on existing golf courses in UK. Trials could be set up to investigate their use at Wentworth.

Irrigation design for future installations should consider a triangular, rather than the existing square, lay-out for the fairway pattern for the sprinklers. This change in configuration alone could improve efficiency by 10 to 15%. It is also important that sprinklers are operated in the middle of their rated application ranges, rather than near the maximum, as this reduces component wear, fogging and gives better control over droplet size and distribution pattern.

Irrigation scheduling should take account of slow infiltration rates and slope. Initially, and perhaps always in some places, applications may need to be broken into short periods during each irrigation schedule to reduce losses due to run-off and surface ponding. Once reseeding and soil improvements have returned the vegetative cover to optimum, applications will need to be adjusted to take account of the new conditions. Management should encourage deeper rooting depths on the fairways as a means of reducing water demand.

The effect of water quality on surrounding vegetation with time will need to be monitored. This will be less important if most of the irrigation water comes from surface water, but if reliance is placed on mains or Chalk groundwater, acid injection or other appropriate methods may be required to maintain the character of the natural vegetation which requires an acidic soil environment.

More frequent applications with smaller amounts of water will generally increase overall water use, as there will be less opportunity for natural rainfall to restore soil moisture deficits.

The limited rooting caused by poor soil characteristics or frequent irrigations will produce several negative effects including reduced plant access to stored soil moisture, increased run-off risk and temporary waterlogging. Any method of addressing these problems will reduce overall water requirements on the fairways.

The Network 8000 controller and Toro valve-in-head sprinklers for the irrigation system now being installed on the West Course give maximum potential for efficient water use. This advanced system is sensitive to a range of site characteristics. Each sprinkler in the system can be individually programmed, thus allowing for different application rates for specific requirements. The Network 8000 can be attached to an automatic weather station and by analyzing basic climatic data, calculate evapotranspiration (Et) and then the irrigation requirement. By controlling application quantities, the Network 8000 will maximise the efficiency of water applied through the system.

Site characteristics such as soil moisture holding capacity, infiltration rates, slope and shade, as well as any number of other variables or control measures can also be fed into the Network 8000 thereby offering course managers the facility to respond to water availability or application in priority areas. As this controller has the capacity to control all irrigation on the Club property, it offers considerable potential for water conservation and reduction in water use.

Irrigation equipment can direct water at the irrigated area only by means of a part or sectored circle pattern, but normally (and sometimes intentionally) spray extends outside the target area. For example, especially when full circle sprinklers are used on greens. The water to these areas has been quantified to add up to 40% extra for greens and 15% extra for fairways. In view of the sensitive plant species, half circle sprinklers will be the norm, especially along the fairways, but on most areas adjoining greens, overthrough to surrounds will be normal.

The West Course tee design has half circle sprinklers covering these areas. This will help to reduce water requirement, but to take account of additional coverage areas, tees have been combined with greens.

Additional carry area or surround sprinklers outside the irrigated area should be considered on the Wentworth Courses, where visual effects for televised tournaments is important.

Chapter 3

WATER RESOURCES ASSESSMENT

The are several potential sources of water available to meet the irrigation requirements of the Wentworth Club. These include the continued use of mains supplies; abstraction from two potential surface sources; pumping of groundwater from the Tertiary strata, the Chalk and/or the Lower Greensand aquifers; and recycling of water from the Club House facilities. The advantages and disadvantages of these different sources have been evaluated in terms of the volume of water available for irrigation, the timing of its availability, cost of abstraction/storage, environmental suitability, long term reliability, and the risks associated with developing each particular source.

3.1 MAINS WATER SUPPLIES

At present the Wentworth Club draws its water requirements for irrigation and the Club House facilities from the mains supplies of the North Surrey Water Company. The Club is currently charged £0.26/m3 for this water but it is anticipated that this cost will increase at a rate higher than the rate of inflation. If the total projected demand for irrigation water was obtained from these mains supplies then it is possible that summer restrictions due to Drought Orders would become more common.

3.2 SURFACE WATER SOURCES

Most of the area to the north of the Virginia Water falls within the Great Windsor Park and comprises either gently undulating country directly underlain by the London Clay, or rolling hills marking the outcrop of the Bagshot Beds. Rolling open heaths and pine woods cover the outcrops of Bagshot and Tertiary strata to the south of Sunningdale. The two streams within this area which have potential as sources of abstraction are the Bourne River and the stream draining Chobham Common. These are shown in Figure 1.

National Rivers Authority (NRA) policy states that licences will not be granted for abstraction for golf course irrigation from surface streams during the summer months. The NRA has indicated that it will consider licencing winter abstraction of surface water with subsequent storage for use during the summer on a case-by-case basis. The primary consideration being the effect of the proposed abstraction upon stream flow. If licences can be obtained, the surface water sources available to meet the irrigation requirements at Wentworth represent relatively reliable supplies.

A risk associated with these supplies is the potential for chemical or biological contamination. It would be advisable to eliminate high risk areas, such as the Longcross defence facility, from the reservoir catchments. The more urbanised areas are potential sources of pollution. These are centred at Ascot, Sunninghill, Sunningdale, Trumps Green, Virginia Water and Englefield Green and represent only a small proportion of each of the two catchments.

3.2.1 Winter Abstraction from the Bourne River

To investigate the feasibility of using the River Bourne as a source of water for golf course irrigation, a flow duration curve was determined for the Virginia Water catchment using the procedures outlined in the Low Flows Report (Institute of Hydrology, 1980) and described in Annex B.

A flow duration curve describes the relationship between any given discharge and the percentage of time that the discharge is exceeded. It is frequently used for assessing licences to abstract water. The procedure for estimating the flow duration curve depends upon the availablity of flow data at or near the site of interest. With no data available, as in this case, it is necessary to use a technique based on catchment characteristics. Since abstraction from the Bourne may only occur during the winter months (October to March inclusive) a seasonal flow duration curve, specific to months was derived.

The following results were obtained for the Virginia Water catchment and represented as Figure 2 :

Average Discharge (ADF) : 0.272 cumecs

	Q95(10)			: 14.86% ADF		
	Oct	Nov	Dec	Jan	Feb	Mar
Q95 :	0.036	0.065	0.091	0.117	0.115	0.094
Q5 :	0.674	1.149	1.371	1.593	1.556	1.183

where the Q5 and Q95 are the five percentile flow (ie. flow exceeded 5% of the time) and 95 percentile flow (ie. flow exceeded 95% of the time) in cumecs for each winter month.

Flow duration curves were drawn for each month by linear interpolation and extrapolation using the 5 and 95 percentiles (see Figure 5). The overall winter season flow duration curve shown in Figure 5 was constructed by combination of the monthly curves. Percentiles for each month of the season were averaged for selected flows.

The effect of abstracting at different rates over the winter period is presented as Table 2. The anticipated average and driest year demands are shown relative to the normal 5 and 95 percentile monthly flows in Figure 6, which also shows the abstraction necesssary to fill a small reservoir having a capacity of 50000 m3, relative to the 5 and 95 percentile flows. The data presented in Figure 6 indicates that abstraction of the projected average year (157979 m3) or the driest year (443400 m3) requirements over the winter period would not exceed the 95 percentile. Abstraction of volumes below the 95 percentile could be expected to have only a minimal effect upon flow in the Bourne River.

Table 2 Virginia Water: Percent Diversion of Alternative Reservoir Capacities

Percentile Percentile Flow cumecs		50 (0.310)	60 (0.250)	80 (0.145)	85 (0.120)	90 (0.095)	95 (0.066)	99 (0.033)
Reservoir capacity m3	Pumping rate cumecs	% of percentile flows.						
50000	0.0032	1.0	1.3	2.2	2.7	3.4	4.8	9.7
100000	0.0064	2.1	2.6	4.4	5.3	6.7	9.7	19.4
150000	0.0095	3.1	3.8	6.6	7.9	10.0	14.4	28.8
200000	0.0127	4.1	5.1	8.8	10.6	13.4	19.2	38.5
250000	0.0159	5.1	6.5	11.0	13.3	16.7	24.1	48.2
300000	0.0191	6.2	7.6	13.2	15.9	20.7	28.9	57.9
350000	0.0223	7.2	8.9	15.4	18.6	23.5	33.8	67.6
400000	0.0254	8.2	10.2	17.5	21.2	26.7	38.5	77.0
450000	0.0286	9.2	11.4	19.7	23.8	30.1	43.3	86.7
500000	0.0318	10.3	12.7	21.9	26.5	33.5	48.2	96.4

3.2.2 Winter Abstraction from Streams Draining Chobham Common

Several streams draining areas such as Chobham Common run through the Wentworth Estate and are potential sources of winter abstraction. Flow duration curves were derived for the Chobham Common catchment using the same techniques as applied to the larger Virginia Water catchment.

The overall winter flow duration curve is shown in Figure 3 and the separate monthly flow duration curves using 5 and 95 percentiles are shown in Figure 5. The effects of abstracting at different rates during the winter period are is shown in Table 3. The anticipated average and peak annual irrigation demands are plotted with the normal 5 and 95 percentile monthly flow in Figure 6.

This data indicate that abstraction of up to 150000 m3 over the winter period would have a minimal effect upon stream flow. Abstraction at higher rates would be in excess of the 95 percentile.

Table 3 Chobham Common: Percent Diversion of Alternative Reservoir Capacities

Percentile Percentile Flow cumecs		50 (0.058)	60 (0.046)	80 (0.026)	85 (0.022)	90 (0.018)	95 (0.066)	99 (0.033)
Reservoir capacity m3	Pumping rate cumecs	% of percentile flows						
50000	0.0032	5.5	7.0	12.3	14.5	17.8	26.7	51.6
100000	0.0064	11.0	13.9	24.6	29.1	35.6	53.3	>100
150000	0.0095	16.4	20.7	36.5	43.2	52.8	79.2	>100
200000	0.0127	21.9	27.6	48.8	57.7	70.6	>100	>100
250000	0.0159	27.4	34.6	61.2	72.3	88.3	>100	>100
300000	0.0191	32.9	41.5	73.5	86.8	>100	>100	>100
350000	0.0223	38.4	48.5	85.8	>100	>100	>100	>100
400000	0.0254	43.8	55.2	97.7	>100	>100	>100	>100
450000	0.0286	49.3	62.2	>100	>100	>100	>100	>100
500000	0.0318	54.8	69.1	>100	>100	>100	>100	>100

3.3 GROUNDWATER SOURCES

3.3.1 Geology

The geological succession is given in Table 4 and the geology of the area around Wentworth is shown in Figure 7. The study area lies near the western edge of the London Basin, an asymetric NE-SW trending syncline of Tertiary and Cretaceous strata dipping eastwards.

Peat deposits occur along the channel draining Chobham Common whilst alluvium and older alluvial terraces (Boyn Hill and Taplow) occur along the River Bourne. The alluvial deposits are of limited extent in this area and are not considered to be a potential source of irrigation water supplies.

Most of the site is underlain by up to about 40m of Bracklesham and Bagshot Beds of Tertiary age. These are mainly fine grained, often silty to clayey sands. Occasional coarser sandy beds within the sequence form an aquifer of importance for domestic supplies. These deposits are underlain by about 110m of London Clay and about 30m of Reading Beds (part of the Lower London Tertiary sequence).

The Upper, Middle and Lower Chalk are present at a depth of about 180m bgl. The Upper Chalk is about 100m thick and a principal aquifer in the London Basin. It is usually in hydraulic continuity with the overlying Lower London Tertiaries.

The Upper Greensand, Gault Clay and Lower Greensand are present at depths of about 450m. The Lower Greensand is an important aquifer with flowing artesian conditions.

Table 4 Geological Succession

Recent and Pleistocene	Alluvium and Peat Terrace Gravels
Tertiary	Barton Beds Brackelsham Beds Bagshot Beds London Clay Reading Berks
Cretaceous	Upper Chalk Middle Chalk Lower Chalk Upper Greensand Gault Lower Greensand

3.3.2 Tertiary Aquifers

The Bagshot and Bracklesham Beds underlie an area of about 2 km2 of the Wentworth Estate, as shown in Figure 7. The overall permeability of the Tertiary sequence is low due to the predominance of clays and other fine grained deposits. Moderately permeable sandy units occur within the middle part of the Bracklesham Beds and the upper part of the Bagshot Beds to form local aquifers of about 5m in thickness. Borehole yields for these sandy units are reported to range from 0.5 to 0.75 l/s (500-700 gph) which would not normally be considered sufficient for irrigation use.

Thin, discontinuous conglomerate bands have also been identified within the Tertiary sequence at the following locations: in the upper part of the London Clay at Mill Ride Golf Club at Ascot; at the base of the Bagshot Beds north of Virginia Water and near Engelfield Green; and in boreholes in the upper part of the Bagshot Beds near Ascot (borehole SU 96/08), Sunninghill (SU 96/14), Chobham Common (SU 96/21) and Longcross (SU 96/19). This would suggest that these conglomerates are also likely to occur within the Wentworth Estate.

The conglomerates are reported to locally yield about 2 l/s (2000 gph). Whilst the sustained yield from these deposits is likely to be low due to their limited extent and thickness, they should be capable of contributing supplies to meet peak daily demands.

Water level data for the Tertiary aquifers are not sufficient to prepare a water table map. The regional direction of groundwater flow is expected to be southwards and consequently recharge may enter the area around Sherbourne Drive from the north. However, as the water table appears to intersect the larger streams, the local pattern of groundwater flow is likely to be determined by the moderately dissected topography.

The water table may lie below the sandy units of the Upper Bagshot Beds in the area of higher elevation where water levels are about 20 m bgl. A perched water table may also be present above the lower Bracklesham Bed clays.

Seasonal water level fluctuations adjacent to the various perennial streams are expected to be small but increasing to about 3 to 4m in the areas of higher elevation. Discharge from the Tertiary deposits into the drainage network during the winter in particular reduces the amount of recharge that can be intercepted by a groundwater abstraction scheme, although this supply could be collected by a surface water scheme.

The annual recharge to the Tertiary deposits within the Wentworth Estate is estimated to be about 280000 m3, assuming 20% recharge and annual rainfall of 700mm. Whilst this is nearly twice the average year irrigation water demand, it would not be possible in practice to intercept all of this recharge by a seasonal abstraction regime. It is therefore considered that the irrigation water requirements cannot be met from the Tertiary aquifer alone.

The volume of groundwater in storage within the sandy units is estimated to be about 500000 m3, assuming a specific yield of 5%. However, only about 30 to 50% of this storage would in practical terms be commanded by a borehole abstraction scheme.

Boreholes penetrating the Tertiary sequence within the Wentworth Estate have produced low yields, although these may represent the lower clayey part of the Bagshot Beds. Yields from this aquifer could be increased by the use of large diameter wells and by drainage collector systems. However, many of the drainage systems on the course channel seepage from the Tertiary sequence to the surface streams, and hence, abstraction from the Tertiary aquifers could reduce the baseflow contribution to streams draining the area.

The quality of groundwater from the Tertiary aquifers is likely to be suitable for irrigation use, although high iron concentrations may have to be reduced by aeration to avoid harmful effects on the vegetation.

A programme of drilling, testing and monitoring will be required to resolve the various uncertainties regarding the presence of suitable Tertiary aquifers and their distribution, resources availability and borehole yields. An important part of such a programme will be to identify the extent of the sand and conglomerate units and whether these lie below the summer water table.

3.3.3 Upper Chalk Aquifer

The Chalk aquifer underlies the Wentworth Estate at depths of about 150 to 180m. This aquifer shows a wide range of transmissivities as fissures, enhanced by preferential solution, are the dominant control on the permeability of the Chalk. Fissure development is largely a surface-related feature and is therefore more diffuse under confined conditions. The permeability of the Chalk also tends to show a marked decrease with increasing thickness of Tertiary deposits. Consequently, boreholes penetrating more than about 75m into the Chalk are unlikely to show a significant increase in yield.

There are several advantages in attempting to obtain supplies from this aquifer:

- the resources of the Chalk aquifer could make a significant contribution to the irrigation water supply

- the Tertiary aquifer is considered to have limited potential and there are restrictions on the availability of water from the Lower Greensand aquifer

- a supply from the Chalk could also provide a winter supply for the Club house facilities.

However, there are several disadvantages of a supply from the Chalk:

- it should be accepted that very low yields may be encountered in boreholes drilled into the Chalk underlying the Wentworth estate. Any geological features, such as faults, which may provide possible drilling targets, are hidden beneath the thick cover of Tertiary deposits. Surface geophysical techniques would also be of limited use due to the thick cover and because of the more diffuse occurrence of fissures.

- the costs of drilling boreholes about 250m deep are high and operating costs can also be significant

- the alkaline chemistry of the Chalk groundwater may affect the heathland vegetation to a greater extent than the mains supply unless acidified.

The yield of a Chalk borehole which does not penetrate fissures is usually negligible. As these fissures are more diffuse and tight due to the overlying Tertiary sediments, the transmissivity of the confined Chalk which occurs in the Wentworth area may be as low as 15 m2/d, compared to 1500-3000 m2/d at outcrop.

Yields recorded from eight Chalk boreholes in the vicinity of the Wentworth Estate are summarised in Table 5. Their locations are shown in Figure 8. The reported yields, which may to some extent reflect the capacity of the pump rather than the potential yield of the borehole, range from 0.6 to 6 l/s. For cost purposes an average yield of 3 l/s (3000 gph) has been adopted based on the average of the limited yield information given in Table 6. However, it should be noted that yields of less than 1.5 l/s (1500 gph) may be encountered.

Specific capacities (yield per unit drawdown) are shown in Table 6 for the three boreholes for which drawdowns were recorded to indicate the pumping rates that might be achieved by assuming an available drawdown to the top of the Chalk.

Table 5 Yield of Chalk Boreholes

Hole No.	Location	Depth to Chalk (m)	Yield l/s (g.p.h)	Drawdown (m)
SU 96/08	Ascot	149.0	"Inadequate"	?
SU 96/14	Sunningdale	168.6	4.21 (4000)	12.2
SU 96/19	Longcross	176.2	3.15 (3000)	53.3
SU 97/45	Old Windsor	81.4	0.82 (780)	?
SU 97/48	Coopers Hill	149.4	1.37 (1300)	?
TQ 06/29	Chertsey	157.2	0.63 (630)	Artesian
TQ 07/86	Wraysbury	51.5	3.15 (3000)	?
TQ 07/102	Staines	133.3	5.47 (5200)	50.0

Table 6 Inferred Maximum Yield from Chalk Boreholes

Hole No.	Location	Available Drawdown to Top of Chalk (m)	Specific Capacity (l/s/m)	Inferred Maximum Yield l/s (gph)
SU 96/14	Sunningdale	110	0.35	38.5 (27000)
SU 96/19	Longcross	101	0.06	6.0 (5630)
TQ 07/102	Staines	132	0.11	14.5 (13728)

This limited information suggests that the average specific capacity is about 0.15 l/s/m, although a more conservative value of 0.10 l/s/m has been adopted to estimate potential borehole yields. Assuming an available drawdown of 100m, then a peak abstraction rate of 10 l/s should be possible for short periods.

The Wentworth Estate is situated just south of the axis of the London basin. Recharge will occur in the outcrop areas at least 15km to the south and west. The amount of groundwater (Q) passing through the Chalk beneath the estate area from the south-west is estimated to be about 135000 m3 over a 6-month period:

Transmissivity (T)	15 m2d
Width (W)	3 km
Hydraulic gradient (I)	0.01

Q = TIW - 15x0.01x3000x180 = 135750 m3 in 6 months

This flow is about the same as the average year irrigation water requirement and not all of this flow could be intercepted. Consequently, on the basis of existing information, it seems unlikely that the average year water requirements could be met solely from the Chalk aquifer without a long-term decline in water levels.

3.3.4 Lower Greensand Aquifer

The Lower Greensand aquifer occurs below the study area at depths of about 430 to 460 m, as shown in Figure 9. This aquifer has a variable thickness, being 22 m thick at Staines (borehole TQ 07/104) and thinning out completely eastwards of Richmond. It is estimated to be about 25 m thick at Wentworth.

Substantial artesian flows up to 25 to 30 l/s are recorded from Lower Greensand boreholes (Table 7), such as the nearby borehole at Virginia Water (TQ 06/47).

Table 7 Recorded Artesian Flows from Lower Greensand Boreholes

Hole No.		Location	Flow l/s	(g.p.h)
SU	97/44	New Lodge[1]	0.12	(120)
TQ	06/36	Ottershaw	5.8	(5500)
TQ	06/47	Virginia Water	26	(25000)
TQ	07/104	Staines	31	(30000)

1 Diameter only 40mm.

A water supply from the Lower Greensand would offer the following advantages:

- flow rates similar to those obtained at Virginia Water (TQ 06/47) may occur from a borehole at Wentworth

- as the flow is likely to be artesian there will be no pumping costs

- the Lower Greensand offers an assured supply of groundwater.

However, there are also certain disadvantages of a water supply from the Lower Greensand, including :

- the high drilling costs and technical difficulty of drilling to the required depths
- the groundwater is likely to have a temperature of about 25°C
- the water quality could be slightly saline (sodium chloride salt content could be of the order of 300 mg/l)
- artesian flow rates from the Lower Greensand usually decrease over a period of years, and hence pumping may eventually become necessary. In several of the West London boreholes while the flow was initially artesian, water levels were quickly depressed by pumping
- the relatively fine grained sandy nature of this aquifer will require careful screen selection
- the NRA are reluctant to licence abstraction from the Lower Greensand.

The transmissivity of the Lower Greensand is expected to be 125 to 500 m2/d. Assuming a hydraulic gradient of 0.01, the volume of water available for possible development within a six-month period would range from about 270000 m3 to 680000 m3. These estimates suggest that the Lower Greensand aquifer could be capable of meeting the average and peak daily irrigation water demands.

Chapter 4

ENVIRONMENTAL IMPACT

4.1 GENERAL

The Wentworth Estate is situated to the north of Chobham Common. The soil types on the Estate are free draining, acid soils that are suitable for the development of heathland vegetation. The largest area of heathland on the Estate is Broomhall Common. It is situated in the South West corner of the Estate and is effectively separated from the golf courses by Birch and Scots Pine woodland. It is an area of conservation interest and has been designated by the Nature Conservancy Council as a Site of Special Scientific Interest. It is also subject to a management agreement with the Surrey Wildlife Trust. The areas of heather on the golf courses themselves are relicts of a formerly more extensive heathland. They are of much lower conservation interest than Broomhall Common because of their fragmented nature but have a high landscape value.

The Wentworth Club are improving the facilities at Sunningdale within the context of an overall environmental management strategy. The recent development of the South Course set aside particular areas of valuable and diverse wet woodland ecology. In addition, the Club has taken steps to ameliorate the potentially adverse effects of using alkaline mains water supplies in an acid heathland environment. Consequently, an important aspect of the current water assessment study has been the evaluation of the likely envrionmental impact associated with developing the different water resources, in particular the impact from:

- the construction and siting of storage reservoirs
- abstraction of surface water during the winter upon the downstream ecology
- spray irrigation water on the heathland.

A survey was made of prospective reservoir sites in January 1991 and flow duration data for the various streams were examined. The available hydrochemical information on the different water sources has been collated and summarized in Table 8 and Appendix III.

4.2 REASONS FOR HEATHLAND LOSS

Possible reductions in the amount of heather may be due to a number of factors; heather being replaced by scrub or trees such as Broom, Gorse, Birch, Oak or Scots Pine or acid grassland species such as Purple Moorp Grass or Wavy Hair Grass. The reasons for changes in the vegetation may be due to the following:-

(i) Loss of heather to scrub or trees due to a natural succession. Some of the woodland on the Estate (such as the remaining areas of Fairway Wood on the Edinburgh Course) have scattered heather plants in the ground flora. This area was not wooded in 1920 (EAU report 1985) and is likely to have been heathland. Trees have been encouraged to grow in areas between the fairways, and if this growth is not too dense and has an open canopy that allows plenty of light through heathland plants can survive as a part of the ground flora. On areas of rough between the fairway and the woodland heather can be maintained by the removal of invading scrub and tree species by occasional light trimming of the vegetation or removal of the saplings by hand.

(ii) The loss of heather to acid grassland vegetation is more complex. In this case there are a number of likely causes. They are:- excessive cutting, trampling, grazing by rabbits, fertilizer additions and extra irrigation.

Cutting is necessary to prevent the invasion of scrub and tree species in the absence of the traditional method of heathland management, burning. Cutting will allow the faster growing grass species to establish, but as the heather regrows the grasses become less common. If cutting is carried out too often the grass will eventually become the dominant vegetation type. Trampling by golfers and grazing by rabbits will have similar effects, maintaining an open vegetation structure allowing the acid grass species to increase.

The addition of fertilizers to fairways is to promote grass growth. Heather is a plant that flourishes on nutrient-poor soils and is less able to compete with grasses if the nutrient level of the soil is increased. This is shown on the course by the recolonisation of bunkers. Bunkers that are no longer in use and have been allowed to grow over are often dominated by heather plants, the low nutrient levels of the bunker sand and soil mixture being ideal for heather growth.

Additional watering of the dwarf shrub areas is likely to have detrimental effects on heather and in, turn, increase the growth of the acid grass species in the driest months of the summer. Heather grows better than acid grass on the free draining, more exposed areas such as steep banks which can be seen at several places around the Wentworth Estate. It is possible that the long-term addition of water to heathland plants will encourage them to produce only shallow roots. This may result in drought death if watering is not available at a time of moisture stress allowing acid grasses to become more abundant. The addition of water will also add nutrients to the system, water quality being most important. Nutrient addition from acid waters is likely to be low but waters containing high levels of calcium may increase the soil pH and thereby the nutrient status of the soil. Higher nutrient levels in the soil will favour the faster growing grass species.

4.3 SURVEY OF HEATHLAND AREAS

The areas of heathland on the Estate were surveyed between the 2nd and 4th January 1991. Excluding Broomhall Heath each of the 41 sites identified as heathland by the 1990 Environmental Audit was recorded. Two sites, numbers 1 and 19, did not have any dwarf shrub vegetation and were not assessed. In addition, an extra site, number 42, was included. Outside of these sites individual heather plants and small groups of heather plants, also occur. However, the 40 recorded sites are the largest and most important areas to maintain for landscape purposes. Field survey sheets are given in Appendix IV.

The following characteristics for each site were recorded:-

- Site size. This was determined from Figure 4 of the 1990 Environmental Audit using a digitizer (site 6 was considered to be more extensive than marked on the map).

- Percentage cover of dwarf shrub vegetation. This figure is given as a percentage and the proportions of Common Heather (Calluna vulgaris), Cross-leaved Heath (Erica tetralix) and Bell Heather (Erica cinerea) give an indication of the type of heathland, dry, humid or wet. Dry heathland is predominantly Common Heather and Bell Heather, humid heath being approximately equal proportions of Common Heather and Cross-leaved Heath, and wet heath being mainly Cross-leaved Heath.

- Age of heather, a subjective assessment based on a 4-phase classification of:-
  - (a) Pioneer heath 0-5 year old plants
  - (b) Building phase 5-20 year old plants
  - (c) Mature phase 20-30 year old plants
  - (d) Degenerate phase 30+ year old plants.

- Other species, the other main components of the vegetation, ie, trees, scrub and acid grass species.

- Slope, aspect and shading. These indicate the degree of exposure of the site.
- Management, sizes of drainage, estimate of cutting frequency, watering etc.
- Location of the site.
- Trampling assessment of the extent to which golfers walk on the heathland.
- Landscape rating. Assessment of the importance of the site to the look of the golf course.
- Comments, including the possibility of successfully maintaining the heathland on the site.

4.4 ENVIRONMENTAL IMPACT OF STORAGE RESERVOIR SITES

A list was compiled of all the potential reservoir sites within the area after discussion with Club managers and inspection of the courses. These sites were assessed according to their impact upon local sites of special ecological value, recreational facilities and engineering design as shown in Table 8.

Table 8 Surface Reservoir Locations - Environmental Impact

Code	Range	Capacity (m3)	Impact
A	Wentworth Lake	75000	Effect upon summer flow, siltation
B	Dukes Copse	37500	Disturbance to Wentworth Pond
C	Broom Hill	28125	Visual effects, loss of wetland
D	Shrubs Hill	50000	Loss of woodland
E	Longcross	37500	Disturbance to Wet Woodland
F	West Drive SW	37500	Disturbance to Wet Woodland
G	West Drive SE	37500	Disturbance to Wet Woodland
H	Fish Ponds	25000	Visual effects of drawdown
I	West Drive N	50000	Visual effects of drawdown
J	West Wood	150000	Conservation Area
K	South West	75000	Conservation Area
L	Club House	25000	Outside Club Lands

A brief assessment of the proposed reservoir sites was carried out between 2nd and 4th January 1991. Most of these are woodland sites and, unlike the heathland sites, it is not possible to give a detailed assessment of these outside of the growing season. Attached, in Appendix IV, are the field sheets relating to each site. From this it can be seen that sites J, G and F are areas of conservation interest, and are subject to a management agreement with the Surrey Wildlife Trust. This may also apply to Sites A and B but further information on conservation interests and species lists from the sites is required.

The final selection of reservoir sites will be determined by these environmental factors and partly by the location of any borehole(s) used to augment supplies.

Environmental problems could develop in the reservoirs as a result of the chemical characteristics of several of the water sources. In particular, water derived from the Bagshot Beds is saturated with respect to iron and can be seen to form an unsightly precipitate upon aeration. Where natural seepage occurs most of this iron is deposited within a few metres or tens of metres of the seepage site and therefore would not cause a problem in any reservoir. However, if groundwater from the Bagshot Beds was pumped from boreholes directly into a reservoir, or directly onto the course, it is probable that large amounts of iron would precipitate due to aeration. Where reservoirs might be fed by drainage from the Bagshot Beds it would be expedient to implement measures to increase aeration along these drains.

It is unlikely that the mixing of groundwater from different sources within a reservoir will result in adverse chemical reactions. There is the potential for the introduction of algae to course reservoirs if water is added from either the mains supplies, or from the River Bourne. However, such algal growths are usually only a seasonal phenomena.

4.5 IMPACT OF SURFACE ABSTRACTION ON DOWNSTREAM ENVIRONMENTS

The abstraction from the surface sources would be restricted to the winter months, and would take only a small percentage of the total flow. With these controls it is unlikely that there will be any significant effect upon the downstream ecosystems.

The different rates of abstraction necessary to meet average, targeted and peak requirements relative to percentile flow in the Bourne and Chobham streams are shown in Figure 6. It is only in the case of the Chobham stream that abstraction of the total annual irrigation demands would exceed the 95 percentile. If the future surface abstraction requirements is only of the order of 50000m3 then this is unlikely to have any noticeable impact upon the winter hydrological regime in either watercourse.

4.6 EFFECT OF SPRAY IRRIGATION UPON HEATHLAND ECOLOGY

The existing environmental monitoring at Wentworth is attempting to ameliorate the impact of irrigation using alkaline mains water supplies on the acid heathland soils. The average alkalinity of mains water is approximately 190 mg/l. The adverse effects of continued use of mains supplies will become more noticeable as irrigation is extended. More extreme effects could arise if significant amounts of the more alkaline Chalk groundwater are utilised for irrigation.

Table 9 Summary of Hydrochemical Data (mg/l)

Parameter	Mains[1]	Surface (Bourne)	Tertiary[2] (Bagshot)	Chalk	LGS
Alkalinity (as CaCO3)	191	36	3.3	265	-
pH	7.4	6.9	5.1	8.3	7.5
Calcium	108	-	32	75	77
Sodium	31	-	23	151	217
Iron	0.03	-	0.08	0.01	0.05
Chloride	57	-	39	126	302
Temp. (C)	16	11	10	12	25

1 Water supply zone F. (Sunningdale and Wentworth). Average composition in 1989 from information supplied by North Surrey Water Company.

2 Average composition from 5 wells in Bagshot Sands at Wokingham (from Kinniburgh and Edmunds, 1984)

It is likely that groundwater abstracted from the Tertiary aquifers would need to be aerated to reduce the iron content before it could be used for spray irrigation. The pH of Tertiary groundwater may be as low as 5.0 and therefore it is also possible that extensive use of these acidic waters may also have an adverse effect upon the heathland. The iron content of groundwater from the Bagshot Sands can be as high as 29 mg/l.

Groundwater from the Lower Greensand is usually potable although it may be slightly salty and ferruginous. The chloride content of the water from the Virginia Water borehole is given as approximately 300 mg/l.

Surface water is probably the most favourable water available for irrigation. Data on the hydrochemistry of the Bourne River is listed in Appendix III, and this suggests that this water would be suitable for use for spray irrigation. There is the possiblity that surface waters may become polluted where they are derived from urban or industrial areas. In this regard abstraction should not take place from streams draining the Longcross Defence site.

It would be possible to blend these waters in order to minimise the adverse effects of the individual sources.

Chapter 5

SOURCE DEVELOPMENT COSTS

5.1 GENERAL

Estimates of demand, sources of supply, reservoir storage and likely borehole abstraction rates considered in this study can be summarised as follows:

Irrigation Water Demand (70% irrigation efficiency)

	Annual m3	Daily m3/d Average	Peak
Average year	158000	875	1600
Target priority	240000	1330	2500
Dry year	443000	2450	3750

Sources

- Mains (North Surrey Water Company)
- Retreatment of Club House supplies
- Surface water : Bourne River
  : Chobham Common catchment
- Groundwater : single aquifer — Tertiary (T); Chalk (Ck); Lower Greensand (LGS)
  : multiple aquifer — T + Ck; T + LGS; Ck + LGS; T + Ck + LGS
- Conjunctive use of above sources.

Storage

- None (direct diversion of surface water or direct abstraction from boreholes)
- Collecting tank (up to 3000m3)
- Small bunded reservoir (50000m3)
- Natural reservoir (50000m3)
- Large bunded reservoir (up to 500000m3)

Borehole Abstraction Rates (l/s)

	Average	Peak
Tertiary	0.5	2
Chalk	3	10
Lower Greensand	20	(20)

Each of the potential sources of irrigation water supply are compared in terms of capital, operating and unit costs. The estimated capital costs have been amortized over a ten year period and operating costs computed in 1990 figures to derive the unit cost per cubic metre of water supplied. These costs are summarized in Table 10.

To assess the relative economic cost of the different water sources available to the Wentworth Club it has been assumed that the existing potable mains supply will continue to provide the Club House facilities. It should be noted that demand estimates based upon a 70% irrigation efficiency have been used in the following cost projections. A reduction in demand resulting from improvements to an 80% efficiency could reduce certain of the projected capital costs by up to 12%.

Table 10 Comparitive Costs

	Availability	Risk Assessment	Capital Cost £	Operating Cost £/m3	Unit Cost £/m3	Environmental Constraint
MAINS	>500,000 m3	Drought Order	-	0.26	0.26	Alkaline Water
SURFACE						
Bourne River	<500,000 m3	Minimal	700,000	0.01	0.90	Reservoir construction
Chobham Common	<150,000 m3	Minimal	700,000	0.01	0.90	Reservoir construction Upper limit on abstraction determined by 95 percentile flow
GROUNDWATER						
Tertiary (0.6 l/s)	<280,000 m3	Locating yield	9000 - 11500 per hole	0.01	0.15	Need for aeration
(2.5 l/s)	<280,000 m3	Locating yield	9000 - 11500 per hole	0.01	0.05	Need for aeration
Upper Chalk (6 l/s)	>500,000 m3	Locating yield	55,000	0.06	0.15	Alkaline water
(12 l/s)	>500,000 m3	Locating yield	55,000	0.06	0.12	Alkaline water
Lower Greensand	>500,00 m3	Licensing restrictions	70,000	0.01	0.03	Temperature and salinity of water
RETREATMENT	<40,000 m3	Minimal	187,000	0.10	0.79	Health problems from spray irrigation

The cost of a distribution system from a reservoir to the fairways, greens and tees has not been included as this is independent of the ultimate source of the water. Cost estimates for a distribution and sprinkler system are discussed in Chapter 2.

5.2 MAINS WATER SUPPLIES

At present, all the water requirements for both irrigation and the Club House facilities are met from the mains supplies of the North Surrey Water Company (NSWC). The current cost of this supply is £0.26/m3 for purchase of this water, plus the cost of pumping facilities to supply the distribution system. At current prices there would be an approximate annual cost of £62500 for purchase of the anticipated targeted irrigation demand, and about £10000 per annum for the anticipated average Club House requirements. It is anticipated that in the future these costs will rise at a rate higher than the rate of inflation. The current purchase prices have been taken as the base rate against which other supplies have been compared.

The continued use of mains supplies avoids the need for the capital expenditure that would be required to develop alternative supplies. This advantage is offset by the high annual recurrent costs of purchasing this water from the NSWC, the rather alkaline water chemistry, and the risk of a loss of the supply during critical drought periods.

5.3 SURFACE WATER SUPPLIES

The predicted average annual irrigation demand for the Wentworth Club is about 160 000 m3 but the anticipated total annual demand in the driest conditions (1976) could increase to nearly 450000 m3. As summer abstraction restrictions are imposed by the NRA on the use of surface water, it will be necessary to construct a reservoir to store surface water drawn off during the winter for use in summer.

Cost estimates for a surface water supply assume a typical layout, rather than specific abstraction or reservoir sites, design or capacity.

There is a small licence fee of approximately 0.001/m3 payable to the NRA for surface water abstraction. This is insignificant compared to other costs and has not been included.

5.3.1 Cost of Diversion Weirs

To estimate the abstraction costs from a surface stream it has been assumed that it would be necessary to construct a small weir to create a draw off pond. Water would be drawn, by gravity, into an adjacent manhole from which two submersible pumps (1 duty + 1 standby) would feed a storage reservoir via a 100 mm diameter pumping main, (200 m of main have been allowed). Costs associated with the installation of power to the pumping station have not been included.

The estimated capital cost for a surface water abstraction and delivery system is £29700, which equates to a unit cost of £0.06/m3. Allowing for maintainance costs of £500 per annum (equivalent to £0.01/m3) and operating costs, estimated at £0.01/m3, the total unit cost for supplying surface water to a reservoir is £0.08/m3, as detailed in Appendix II - B.

5.3.2 Cost of Reservoir Construction

Two types of surface storage reservoir have been considered: a reservoir formed behind a dam/bunded embankment across a natural or formed valley and an excavated reservoir surrounded by bunded embankments.

For costing purposes the latter option has been used and it has been assumed that such a reservoir would be located in an unobtrusive location. The following advantages would result from such a layout:

- Environmental effects resulting from fluctuations in water level would be less problematic.

- An excavated reservoir would not be considered a reservoir under the terms of the Reservoirs Act, which imposes constraints on the construction and maintainance of reservoir structures when the volume of water stored above the lowest adjacent ground level exceeds 25000 m3.

In view of the restricted areas available for the storage of water a nominal capacity of 50000 m3 has been adopted and pricing has been based on an open bunded reservoir, sealed with a PVC geomembrane and gravel lining. Prices include for general landscaping/grassing and fencing, but exclude the following: disposal of excess excavated material off site; provision of access to the reservoir location from existing surface roads; and extensive site clearance or demolition.

The estimated construction cost of a 50000 m3 reservoir is approximately £405000, which when amortized over a ten year period equates to a cost of £0.81/m3 of water stored. Allowing for maintainance costs of £1000 per annum (equivalent to £0.01/m3), unit costs for reservoir storage are in the order of £0.83/m3. Doubling the capacity of the reservoir will only result in economies of scale of approximately 5%. The total unit cost of abstraction from a surface stream using a weir, and storage in a reservoir has accordingly been assessed as £0.90/m3. The detailed basis for these estimates is given in Appendix II-A.

The capital costs required to construct sufficent reservoir storage to meet the different levels of annual irrigation demand are as follows:

	Annual Demand (m3)	Estimated Cost £M	Payback Period* (Years)
Average Year -	158000	1.245	20
Targeted Year -	24000	1.900	30.5
Driest Year -	443000	3.5	56

* - compared to mains at £62500/annum

These estimates should be considered as indicative due to the following factors:

- The specific location, layout and size of the proposed reservoir is uncertain.

- Construction rates have been estimated from recent tenders and standard reference material. Rates for earthworks of this nature and of the actual excavation of the reservoir in particular are extremely variable. It would therefore be necessary to obtain estimates from a number of local contractors in order to accurately estimate such construction costs. Local excavation rates may be up to 50% lower than those used in the above estimates.

- These estimates do not include the cost of trucking and disposal of excavated material off site. This form of disposal would be necessary if larger capacity reservoirs were being considered and could increase reservoir capital costs by up to 50%.

The costs of reservoir construction are very high. Any conjunctive water resources strategy should identify existing sites where a natural reservoir capacity already exists in order to reduce storage costs.

5.4. RETREATMENT OF CLUB HOUSE SUPPLIES

The projected volumes of water available for re-use from the Club House facilities are as follows :

	Average Daily (m3)	Peak Daily (m3)
Recycled Sewage Effluent	75	95
Rainfall Runoff	25	15
Total	100	110

This equates to an annual average total volume of about 36000 m3 and a peak volume of about 41000 m3. The peak daily throughput of water by the Club House in an average year and available for retreatment represents approximately 6% of the anticipated demand for irrigation water (Appendix II - C).

In order to utilise such potential water sources it would be necessary to have two separate systems feeding a storage reservoir as follows :

- Stormwater would be sewered direct to storage as a sewage works would not be able to treat the highly fluctuating flows resulting from rainfall.

- Foul drainage would require a high and strictly monitored degree of treatment, including superchlorination, prior to mixing with stormwater. It must however be stressed that, even with such treatment, the use of effluent for spray irrigation, as opposed to an underground drip system, could not be recommended on medical health grounds in areas so accessible to groundstaff, players, the public and local residents.

It has been assumed that only nominal local storage would be provided with the treated/stormwater being pumped to a main storage reservoir.

Preliminary enquiries to sewage works manufacturers/plant suppliers and estimates for the associated civil works have indicated that a suitable sewage treatment works would cost approximately £187000. This equates to a water cost of £0.69/m3. This high unit cost, which excludes the costs associated with construction of the necessary local storage and pumping facilities together with operating and maintenance costs, coupled with the following factors are considered to make this option unrealistic :

- Environmental/medical health considerations resulting from the sewage works itself and, in particular, the spraying of effluent on the golf courses makes this option unacceptable.

- Such a facility could only make a positive contribution during the summer months as water is available from alternative and cheaper sources during the winter. During the summer the rainfall contribution would be relatively small.

- Stormwater volumes are relatively small and would not significantly effect the estimated water cost from this source. Run-off from car park areas would be subject to oil pollution.

5.5 GROUNDWATER SUPPLIES

Surface water schemes usually involve high capital costs but lower operating costs whereas groundwater supplies usually have relatively low capital costs but generally high operating costs. The capital, operating and unit costs of meeting demands from groundwater with and without reservoir storage are examined.

In order to make the cost estimates which follow it has been necessary to estimate typical yields for the different aquifers. It should not be assumed that yields of this order will necessarily be found at Wentworth. There is a licence fee payable to the NRA of approximately £0.01/m3 for summer groundwater abstraction. This has been included in the calculations.

5.5.1 Abstraction Costs

(i) Costs of Abstraction from Tertiary Aquifers

A detailed listing of the costs for developing the Tertiary aquifers is presented in Appendix II-D, and compared with other supplies in Table 10.

Each borehole constructed in the Tertiary aquifers would involve a capital cost of about £7500 per borehole, with a further £4000 for power connection and piping for each borehole. Unit costs for groundwater abstracted will vary between £0.15/m3 and £0.05/m3 for yields between 0.5 l/s (500gph) and 2.0 l/s (2000gph), respectively. These two yields represent the sandy and conglomeratic units respectively.

It will be necessary to undertake a reconnaissance drilling programme of about six boreholes in order to determine whether potential aquifers within the Tertiary sequence would warrant development. The cost of undertaking this programme has been included in the assessment of the financial aspects of utilising Tertiary aquifer sources. This reconnaissance programme would seek to locate conglomeratic units within the sequence, and allow aquifer property tests to be undertaken on the sandy portions of the Brackelsham and Bagshot Beds. If an adequate supply was found in any of these reconnaissance boreholes they could be developed as production wells.

Each successful borehole would require a separate power supply and a water collection network connecting the various boreholes to a reservoir. As the scale of these facilities depend upon their location only a very broad cost estimate is possible. As such, the power supply infrastructure and the water collection network is assumed to add a further £4000 to the capital cost of each borehole, and between £0.05/m3 and £0.02/m3 to the unit costs for yields of 0.5 l/s and 2.1 l/s respectively.

(ii) Costs of Abstraction from Upper Chalk Aquifer

The costs associated with constructing a borehole into the Upper Chalk are given in Appendix II-E , and compared with other supplies in Table 10.

The capital cost of a borehole penetrating the Upper Chalk will be approximately £55000. In estimating the unit costs for water supplied from the Upper Chalk yields of both 5.3 l/s (5000 gph) and 10.5 l/s (10000 gph) have been assumed. In both cases the unit cost is approximately £0.13/m3, the higher yield in the latter case being offset by the higher purchase price and operating costs of the pump.

As the exact locality of any future Chalk borehole(s) is unknown it is not possible to include costs for connecting power supplies to the pumphouse, or for piping water from the borehole to a storage reservoir.

(iii) Cost of Abstraction from Lower Greensand Aquifer

The various costs associated with drilling a borehole to the Lower Greensand are included in Appendix II-F, and compared with other supplies in Table 10.

A borehole drilled to explore the Upper Chalk could also be deepened to explore the Lower Greensand. This would require adequate design of the initial Chalk borehole. Capital costs for construction of a borehole from surface to the Lower Greensand will be approximately

£70000, although exceptional drilling conditions might increase this estimate by 15-20%.

There would be an increase in unit costs if pumping is required from the Lower Greensand, although the low heads involved means that operating costs would be relatively low. Whilst there is sufficient artesian flow the unit cost for groundwater from the Lower Greensand is approximately £0.02/m3.

5.5.2 Groundwater Abstraction without Reservoir Storage

To meet the entire irrigation requirement directly from groundwater, without any reservoir storage, the combined borehole yield would need to satisfy the peak daily demands during the six hour irrigation period. These circumstances represent the maximum demands that could be placed upon the groundwater resources. The yields necessary to meet both the peak daily and the average daily requirements are shown in Appendix II-G.

The large number of boreholes required to meet the anticipated targeted peak daily irrigation demands solely from the Tertiary aquifers is impractical. Similarly, it would require yields in the order 10.5 l/s (10000gph) to be encountered in nine Chalk boreholes before the targeted peak daily demand could be met directly from this aquifer. Only the Lower Greensand aquifer could possibly meet the targeted peak daily demand, although this would still require five boreholes.

Technical as well as licencing limitations make it unlikely that any of the aquifers by itself could produce a sufficient yield to meet the target peak daily demand directly from boreholes. However, for comparitive purposes, yields and costings for this type of scheme are listed in Table 12. The conjunctive use of the three aquifers could overcome these limitations.

Table 12 Multiple Aquifer Abstraction without Reservoir Storage

Aquifer	Number of Boreholes	Pumping Rate l/s	Daily Abstraction[1] m3	Capital £	Cost £/m3
Tertiary -	5	2.1	227	57500	0.20
Chalk -	3	10.1	655	180000	0.52
Lower Greensand -	4	21	1814	280000	0.08
TOTAL			2687	520000	0.25 [8.3][2]

1 Assuming 6 hour pumping

2 Payback Period compared to mains water at £62500 per annum

These boreholes would not be pumped continuously at these rates, either on a daily or seasonal basis, and this would allow some recovery of groundwater levels during non-pumping periods. In these circumstances it would be possible to produce higher yields over short periods of time which could not otherwise be sustained with continuous pumping. These higher rates allow a more flexible scheme and the potential to reduce the final number of boreholes.

The unit costs are higher for this scheme because of the discontinuous pumping. It should be noted that the unit costs of Chalk groundwater are appreciably higher than mains supplies, although the scheme illustrated above has almost the same overall unit costs as mains supplies.

5.5.3 Groundwater Abstraction with Reservoir Storage

(a) With Collecting Tank

The peak daily irrigation demand could also be met by groundwater abstraction to a small reservoir or collecting tank to allow pumping on a 24 hour basis. The storage requirement would be approximately 75% of the peak daily demand. Fewer boreholes would be required than in the case where no storage was available and the capital cost associated with storage tank construction would be off-set against reduced drilling costs. Where a storage tank or reservoir is utilised it would be possible to mix and blend waters from different sources to optimise yields, cost efficiency and water chemistry.

A small reservoir or tank having a capacity of between 1000 and 3000 m3 could allow the use of a purpose built fibreglass storage tank rather than the need to excavate a bunded reservoir. It may even be possible to adapt a structure that already exists at Wentworth, such the World War II bunker system. The cost of a fibreglass tank or the necessary works to adapt the bunker system or other possible structures on site, is estimated to be £30000.

A possible scheme using the three aquifers might be as follows:

Table 13 Multiple Aquifer Abstraction with Collecting Tank

Aquifer	Number of Boreholes	Pumping Rate l/s	Daily Abstraction[1] m3	Capital £	Cost £/m3
Tertiary	5	2.1	727	46000	0.05
Chalk	2	5.3	908	120000	0.13
Lower Greensand	1	21	1816	70000	0.02
Storage Tank	(3000m3)			30000	
	TOTAL		3451	266000	0.06 [4.3][2]

1 Assuming 24 hour pumping

2 Payback Period compared to mains water at £62500 per annum

A small collecting tank allows more continuous pumping and therefore fewer boreholes. This reduces the capital costs by 50% and the overall unit cost by 75% compared to a scheme without reservoir stroage (see 5.5.2).

Surface water would not form part of this scheme, although mains supplies could provide either a back-up or alternative to one of the groundwater sources (see 5.5.3b). Substitution of the Lower Greensand contribution with a mains supply would reduce capital costs but increase unit costs to approximately £0.10/m3.

(b) With Collecting Tank and Mains Supply

It may not be possible to utilize the Lower Greensand aquifer due to licencing or water quality constraints and the resources of the Tertiary and Chalk aquifers may not be capable of meeting the full irrigation water requirements. Consequently, in the following alternative scheme, it is assumed that mains supplies are still obtained and used in conjunction with groundwater abstraction from the Tertiary and Chalk aquifers.

The following assumptions have been used to assess this type of scheme:

- the scheme should aim to meet the target priority irrigation water demands using simultaneous abstraction from the Tertiary and Chalk aquifers

- the number of boreholes is restricted to six Tertiary and two Chalk boreholes with peak demand being met by higher pumping rates rather than from an increased number of boreholes

- there is no abstraction from the Lower Greensand aquifer to avoid possible licencing and water quality constraints, although the use of this source is not ruled out if the Chalk and Tertiary resources or borehole yields are found to be insufficient

- a collecting tank of 3000 m3 is constructed to allow peak demands to be met by spreading abstraction over 24 hours rather than 6 hours

- that the following average and peak borehole abstraction rates can be obtained:

		Pumping Rate l/s	Abstraction m3 6h	24h	180d
Tertiary	Average	0.5	-	45	8000
	Peak	2	45	180	-
Chalk	Average	3	-	260	47000
	Peak	10	215	860	-

- each borehole would have a fitted pumping capacity capable of providing the peak rate for short periods to meet peak daily demands. The average rate is considered to be the pumping rate that can be sustained continuously over the 6 month irrigation period.

On the basis of these assumptions, this type of scheme could contribute the following irrigation water supplies:

(a) Average annual target demand (240000m3)

Two Chalk boreholes	x 47000 m3	=	94000 m3
Six Tertiary boreholes	x 8000 m3	=	48000 m3
	Total		142000 m3

(b) Peak daily target demand (2500m3)

Two Chalk boreholes 24h	x 860 m3	=	1720 m3/d
Six Tertiary boreholes 24h	x 180 m3	=	1080 m3/d
	Total		2800 m3/d

This would give an annual shortfall of 98000 m3 (or about 40% the annual demand), which would have to be obtained from mains supply or another source, but would be sufficient to meet the predicted peak daily demand. The average annual demand (158000m3) could almost be met from this scheme with a mains upply of only 16000m3 at a cost of £4160.

The costs of such a scheme are estimated to be as follows (in £):

	Capital	Operating	Unit
Two Chalk boreholes	110000	0.12	0.18
Six Tertiary boreholes	69000	0.14	0.15
Collecting Tank 3000m3	30000	-	0.01
	179000		0.17

Groundwater cost	142000	@ 0.17/m3	=	24140
Mains supply	98000	@ 0.26/m3	=	25500

Total £ 49640, say 50000

Thus an investment of about £180000 in such a groundwater scheme would reduce the annual cost by £12500 compared to using only a mains supply.

The benefits from this scheme include:

- a more secure supply during the summer as the fitted pumping capacity would be able to replace the mains supply, at least for short periods, if Drought Orders are in force

- the peak daily target priority demand as well as the average daily demand in a dry year can be met

- the boreholes (if of potable quality) could also be operated during the winter to reduce the demand and therefore the cost of mains supplies for the Club House facilities and when irrigation demands are less than average could also meet part of the summer water requirements of the Club House facilities

- blending would be possible at the collecting tank (in the ratio of 0.4 Chalk: 0.4 mains: 0.2 Tertiary under average annual target demands). This should reduce the potential ecological impact of a supply obtained solely from the mains or Chalk aquifer.

- less demand on uncertain aquifer resources.

The main disadvantage of this scheme is the uncertainty as to whether these two aquifers will be able to provide and sustain the anticipated pumping rates. If the anticipated yields cannot be obtained additional standby boreholes or a borehole into the Lower Greensand aquifer would still be required.

A significant supply from the mains would also be required with this scheme, perhaps 40% of the annual total target water demand but only about 10% in an average year. However, to completely avoid the use of mains supplies as part of this scheme to meet the annual target water demands would require either two more Chalk boreholes costing £110000, or a reservoir of 100000 m3 and a diversion structure costing a total of about £830000 to store surface water diverted during the winter. Both options would have a greater environmental impact due either to the higher proportion of alkaline groundwater or a more obtrusive reservoir structure.

The multiple aquifer groundwater scheme using the Tertiary and Chalk aquifers would not be capable of meeting the annual or peak daily water requirements in an exceptionally dry year. There would be a shortfall of about 300000 m3 in the annual availability and about 1000 m3/d in the peak daily availability. This could be overcome by drilling and equipping a single Lower Greensand borehole at a cost of about £70000 which would be pumped continuously at 20 l/s. A licence to use the Lower Greensand aquifer might perhaps be granted if this borehole was used only as a standby supply to meet exceptional dry year conditions. Yields of 20 l/s should be possible from this aquifer but water quality may be a constraint. It would therefore be preferable to explore the Lower Greensand aquifer at an early stage to examine the feasibility of this option.

(c) With Bunded Reservoir of 50000m3

The number of boreholes could be reduced if groundwater is used to meet average daily demands and surface water storage to meet periods of peak daily demand. The size of the reservoir required for this scheme would be determined by the magnitude and total duration that peak demands exceed average daily demand.

The optimum size of such a reservoir may be determined by several methods, such as a detailed study of demand figures to determine the amount and time over which actual demand exceeds average demand, or by defining the number of days the system must be able to sustain peak demand.

The capacity and cost of a reservoir to meet peak demands for the following periods of time are:

	Reservoir Storage Requirement m3		
Number of days of supply	Average Conditions	Target Conditions	Driest Conditions
30	25350	40650	49680
40	33800	54200	66240
50	42250	67750	82800

A reservoir with a capacity of about 50000 m3 would maintain supplies for 30 days in the driest year and for 50 days in an average year.

These estimates can be compared with figures for the driest single month (June, 1976) where total demand exceeded targeted average monthly demand by 28900 m3. During particularly dry years there should need to be adequate reservoir capacity (or a standby supply of groundwater) of about 2440 m3/day.

The capital costs associated with groundwater pumping rates equivalent to the targeted average daily irrigation demands backed up by a smaller 50000 m3 bunded reservoir are tabulated in Appendix II-G. A possible groundwater scheme of this type capable of meeting the targeted average annual demand but without abstraction from the Lower Greensand aquifer would be as follows:

Table 14 Multiple Aquifer Use with Bunded Reservoir

Aquifer	Number of Boreholes	Pumping Rate l/s	Daily Abstraction[1] m3	Capital £	Cost £/m3
Tertiary	2	2.1	363	23000	0.05
Chalk	1	5.3	908	60000	0.13
Reservoir	(50000m3)			404000	0.17
	TOTAL		1271	487000	0.27 [7.8][2]

1 Assuming 24 hour pumping
2 Payback Period compared to mains water at £62500 per annum

Surface water could be used to fill the reservoir during the winter months to reduce the total volume of water required from groundwater. This would result in a slight reduction in operating, and hence unit costs but would not reduce the combined yield requirements or capital costs.

The capital costs associated with excavation and construction of a bunded reservoir form a large proportion of the total costs in the above scheme. Therefore the use of an existing natural valley or pond that could be adapted for reservoir storage would significantly improve the economic viability of this form of scheme.

(d) Multiple Aquifer Use with a Natural Reservoir

To be economically viable relative to a scheme using a small reservoir tank, the capital expenditure necessary to form a reservoir in a natural valley should not exceed the savings resulting from the use of fewer boreholes. For most sources of groundwater the cost of a natural valley reservoir should not exceed £100000 and, as with the bunded reservoir, it should have a capacity of approximately 50000 m3. This storage capacity would probably need to be made up as two separate reservoirs so as not to come within the terms of the Reservoir Act.

Costings for a natural valley reservoir filled from different groundwater sources are tabulated in Appendix II-G. A possible scheme to meet targeted peak daily and targeted annual irrigation demands is shown in Table 15 below :

Table 15 Multiple Aquifer Use with Natural Valley Reservoir

Aquifer	Number of Boreholes	Pumping Rate l/s	Daily Abstraction[1] m3	Capital £	Cost £/m3
Tertiary	2	2.1	363	23000	0.05
Chalk	1	5.3	908	60000	0.13
Reservoir	(50000m3)			100000	0.05
	TOTAL		1271	183000	0.11 [2.9][2]

1 Assuming 24 hour pumping
2 Payback Period compared to mains water at £62500 per annum

This option assumes that two natural reservoirs can be created with a total volume of about 50000 m3 for an investment of £100000. Surface water may partially fill the natural valley reservoir at the end of winter, but as with the bunded structure this will only reduce operating costs by a small amount. Similarly the mains can serve as a back up supply, but may be more important where suitable sites and capital expenditure limitations may result in a smaller final reservoir capacity. Abstraction can be spread over a longer period each year to reduce the number of boreholes required, although evaporation from the reservoir will result in losses from this groundwater contribution.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

* Irrigation water demands are expected to increase to about 240000 m3/y with a peak requirement of 2500 m3/d. In addition, the Club House and associated facilities are expected to increase to about 30000 m3/y with a peak requirement of 83 m3/d. The annual cost of purchasing these supplies from the North Surrey Water Company based on 1990 prices is £62500 for the irrigation and £10000 for the Club House facilities.

* The estimated cost of improving the irrigation system is about £1.27 million.

* Retreatment of the Club House water supply is not considered viable due to the relatively small contribution, the costs of a treatment plant and storage reservoir, and potential health risks associated with spray irrigation.

* A hydrological model indicates that surface water supplies are sufficient to meet the predicted water demands without a significant effect on the residual flow during the winter and therefore the downstream environment. However, diversion is only permitted during the winter and consequently an investment of nearly £2.0 million would be required to construct a reservoir with sufficient storage to meet the entire anticipated demand in the summer irrigation season. The Reservoirs Act restricts the use of surface impoundment schemes. A reservoir having a capacity of about 50000m3 is considered to be an optimum size for the Wentworth estate. The quality of the surface water would be suitable for irrigation but there is a higher risk of such supplies being polluted.

* There are three aquifers (Tertiary, Upper Chalk and Lower Greensand) underlying the Wentworth site at depths of up to 450m. Neither the resources of borehole yields of the Tertiary or the Chalk aquifer are considered sufficient to provide a direct source of supply. A licence is unlikely to be granted to abstract water from the Lower Greensand until the NRA are satisfied that no other alternative sources are available.

* Soils on the estate are free draining and acidic and suitable for heathland vegetation. Most of the areas of heathland are small and of value for landscape purposes but the largest area, Broomhall Common, is designated as a SSSI. Current management techniques maintain a dwarf shrub/acid grassland heath. The most common heather species are

characteristic of dry heaths. Extra watering of the heathland area is likely to reduce the dwarf shrub content of the vegetation. The alkaline water composition of the Chalk aquifer, the high iron content of the Tertiary aquifers, and the possibility slightly saline Lower Greensand aquifer could have an adverse effect on the vegetation.

6.2 RECOMMENDATIONS

A summary of the various schemes to provide the target year water requirements is given in Table 16.

A groundwater supply scheme is recommended. This would provide a blended supply capable of meeting target year water demands by simultaneous abstraction from the Tertiary and Chalk aquifers supplemented by mains water with a collecting tank (see section 5.5.3b).

Preliminary estimates of borehole yields suggest that a scheme involving two Chalk boreholes and six Tertiary boreholes abstracting a total of 142000 m3 over a 6 month irrigation season with a fitted pumping capacity of 2800 m3/d should be possible provided water is pumped to a collecting tank with a capacity of 3000 m3.

This scheme would be capable of meeting average annual demands and peak daily target demands with a supplementary mains supply requirement of 16000 m3/y. It could also contribute supplies to the Club House and facilities. Blending is recommended to reduce the environmental impact of the more alkaline Chalk water.

There would still be a shortfall of about 98000 m3 (40%) in the target year requirements which would have to be met from the mains supply or another source. Consideration should be given to constructing a borehole into the Lower Greensand aquifer or constructing reservoirs with a total capacity of 50000 m3 to meet peak demands in exceptionally dry years.

The costs of this scheme are estimated to the £180000 with an additional recurrent cost of £4000 to £25000 to provide supplementary mains supplies up to the target level water requirements.

The presence of permeable zones in the Tertiary sequence needs to be proved. There is also a real risk of dry Chalk boreholes and of encountering saline water in the Lower Greensand aquifer. These uncertainties can only be resolved by a "rolling" programme of drilling and testing designed to provide production boreholes as part of a phased development.

Table 16 Schemes to supply annual (240000m3), average daily (1140 m3/d) & peak daily (2500 m3/d) target year demands

Scheme	Capital cost (£K)	Operating cost (£/m3)	Unit cost (£/m3)	Payback period (yrs)	Mains Required	Meets Peak Daily	Meets Annual	Visual Impact	Water Quality	Borehole Requirements No	Aquifer	Rate l/s	Rate m3/d
Reservoir Storage of Surface Water (240000m3)	1900	0.04	0.90	30.4	Back-up	Yes	Yes	Very High	Good	None			
Groundwater with 50000m3 bunded reservoir. Pumping 24hrs/d @ average daily rate.	547	0.06	0.27	8.8	Back-up	For 37 successive peak days	Yes	Moderate - High	Moderate (depends on blend)	2 2	T Ck	2.1 5.3	363 908 1271
Groundwater with 50000m3 valley reservoir. Pumping 24 hrs/d @ average daily rate.	243	0.06	0.11	3.9	Back-up	"	Yes	Moderate	"	"			
Groundwater with occasional pumping above sustainable rates. Pumping 24 hrs/d to 3000m3 storage tank.	179	Peak 0.05 Av 0.12	Peak 0.09 Av 0.21	2.9	Yes	Yes	Yes	Low	"	Peak 6 2 Av 6 2	 T Ck T Ck Mains	 2.1 10 0.5 3.0	 1037 1728 2765 259 518 363 1140
Groundwater. Pumping 24hrs/d @ peak daily rate to 3000m3 storage tank.	183	0.02	0.05	2.9	Back-up	Only with LGS Borehole	Yes	Low	"	2 1 1	T Ck LGS	2.1 5.3 21	363 458 1816 2637
Groundwater. Direct pumping 6hrs/d @ peak daily rate.	520	0.03	0.25	8.3	Back-up	Only with LGS boreholes	Yes	Numerous Boreholes	"	5 3 4	T Ck LGS	2.1 10.1 21	227 665 1814 2687
Mains	-	0.26	0.27	-	-	Yes	Yes	Low	Moderate	None			

The following development strategy is proposed. This is intended to investigate the groundwater potential of successively deeper aquifers to gradually reduce the mains supply contribution, but which would eventually incorporate a surface water reservoir if required.

- explore the Tertiary aquifers by drilling and testing six boreholes. Apply for an abstraction licence for about 50000 m3/y if successful.

- drill and test two boreholes penetrating 75m into the Chalk (total depth about 250m). Assess their contribution (average and peak capacities) taking into account the benefits from blending. Apply for an abstraction licence of about 100000 m3/y if successful.

- if insufficient supplies are obtained from either the Tertiary or especially the Chalk aquifer, then deepen the lowest yielding Chalk borehole to about 475m, to test the yield and water quality of the Lower Greensand aquifer. If suitable then apply for an abstraction licence of up to about 30000 m3/y or a short duration abstraction rate of 20 l/s.

- if supplies from the Lower Greensand aquifer are found to be unsuitable, then determine the size and location of a surface water reservoir to provide a capacity not more than about 50000 m3 if constructed or two reservoirs of 25000 m3 if formed by the impoundment of a natural valley.

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WENTWORTH CLUB

Catchment Boundaries

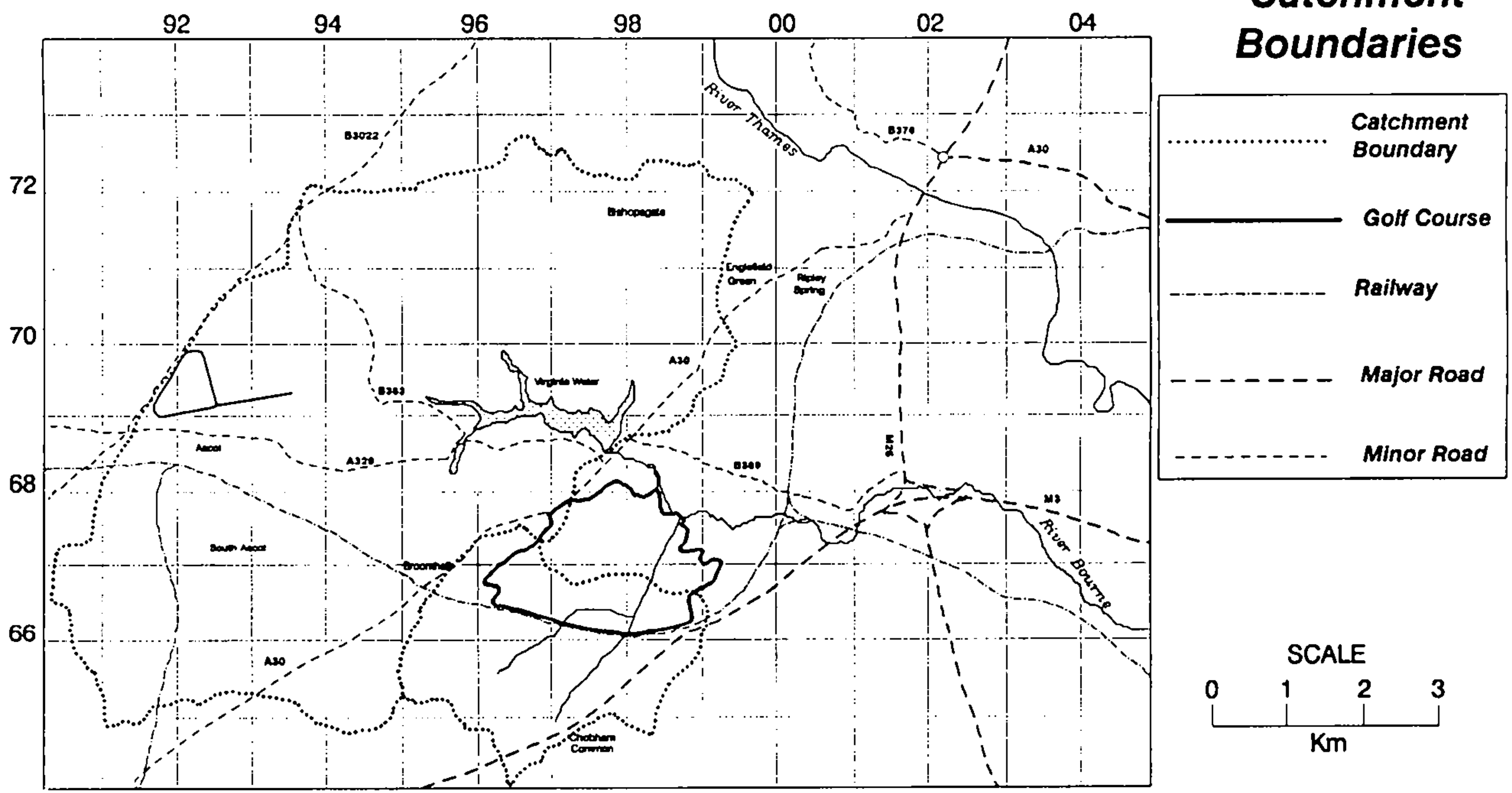
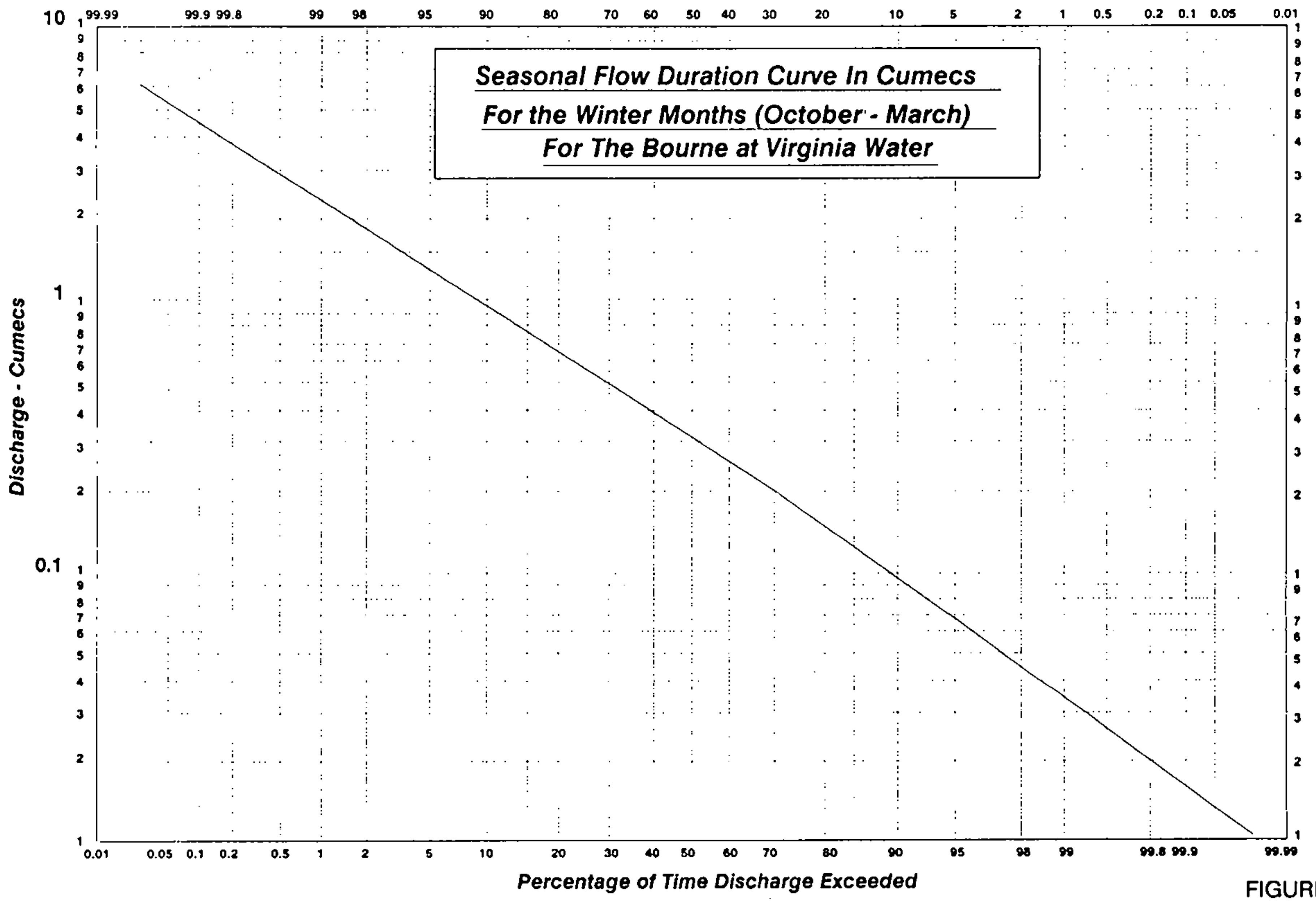


FIGURE 1



Seasonal Flow Duration Curve In Cumecs
For the Winter Months (October - March)
For The Bourne at Virginia Water
Discharge - Cumecs
Percentage of Time Discharge Exceeded
10
1
0.1

FIGURE 2

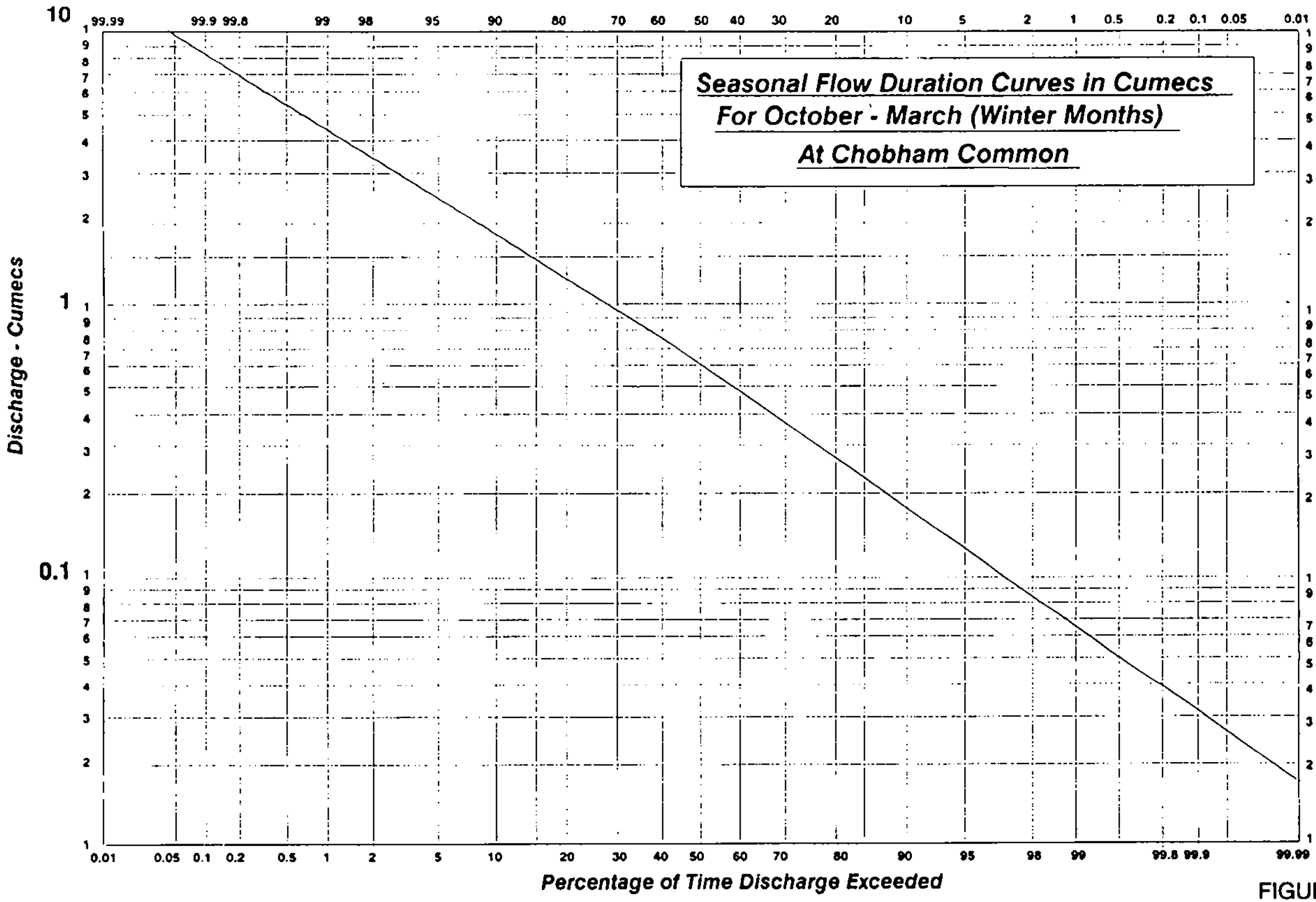
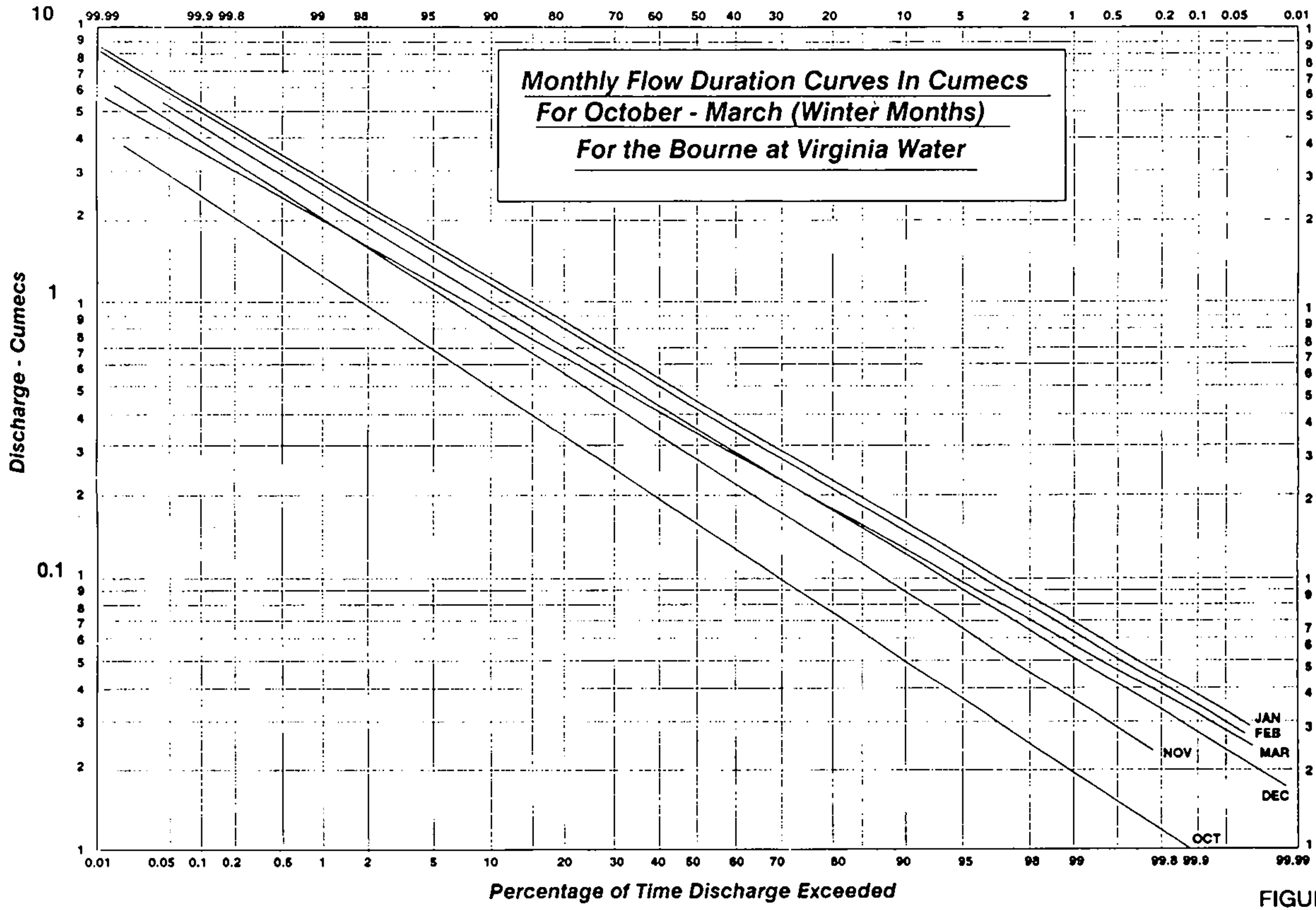

Seasonal Flow Duration Curves in Cumecs
For October - March (Winter Months)
At Chobham Common
Discharge - Cumecs
Percentage of Time Discharge Exceeded

FIGURE 3



Monthly Flow Duration Curves In Cumecs
For October - March (Winter Months)
For the Bourne at Virginia Water
Discharge - Cumecs
Percentage of Time Discharge Exceeded
JAN
FEB
MAR
DEC
NOV
OCT

FIGURE 4

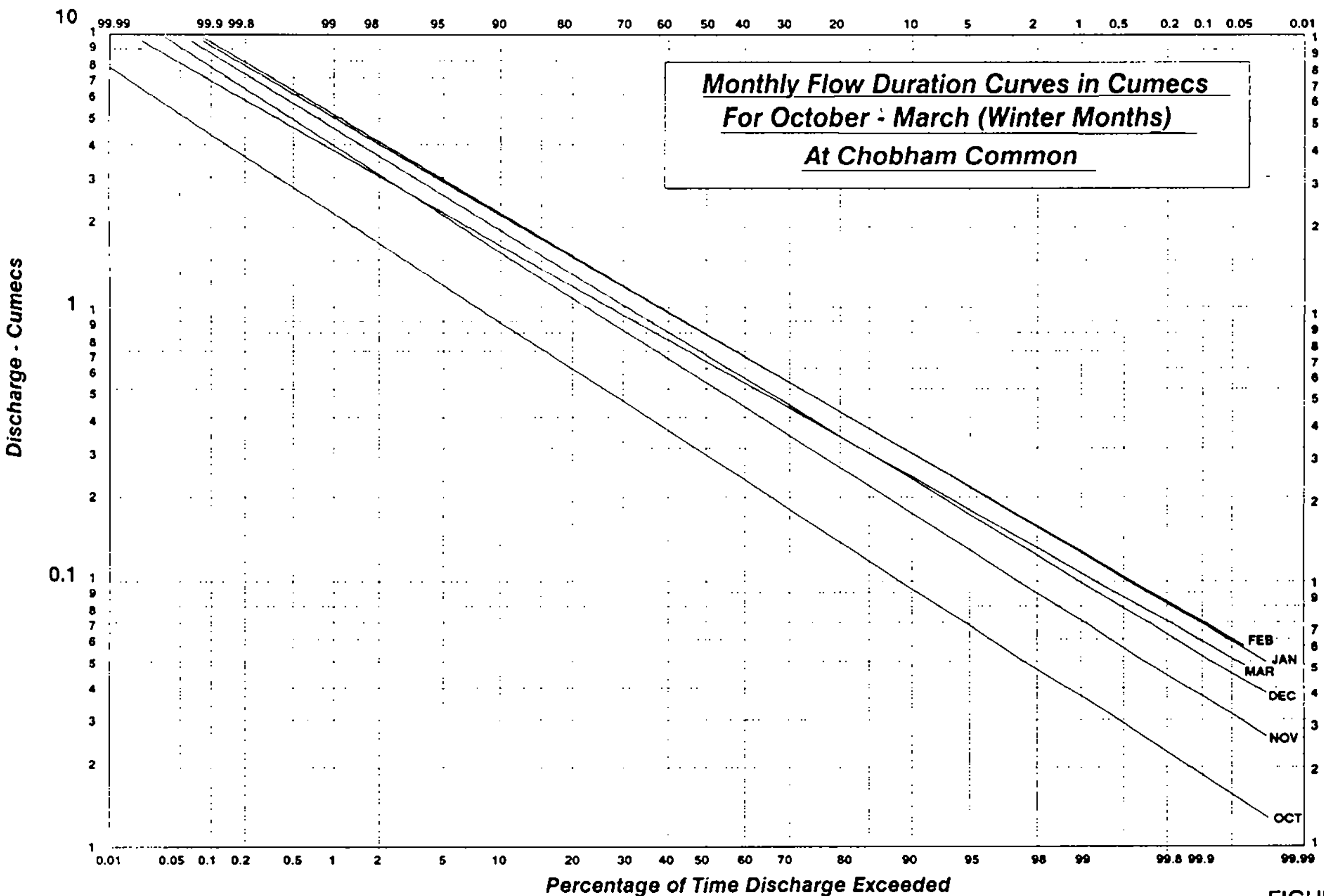

Monthly Flow Duration Curves in Cumecs
For October - March (Winter Months)
At Chobham Common
Discharge - Cumecs
10
1
0.1
Percentage of Time Discharge Exceeded
FEB
JAN
MAR
DEC
NOV
OCT

FIGURE 5

WENTWORTH CLUB

Abstraction Rates and Monthly Flow Duration Percentile

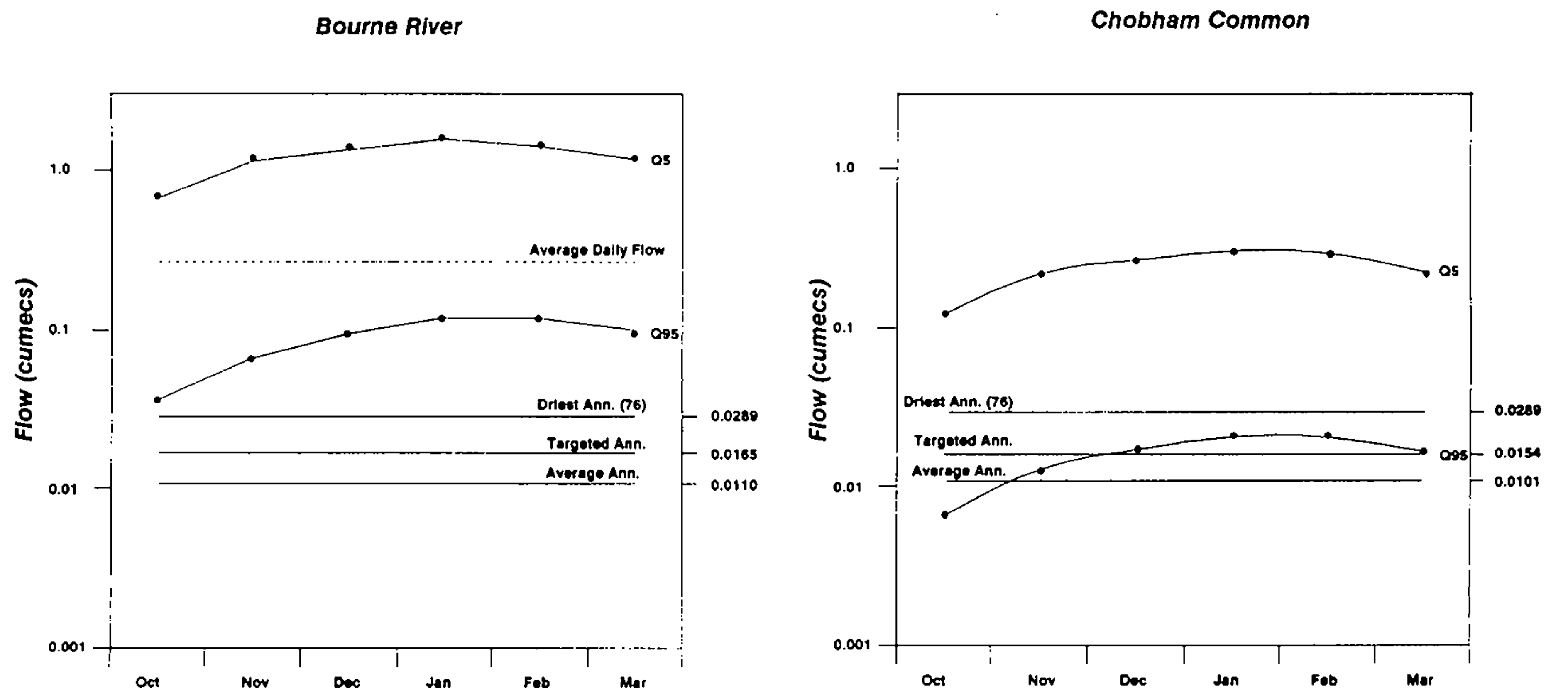


FIGURE 6

WENTWORTH CLUB

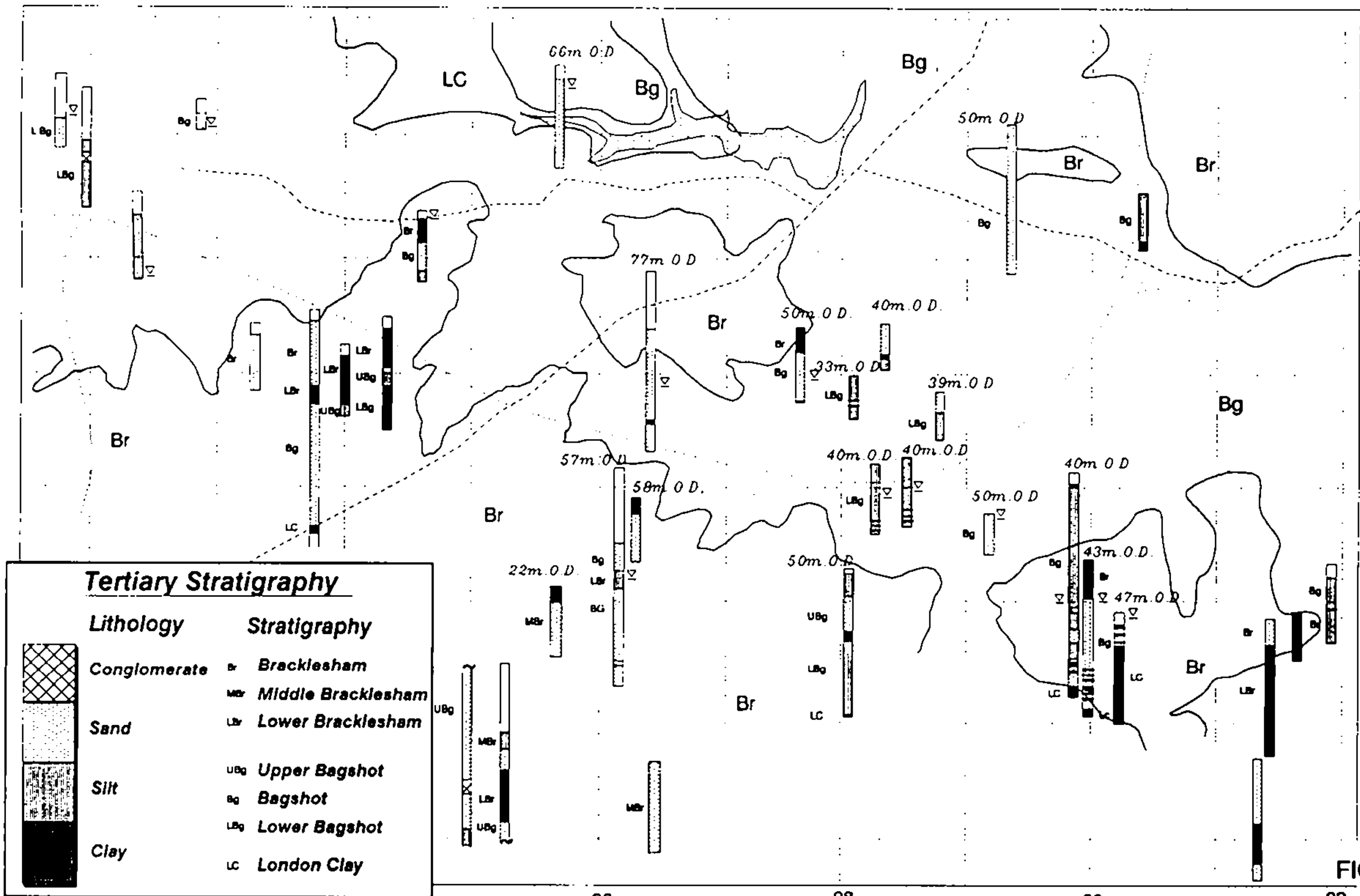


FIGURE 7

WENTWORTH CLUB

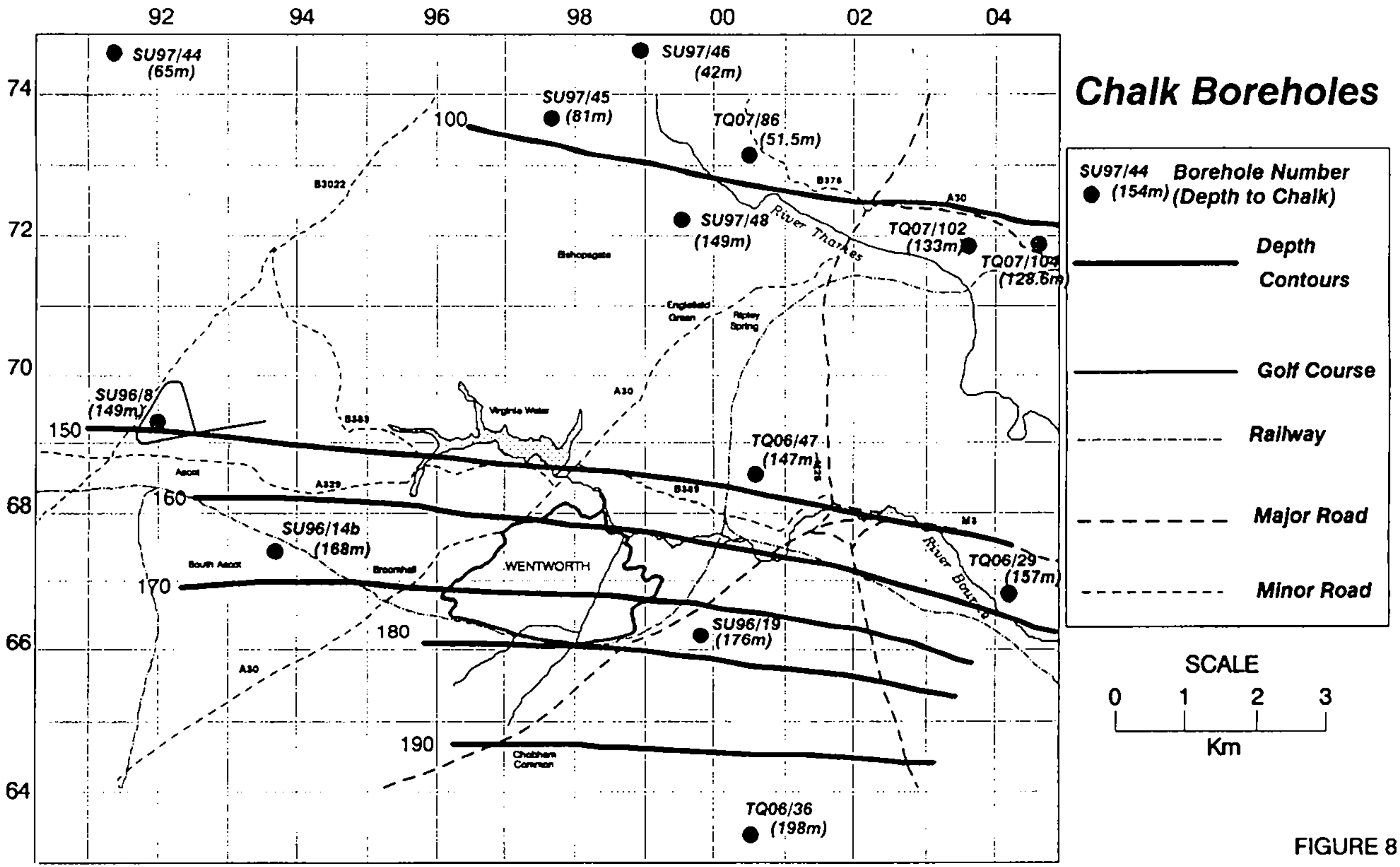
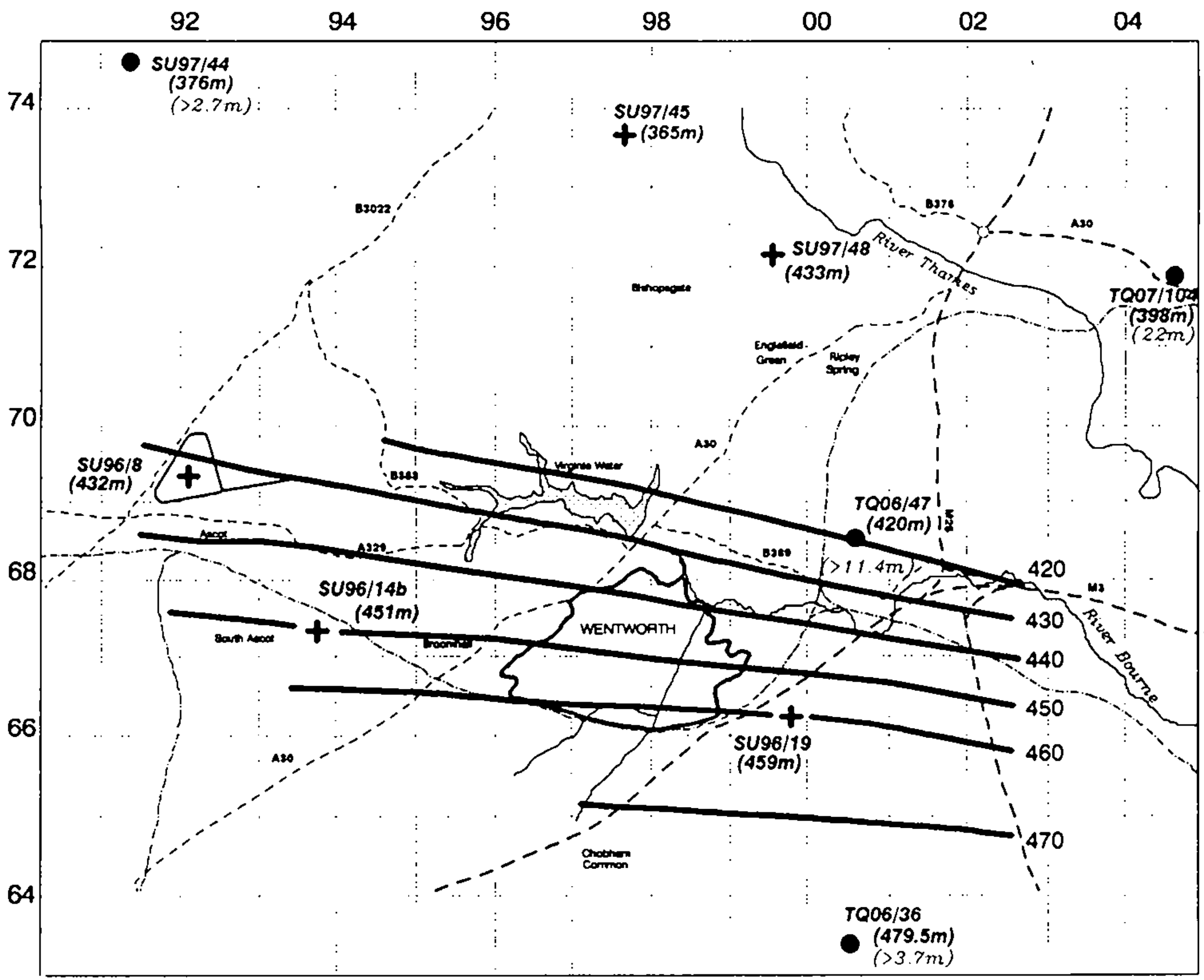


FIGURE 8

WENTWORTH CLUB



Depth To Top Of Lower Greensand

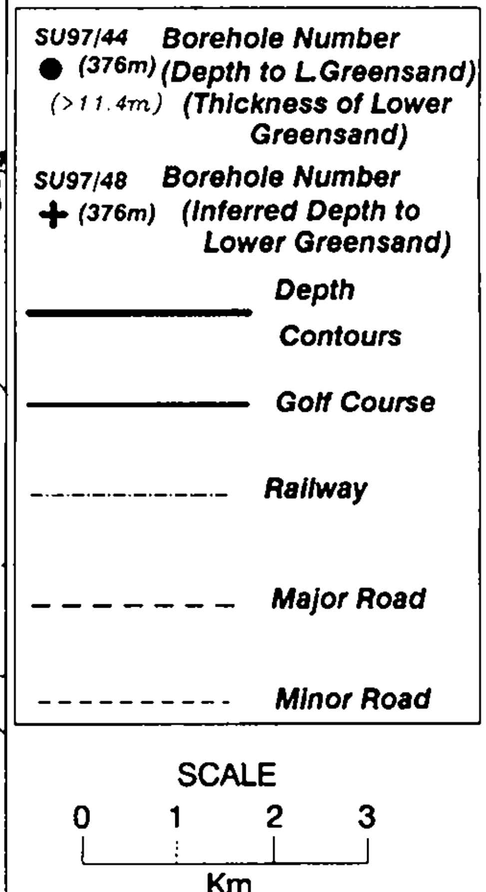
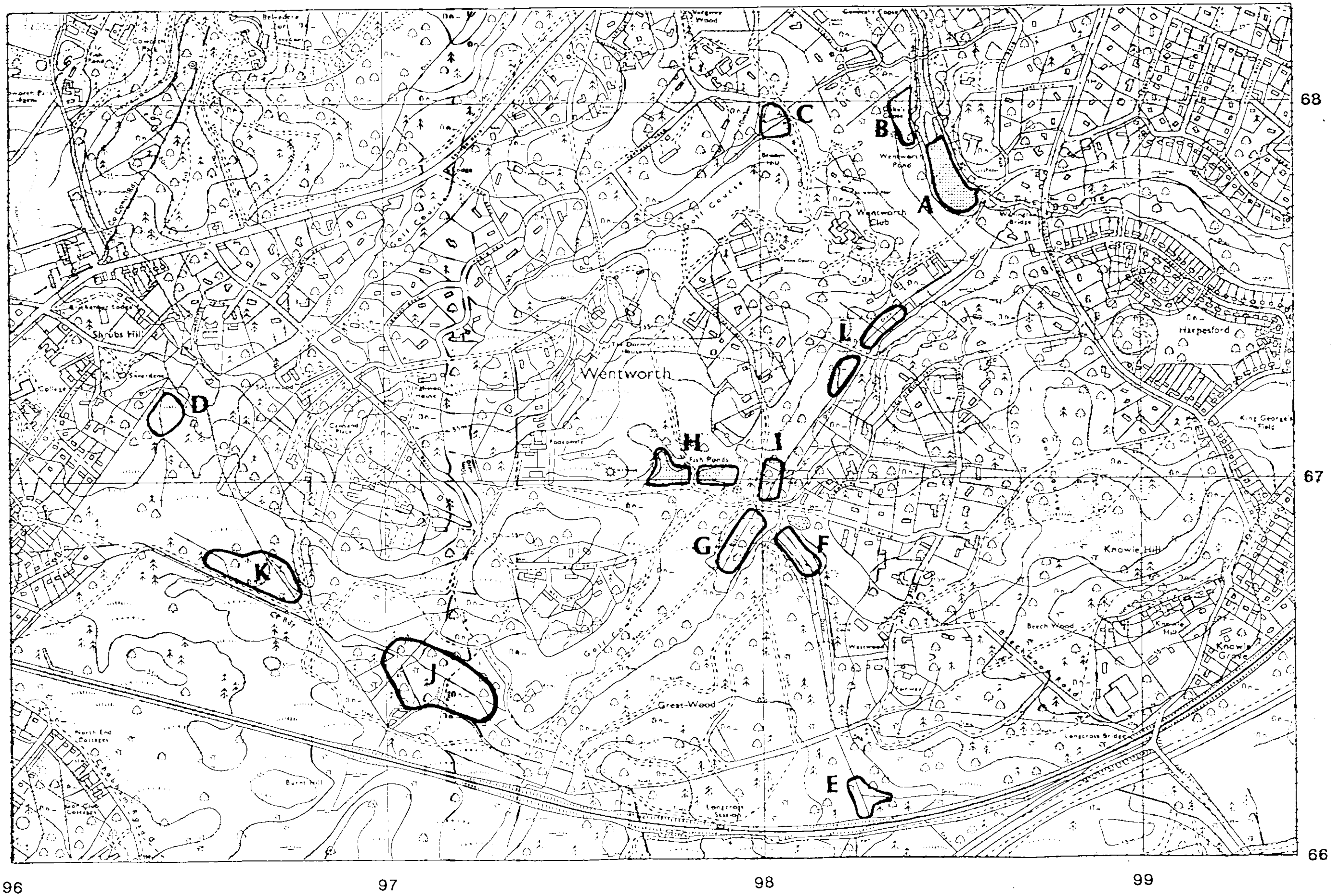


FIGURE 9

WENTWORTH CLUB

WATER RESOURCES ASSESSMENT - POTENTIAL RESERVOIR SITES



1:10000 DECEMBER 1990

INSTITUTE OF HYDROLOGY

FIGURE 10

Annex A

OUTLINE TERMS OF REFERENCE

Phase I

- Assessment of the quantity of water required for the projected irrigation programme on an average annual, an average peak daily basis and an absolute peak daily basis.

- Assessment of the excess winter flow of the Bourne, and the impact of an abstraction of this flow or that part of it necessary to meet the irrigation demand. Assessment of the capital investment and running costs aspects and the local ecology and environment with an assessment of the likelihood, or otherwise, of formal permissions for abstraction being obtained.

- Assessment of the availability, or otherwise, of groundwater from shallow aquifers to form all or part of the irrigation demand and the impact on capital investment, running costs and the local ecology and environment that would stem from the abstraction, along with the assessment of the likelihood, or otherwise, of formal permissions for abstraction being obtained.

- Assessment of the availability, or otherwise, of water for irrigation to form all or part of the irrigation demand from other sources, such as retreatment of water from the Clubhouse facilities, and the impact on capital investment, running costs and the local ecology and environment that would stem from the use of such water, along with an assessment of the likelihood, or otherwise, of formal permissions for them being obtained if necessary.

- An assessment of the cost and continuous availability of potable water for irrigation and the effects of its long term and large scale use on the ecology and environment.

- A recommended water development strategy using some, or all of the identified water sources to meet the irrigation requirements, with or without potable water inputs.

Phase II

This will consist of work necessary to obtain any necessary permissions, and will be undertaken after the Club has decided upon their preferred development strategy.

Annex B

METHODOLOGY FOR DETERMINATION OF FLOW DURATION CURVES

The procedure for estimating flow duration curves at sites with no flow data is founded on estimating the 95 percentile 10 day flow from the annual flow duration curve Q95(10). That is the average 10 day flow that will be exceeded by 95% of 10 day average discharges. The estimate of Q95(10) requires data on the catchment's annual average rainfall (SAAR) and baseflow index (BFI). The full method for estimating Q95(10) is outlined in the Low Flows Report, and the catchment characteristics are listed below.

Virginia Water Catchment Characteristics

Area	42.6 km2
STMFRQ	0.446
Stream Length (L)	7.1 km
Lake Area	0.845 km2
FALAKE	0.02
SLOPE	8 m/km
SAAR	702 mm
Urban Area	6 km2
Potential Evaporation (PE)	550 mm
BFI	0.45

The baseflow index (BFI) can be thought of as the proportion of river runoff that is derived from stored sources. The principal control on BFI is catchment geology but other factors such as catchment area, proportion of area urbanised, the area covered by lakes, vegetation type and catchment topography will all affect BFI.

The geology of the Virginia Water catchment consists of :

Bagshot Beds	52%
Brackelsham Beds	26%
London Clay	19%
Barton Beds	3%
Plateau Gravel	20%

The London Clay is fairly impermeable but the other beds are of mixed permeability with a large degree of spatial variability. Criteria for BFI calculation in the ungauged case cannot be given entirely objectively. A good approximation to the BFI can be deduced by comparing the BFI calculated by three different qualitative methods.

Method 1 : BFI's Indicated in the Low Flows Report

For the stratigraphic units occurring within the Virginia Water catchment the Low Flows Study indicates that BFI's will be in the range 0.15 to 0.55.

Method 2 : Comparison with Equivalent Catchments of Known BFI

There are no catchments within the Thames Basin with a comparable ratio of the stratigraphic units to that which occurs within the Virginia Water catchment. Catchments with similar geology occur within the Weald area, where the Cockhaise Brook (041024) and the Cuckmere at Cowbeck (041016) have BFI's of 0.53 and 0.38 respectively. Both are rural catchments of mixed geology although the Hastings Beds are the predominate lithology within these areas. The Hastings Beds are intergranular in nature with fairly low storage and are very similar to the Bagshot and Brackesham Beds.

Method 3 : BFI's Indicated using FREND

The FREND (Flow Regimes from Experimental and Network Data) project (Gustard, et al, 1989) showed that BFI has a strong relationship to soil type. The hydrological classification of soils is interpreted in terms of "Winter Rain Acceptance Potential" (WRAP). All the soils of the UK are divided into five WRAP classes on the basis of their permeability. From the WRAP map of the UK the Virginia Water catchment was found to be 12% soil type 1 and 88% soil type 4.

The FREND relationship between BFI and WRAP calss for the UK is:

$$BFI = 0.39 + 0.49S1 + 0.19S2 + 0.09S3 - 0.05S5$$

where S1 etc. are the proportions of each soil type across the catchment. Substituting the values obtained for the Virginia Water catchment into this equation gives a BFI value of 0.45.

After comparison of the results obtained using the three methods described above an optimum BFI value of 0.45 was selected for the Virginia Water catchment. It may be expected that there would be a slight increase in the BFI as a result of lake storage on the catchment characteristics. This increase is difficult to quantify and for water abstraction purposes a lower estimate of BFI is to be preferred.

The Standard Average Annual Rainfall (SAAR) for the 1941-70 period was determined from the Flood Study Report (Institute of Hydrology, 1975) as 702 mm.

APPENDIX I

Appendix I

PUMPING RATES REQUIRED TO MEET RESERVOIR CAPACTIES

Pump rate assuming no abstraction of flows less than the following percentile flows (m3/sec).

Total Abstraction m3	95 (173)	90 (164)	85 (155)	80 (146)	60 (109)	50 (91)
50000	0.0033	0.0035	0.0037	0.0039	0.0053	0.0064
100000	0.0067	0.0071	0.0075	0.0079	0.0106	0.0127
150000	0.0100	0.0106	0.0112	0.0119	0.0159	0.0191
200000	0.0134	0.0141	0.0150	0.0159	0.0212	0.0254
250000	0.0167	0.0177	0.0187	0.0199	0.0265	0.0318
300000	0.0201	0.0212	0.0224	0.0238	0.0318	0.0382
350000	0.0234	0.0247	0.0262	0.0278	0.0371	0.0445
400000	0.0268	0.0283	0.0299	0.0318	0.0424	0.0509
450000	0.0301	0.0318	0.0337	0.0358	0.0477	0.0572
500000	0.0335	0.0353	0.0374	0.0397	0.0530	0.0636

(xxx) number of days on which abstraction would be possible

These results are applicable to both the Bourne River and Chobham Common catchments.

APPENDIX II

COST ESTIMATES

Appendix II - A

COST ESTIMATES - OPEN BUNDED STORAGE RESERVOIR
(Nominal Capacity 50 000 m3)

Capital Cost

			Cost £
Site Clearance			2 000
Removal, Storage & Reinstatement of Topsoil	5300 m3 @ £5.81		30 793
Bulk Excavation	47 581 m3 @ £3.41		62 251
Formation of Bunds	21 830 m3 @ £3.76		82 081
Lining (PVC & Gravel)	13 165 m3 @ £6.00		78 990
Landscape/Grassing			1 725
Fencing & Gates			8 248
Overflow/Miscellaneous Works			2 000
		Sub Total	368 088
Allowance for Contingencies (10%)			36 809
		Total	404. 897
Cost/m3 of water stored			0.81*

Maintenance Cost

Allowance for maintenance of reservoir (per annum)	1 000
Cost/m3 of water stored	0.02

* Amortized over 10 year period

Appendix II - B

COST ESTIMATE - SURFACE WATER ABSTRACTION AND DELIVERY

(Nominal Abstraction 50 000 m3 per annum)

Capital Cost

		Cost £
Construction of small weir across existing stream		10 000
Collection manhole with 2 No. submersible pumps:		
- Civil Works		5 000
- Plant (Excluding Electrical Supply)		4 000
Pumping Main to reservoir (Assume 200 m)		8 000
	Sub Total	27 000
Allowance for Contingencies (10%)		2 700
	Total	29 700
	Cost/m3 of water pumped	0.06*

Maintenance Cost

Allowance for maintenance of weir/pumps (per annum)		500
	Cost/m3 of water pumped	0.01

Operating Costs

Power requirements of pumpset 3KW

(Pumpset duty 23 m3/hr @ say 30m head)

Assuming a power cost of £0.06 / KWhr

	Cost/m3 of water pumped	0.01

* Amortized over 10 year period

Appendix II - C

COST ESTIMATE - SEWAGE TREATMENT WORKS

(Nominal Capacity 97 m3 per day, Average 74 m3 per day)

Capital Cost

		Cost £
Supply/Installation of sewage treatment plant suitable for producing an effluent of 10 : 10 (BOD : SS) standard		130 000
Estimated cost of civil works		40 000
	Sub Total :	170 000
	Allowance for Contingencies (10%)	17 000
	Total :	187 000
	Cost/m3 of water treated (based on average flow)	0. 69 *

* Amortized over 10 year period

Appendix II - D

COST ESTIMATE - TERTIARY BOREHOLES

Reconnaissance Drilling

		Cost £
Mobilisation & moving between holes		3 000
Drilling 30 m deep boreholes, supply and install 150 mm diam PVC lining and 10 m screen (6 boreholes @ 3500 per hole)		21 000
Pumping Tests (3 tests of 3 days duration @ £3000 per test)		9 000
Cost per borehole £5500	TOTAL :	33 000

Production Drilling

	Cost per borehole
Mobilisation, moving, drilling, lining and pumping tests.	5 000
Rising Mains	1 000
Pump	500
Surface facilities, pumphouse, etc	1 000
	7 500 *

Assuming continuous pumping for six months per year
Assuming £4000 for connection to power supplies, and water collection network.

Production Rates	Capital Costs	Operating Costs	TOTAL
500 gph (8250 m3/six months)	£ 0.150/m3	£ 0.012/m3	£ 0.162/m3
2000 gph (33000 m3/six months)	£ 0.035/m3	£ 0.009/m3	£ 0.044/m3

* Amortized over 10 year period

Appendix II - E

COST ESTIMATE - UPPER CHALK BOREHOLES

	Cost £
Mobilisation	4 000
Drilling (200m deep @ 200mm diam)	15 000
Lining Tubes (150m)	13 000
Acidification	4 000
Rising Main (150m @ 100mm diam)	3 000
Pump	4 500
Development	3 000
Pumping Test (3 days)	3 000
TOTAL :	55 000 *

Assuming continuous pumping for six months per year
Assuming pumping against 150m head
Cost of power 0.06/KWH
Assuming £5500 for connection to mains power supply, and pipework between borehole and reservoir.

Production Rates	Capital Cost	Operating Cost	TOTAL
5000 pgh - 19KW pump (82500 m3/six months)	£0.074/m3	£0.059/m3	£0.133/m3
10000 gph - 37KW pump (165000 m3/six months)	£0.074/m3	£0.059/m3	£0.133/m3

Appendix II - F

COST ESTIMATE - LOWER GREENSAND BOREHOLES

	Cost £
Mobilisation, site preparation & restoration	5 000
Drilling (450m borehole @ 200mm diam)	25 000
Lining Tubes	22 000
Screen	1 500
Rising Main (60m @ 100mm diam)	3 000
Pump	4 000
Development	3 000
Pumping Test (4 days)	4 000
Pump house and civil works	5 000
TOTAL :	72 500 *

Assuming either artesian or pumped flow at 20 000 gph for six months of the year (equivalent to 1820 m3/day or 330000 m3/six month period).
Pumping against a head of 30m.
Cost of power £0.06/KWH.

Production Rates 20,000 gph	Capital Costs	Operating Cost	TOTAL
Artesian Flow	£0.021/m3	-	£0.021/m3
Pumped - 11KW pump	£0.021/m3	£0.001/m3	£0.022/m3

Appendix IIG

CAPITAL COST OF MEETING PEAK DAILY DEMAND DIRECTLY FROM GROUNDWATER

	Demand m3/d	l/s	Tertiary 0.5 l/s	Cost		Tertiary 2.1 l/s	Cost		Chalk 5.3 l/s	Cost		Chalk 10.5 l/s	Cost		Lower Greensand 21 l/s	Cost	
Expenditure required to meet peak daily demand directly from groundwater[1]																	
Average Year	1600	74	(117)	1.34	[21.5]	(29)	0.33	[5.3]	(12)	0.72	[11.5]	(6)	0.36	[5.8]	(3)	0.22	[3.5]
Target Year	2500	116	(182)	2.10	[33.5]	(45)	0.52	[8.3]	(18)	1.08	[17.3]	(9)	0.54	[8.6]	(5)	0.36	[5.8]
Driest Year	3750	174	(275)	3.16	[50.6]	(69)	0.51	[8.1]	(28)	1.68	[26.9]	(14)	0.84	[13.4]	(7)	0.51	[8.1]
Expenditure required to meet peak daily demand from groundwater with Collecting Tank of 3000 m3 capacity																	
Average Year	1600	18.5	(30)	0.37	[6]	(8)	0.12	[2]	(3)	0.21	[3.4]	(2)	0.15	[2.4]	(1)	0.1	[1.9]
Target Year	2500	29	(46)	0.56	[8.9]	(12)	0.17	[2.7]	(5)	0.33	[5.3]	(3)	0.21	[3.4]	(2)	0.17	[2.8]
Driest Year	3750	43.5	(69)	0.82	[13.2]	(17)	0.22	[3.6]	(7)	0.45	[7.2]]	(4))	0.27	[4.3]	(3)	0.17	[2.8]
Expenditure required to meet average daily demand from groundwater with a bunded reservoir of 50000 m3 storage capacity																	
Average Year	750	8.7	(16)	0.59	[9.4]]	(4)	0.45	[7.2]	(2))	0.52	[8.4]	(1)	0.46	[7.4]	(1)	0.47	[7.6]
Target Year	1140	13.2	(24)	0.68	[10.9]	(6))	0.47	[7.6]	(3)	0.58	[9.3]	(2)	0.52	[8.4]	(1)	0.47	[7.6]
Driest Year	2100	24.3	(45))	0.92	[14.7]	(11)	0.53	[8.5]	(5)	0.7	[11.3]	(3)	0.58	[9.3]	(2)	0.55	[8.8]
Expenditure required to meet average daily demand from groundwater with natural reservoir[2]																	
Average Year	750	8.7	(16)	0.28	[4.5]	(4)	0.15	[2.3]	(2)	0.22	[3.5]	(1)	0.16	[2.6]	(1)	0.17	[2.8]
Target Year	1140	13.2	(24)	0.38	[6]	(6)	0.17	[2.7]	(3)	0.28	[4.5]	(2)	0.22	[3.5]	(1)	0.17	[2.8]
Driest Year	2100	24.3	(45)	0.62	[10]	(11)	0.23	[3.6]	(5)	0.4	[6.4]	(3))	0.28	[4.5]	(2)	0.24	[3.9]

Costs shown in £million.

1. No reservoir capacity and therefore borehole pumping occurs only six(6) hours each day.
2. Investment in creating natural reservoir limited to £100000

( ) Number of boreholes

[ ] Payback period in years compared to mains supplies at £62500/y

APPENDIX III

CHEMICAL ANALYSES

CHEMICAL ANALYSIS OF MAINS WATER

Supplied by North Surrey Water Company

Results for Year Ending 31 December, 1989
Water Supply Zone F - (Including Sunningdale)

Parameter	No. of Tests	Maximum	Minimum	Mean
pH	47	7.7	7.2	7.4
Turbidity	48	6.3	0.20	0.84
Aluminium ug Al/l	67	389	<10	47
Temperature as C	5	18	11	16
Nitrate mg N/l	11	8.2	5.6	7.1
Nitrite mg N/l	11	0.041	<0.001	0.006
Ammonia mg N/l	11	0.07	<0.01	0.03
Iron ug Fe/l	11	110	<10	27
Manganese ug Mg/l	11	16	<10	<10
Colour Hazen units	11	8	<1	4
Trichloromethane ug/l	4	40.5	18.5	28.9
Total THM's	4	84.9	40.8	58.7
Tetrachloromethane ug/l	4	<1	<1	<1
Trichloroethene ug/l	4	2.5	<1	<1
Tetrachloroethene ug/l	4	<1	<1	<1
Copper ug Cu/l	5	27	11	18
Lead ug Pb/l	5	16	<10	<10
Benzo 3,4 pyrene ng/l	3	<5	<3	<3
Total P.A.H. ug/l	3	<0.2	<0.2	<0.2
Kjeldahl Nit. mg N/l	2	0.495	0.369	0.432
Chloride mg Cl/l	3	66	48	57
Sulphate mg SO4/l	3	96.8	90.0	94.4
Calcium mg Ca/l	2	110	106	108
Magnesium mg Mg/l	2	5.8	4.7	5.3
Sodium mg Na/l	2	38.8	23.8	31.3
Potassium mg K/l	2	7.6	4.5	6.1
Dry Residues mg/l	2	508	410	459
Oxidisibility mg O2/l	2	2.10	2.00	2.10
T.O.C. mg/l	2	3.67	2.29	2.98
Boron ug/l	2	400	250	325
Surfacants ug/l	2	32	17	25
Phosphorus ug P/l	2	1230	90	660
Fluoride ug F/l	2	190	170	180
Barium ug Ba/l	2	19	15	17
Silver ug Ag/l	2	<20	<20	<20
Arsenic ug As/l	2	1.3	0.7	1.0
Cadmium ug Cd/l	2	<1	<1	<1
Cyanide ug CN/l	2	<0.050	<0.050	<0.050
Chromium ug Cr/l	2	<20	<20	<20
Mercury ug Hg/l	2	0.3	<0.1	0.1
Nickel ug Ni/l	2	<20	<20	<20
Antimony ug Sb/l	2	0.1	<0.1	0.1
Selenium ug Se/l	2	0.4	0.1	0.3
Tot. Hardness mg CaCo3/1	2	300	284	292
Alkalinity mg CaCO3/l	2	206	175	191

RIVER BOURNE

Location: Thorpe Green Bridge (TQ0140068000)

NRA Water Quality List for 12 months 01/09/89 - 20/10/90

Number of Samples : 12

Determinand	Results in mg/l				
	Highest	Lowest	Mean	Std. Dev	Median
pH	7.7	6.6	6.9	0.305	6.85
B.O.D. (5 days using ATU	2.3	<1.0	1.18	0.805	1.30
Temp deg C	16.5	6.2	10.93	3.43	9.5
Diss Oxygen	8.0	8.0	8.0	0.00	-
Diss Oxygen % Sat Ammoniacal	124.0	79.2	92.72	11.975	90.5
Ammonia, Nitrogen	0.28	0.05	0.123	0.065	0.10
Ammonia, un-ionised, as Nitrogen	0.002	0.0	0.0	0.0	
Nitrogen, totla oxidised	2.70	<0.5	1.43	0.88	1.25
Chloride as Cl	46.0	36.0	39.33	3.08	39.00
Orthophosphate as P	0.17	0.20	0.08	0.079	0.05
Alkalinity as CaCO3	38.0	34.00	36.00	2.83	36.00

GROUNDWATER ANALYSES (mg/l)

Aquifer	Chalk	Lower Greensand[1]
Location	Longcross	Virginia Water (Holloway Sanitorium)
Year	1939	1926
Borehole Ref	SU96/19	TQ06/47
TDS	460	835
EC	-	1290
pH	8.3	7.5
Alkalinity (as CaCO3)	185	-
Ca	17	77
Mg	5.5	11
Na	151	217
CO3	111	63
SO4	28	94
Cl	126	358
SiO2	12	7
Fe	0.05	1.4

1 Sample collected on penetrating LGS aquifer.

APPENDIX IV

ENVIRONMENTAL ASSESSMENT FIELD SHEETS

WENTWORTH HEATHLAND SITES.

SITE NUMBER 1 Not Heathland, not recorded.

SITE SIZE (m^2)

% DWARF SHRUB COVER PROPORTIONS OF CALLUNA

TETRALIX

CINEREA

AGE OF HEATHER

OTHER SPECIES

SLOPE ASPECT SHADING

MANAGEMENT

LOCATION

TRAMPLING LANDSCAPE RATING

COMMENTS

Possibly incorrect code.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 2

SITE SIZE (m²) 1365

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 1.0
TETRALIX 0
CINEREA 0

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Regular cut

LOCATION On fairway near bunkers. East Course hole 17

TRAMPLING Moderate LANDSCAPE RATING Moderate/High

COMMENTS The site is in the middle of the fairway and therefore receives rather more cutting ~~and~~ than fairway edge sites and more trampling by golfers. The new irrigation system ~~may~~ is likely to increase the amount of watering on this site. These factors make this area one that will be difficult to maintain.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 3

SITE SIZE (m²) 1716

% DWARF SHRUB COVER 35 PROPORTIONS OF CALLUNA 1·0
TETRALIX 0
CINEREA 0

AGE OF HEATHER Mature

OTHER SPECIES acid grass.

SLOPE FLAT ASPECT N/A SHADING NONE.

MANAGEMENT Regular cut.

LOCATION Edge of fairway in front of green. East Course hole 16.

TRAMPLING moderate LANDSCAPE RATING MODERATE

COMMENTS Site has low proportion of dwarf shrub vegetation and high level of Molinia indicating a slightly wetter habitat. Increased precipitation is likely to increase the Molinia still further.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 4

SITE SIZE (m^2) 4679

% DWARF SHRUB COVER 70 PROPORTIONS OF CALLUNA 100
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE / BUILDING.

OTHER SPECIES Dwarf gorse, acid grass

SLOPE SLIGHT ASPECT SOUTH SHADING NONE

MANAGEMENT Regular cut

LOCATION Between tee and fairway East Course hole 15.

TRAMPLING High on tracks & fairway LANDSCAPE RATING HIGH.

COMMENTS One of the larger sites with a high level of heather cover. The level of cover could be increased by having just one track between tee and green. This area is likely to be unaffected by the new irrigation scheme

WENTWORTH HEATHLAND SITES.

SITE NUMBER 5

SITE SIZE (m^2) 1565

% DWARF SHRUB COVER 40 PROPORTIONS OF CALLUNA 1.0

TETRALIX 0

CINEREA 0

AGE OF HEATHER Mature

OTHER SPECIES Acid grass.

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Occasional cut.

LOCATION Edge of fairway on the East Course hole 14.

TRAMPLING Moderate LANDSCAPE RATING Moderate.

COMMENTS Site is predominantly acid grass ~~the~~ the heather content is likely to reduce if ~~watering~~ the area receives extra water.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 6

SITE SIZE (m^2) 3600

% DWARF SHRUB COVER 75 PROPORTIONS OF CALLUNA 0.95

TETRALIX 0

CINEREA 0.05

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass, Bracken and Dwarf gorse.

SLOPE SLIGHT ASPECT NORTH SHADING NONE.

MANAGEMENT Occasional cut.

LOCATION Edge of fairways on East Course near 14th hole tee and 15th hole green.

TRAMPLING SLIGHT LANDSCAPE RATING HIGH.

COMMENTS Site is larger than that marked on the vegetation map and probably receives some watering from the 15th green. Extra watering may come from the 14th tee area but the majority of the site will remain unwatered.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 7

SITE SIZE (m^2) 5634

% DWARF SHRUB COVER 80 PROPORTIONS OF CALLUNA 0.95
TETRALIX 0
CINEREA 0.05

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass, Bracken, Dwarf gorse.

SLOPE FLAT ASPECT N/A SHADING NONE.

MANAGEMENT Occasional cut.

LOCATION Between tee and fairway East course hole 16.

TRAMPLING SLIGHT LANDSCAPE RATING HIGH.

COMMENTS One of the larger areas of heath on the course. Unlikely to be affected by irrigation of the fairways.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 8

SITE SIZE (m^2) 2416

% DWARF SHRUB COVER 65 PROPORTIONS OF CALLUNA 0.75
TETRALIX 0
CINEREA 0.25

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass, Dwarf gorse

SLOPE MODERATE ASPECT WEST SHADING PARTIAL

MANAGEMENT Regular cuts

LOCATION Bank on edge of fairway, East Course hole 13.

TRAMPLING Moderate LANDSCAPE RATING MODERATE.

COMMENTS Part of site is likely to receive water from fairway irrigation. However the slope is likely to reduce its effect.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 9

SITE SIZE (m^2) 2928

% DWARF SHRUB COVER 40 PROPORTIONS OF CALLUNA 1.0
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass, Broom

SLOPE FLAT ASPECT N/A SHADING PARTIAL

MANAGEMENT Regular cut.

LOCATION Edge of fairway bounded by Birch/Oak wood on East Course hole 12.

TRAMPLING HIGH LANDSCAPE RATING HIGH

COMMENTS This area of heath has a high landscape rating it currently has a low proportion of dwarf shrub cover, probably due to excessive trampling. Extra watering is likely to increase the proportion of acid grass still further.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 10

SITE SIZE (m^2) 6375

% DWARF SHRUB COVER 35 PROPORTIONS OF CALLUNA 0.35
TETRALIX 0
CINEREA 0.15

AGE OF HEATHER BUILDING/ MATURE

OTHER SPECIES Acid grass, Gorse, bramble, broom.

SLOPE STEEP ASPECT SOUTH WEST SHADING NONE.

MANAGEMENT Part frequently mown part not managed.

LOCATION Bank running diagonally across fairway East Course Hole 11.

TRAMPLING NONE LANDSCAPE RATING HIGH.

COMMENTS Not likely to receive extra irrigation removal of scrub species may encourage more heather growth.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 11

SITE SIZE (m^2) 2356

% DWARF SHRUB COVER 20 PROPORTIONS OF CALLUNA 0.3
TETRALIX 0.2
CINEREA 0.5

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass, Bracken

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Regular cut on fairway, occasional cut on rough.

LOCATION Across fairway and in rough on the Edinburgh course hole 8.

TRAMPLING Low in rough higher fairway LANDSCAPE RATING MODERATE.

COMMENTS The small proportion of dwarf shrub cover is likely to decrease even further if watering is applied to the fairway area.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 12

SITE SIZE (m^2) 2094

% DWARF SHRUB COVER 90 PROPORTIONS OF CALLUNA 0.80
TETRALIX 0.05
CINEREA 0.15

AGE OF HEATHER MATURE

OTHER SPECIES Birch, Scots Pine, Dwarf gorse.

SLOPE SLIGHT ASPECT SOUTH WEST SHADING PARTIAL

MANAGEMENT NONE

LOCATION Within scattered Birch and Scots Pine trees on the Edinburgh course near 8th green

TRAMPLING NONE LANDSCAPE RATING MODERATE.

COMMENTS There is no likelihood of spraying on this site and heather will be easily maintained by controlling tree seedlings.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 13

SITE SIZE (m^2) 914

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 0.4
TETRALIX 0
CINEREA 0.6

AGE OF HEATHER Mature

OTHER SPECIES Scots Pine.

SLOPE SLIGHT ASPECT WEST SHADING PARTIAL

MANAGEMENT Occasional Cut.

LOCATION Between tee and fairway and extending into Pine woodland on Edinburgh course hole 10.

TRAMPLING SLIGHT LANDSCAPE RATING HIGH

COMMENTS Heather area some distance from both tee and fairway. Therefore likely to be unaffected by irrigation system.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 14

SITE SIZE (m^2) 1473

% DWARF SHRUB COVER .65 PROPORTIONS OF CALLUNA 0.65
TETRALIX 0
ULEX 0.35

AGE OF HEATHER MATURE / DEGENERATE

OTHER SPECIES Acid grass, bracken, gorse.

SLOPE SLIGHT ASPECT SOUTH SHADING NONE

MANAGEMENT Occasional cut.

LOCATION Edge of fairway on East Course hole 10.

TRAMPLING SLIGHT. LANDSCAPE RATING LOW.

COMMENTS Area bounded by gravel track and fairway
Some fairly old heather unlikely to survive watering.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 15

SITE SIZE (m^2) 3444

% DWARF SHRUB COVER 40 PROPORTIONS OF CALLUNA 1.0
TETRALIX 0
SINGLEA 0

AGE OF HEATHER DEGENERATE (TUSSOCK HEATH).

OTHER SPECIES Acid grass, Broom, Birch and Oak

SLOPE FLAT ASPECT N/A SHADING NONE.

MANAGEMENT NONE.

LOCATION Fairway edge backed by Birch/Oak woodland on the East Course hole 9.

TRAMPLING SLIGHT LANDSCAPE RATING MODERATE.

COMMENTS Old heather being overgrown by acid grassland species. Irrigation system is unlikely to affect this area.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 16

SITE SIZE (m^2) 3368

% DWARF SHRUB COVER 85 PROPORTIONS OF CALLUNA 1.0
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES BIRCH

SLOPE FLAT ASPECT NONE SHADING PARTIAL

MANAGEMENT NONE.

LOCATION Fairway edge backed by Birch on the East Course hole 9.

TRAMPLING SLIGHT LANDSCAPE RATING MODERATE

COMMENTS Possibility of some watering of heather near green. The majority of heather likely to be unaffected.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 17

SITE SIZE (m²) 2197

% DWARF SHRUB COVER 15 PROPORTIONS OF CALLUNA 0.90

TETRALIX 0

CINEREA 0.10

AGE OF HEATHER DEGENERATE.

OTHER SPECIES Acid grass, Oak, Birch, Broom and Gorse.

SLOPE MODERATE ASPECT NORTH SHADING NONE.

MANAGEMENT NONE

LOCATION Edge of fairway on East Course hole 3.

TRAMPLING SLIGHT/MODERATE. LANDSCAPE RATING LOW.

COMMENTS Very little old heather left on this site rabbit grazing is likely to reduce seedling regeneration. Spraying of water is not likely to affect this site.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 18

SITE SIZE (m^2) 4237

% DWARF SHRUB COVER 20 PROPORTIONS OF CALLUNA 0.90
TETRALIX 0
CINEREA 0.10

AGE OF HEATHER MATURE (TUSSOCK HEATER).

OTHER SPECIES Birch, Oak, Broom

SLOPE MODERATE ASPECT NORTH EAST SHADING PARTIAL

MANAGEMENT NONE

LOCATION Fairway edge backed by Birch/oak woodland
on East Course hole 3.

TRAMPLING MODERATE LANDSCAPE RATING MODERATE.

COMMENTS Area mainly acid grassland, the ~~possibility~~ possible ~~of~~
extra watering is likely to reduce the heather even further

WENTWORTH HEATHLAND SITES.

SITE NUMBER 19 No longer heath now part of fairway.

SITE SIZE (m^2)

% DWARF SHRUB COVER

PROPORTIONS OF CALLUNA

TETRALIX

CINEREA

AGE OF HEATHER

OTHER SPECIES

SLOPE

ASPECT

SHADING

MANAGEMENT

LOCATION Edge of fairway on East Course hole 2.

TRAMPLING

LANDSCAPE RATING

COMMENTS Not assessed.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 20

SITE SIZE (m^2) 4697

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 0.90
TETRALIX 0
CINEREA 0.10

AGE OF HEATHER BUILDING.

OTHER SPECIES Acid grass, gorse, broom, oak and birch.

SLOPE SLIGHT ASPECT NORTH WEST SHADING NONE.

MANAGEMENT Regular cut.

LOCATION On West course 5th hole and East course 4th hole.

TRAMPLING HIGH LANDSCAPE RATING HIGH.

COMMENTS Complex area near to tees and greens. Therefore high levels of trampling and possibly extra water from sprays. Heather at risk of being lost.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 21

SITE SIZE (m^2) 2280

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 0.95
TETRALIX 0
CINEREA 0.05

AGE OF HEATHER Building.

OTHER SPECIES Acid grass, oak, birch and bracken.

SLOPE SLIGHT ASPECT NORTH SHADING PARTIAL

MANAGEMENT Regular cut.

LOCATION Between greens of 5th on West course and 4th on the East Course.

TRAMPLING MODERATE LANDSCAPE RATING HIGH

COMMENTS Area is likely to receive extra water from new irrigation system increasing the acid grass content of the vegetation.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 22

SITE SIZE (m^2) 1051

% DWARF SHRUB COVER 35 PROPORTIONS OF CALLUNA 0.70
TETRALIX 0
CINEREA 0.30

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass, Bracken.

SLOPE SLIGHT ASPECT SOUTH WEST SHADING NONE.

MANAGEMENT Regular cut.

LOCATION Between tee and fairway on west course hole 6.

TRAMPLING HIGH LANDSCAPE RATING HIGH

COMMENTS The high levels of trampling by golfers has resulted in a predominantly acid grass heath. Extra irrigation is likely to decrease the heather content still further.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 23

SITE SIZE (m²) 2141

% DWARF SHRUB COVER 50 PROPORTIONS OF CALLUNA 0.60
TETRALIX 0.20
CINEREA 0.20

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass.

SLOPE MODERATE ASPECT SOUTH SHADING NONE

MANAGEMENT Regular cut.

LOCATION Area between tee and fairway on East Course hole 5.

TRAMPLING MODERATE. LANDSCAPE RATING HIGH.

COMMENTS Much of this site is likely to receive some spray irrigation but being on a south facing slope this may not have a serious effect.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 24

SITE SIZE (m^2) 3019

% DWARF SHRUB COVER 80 PROPORTIONS OF CALLUNA 0.95

TETRALIX 0

CINEREA 0.05

AGE OF HEATHER MATURE

OTHER SPECIES Oak Birch Broom and Bracken.

SLOPE NONE ASPECT N/A SHADING NONE

MANAGEMENT NONE

LOCATION Fairway edges of holes 5 and 8 on the East Course.

TRAMPLING SLIGHT LANDSCAPE RATING MODERATE

COMMENTS One of the best areas of heath on the course it is not cut and may need to have scrub and tree species removed to maintain it. Spray irrigation is not likely to affect this site.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 25

SITE SIZE (m^2) 3126

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 1.0
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass.

SLOPE SLIGHT ASPECT EAST SHADING NONE

MANAGEMENT OCCASIONAL CUT.

LOCATION Between the tee and fairway of 7th hole on the East Course

TRAMPLING SLIGHT LANDSCAPE RATING HIGH

COMMENTS site includes a heather covered boundary bank and is unlikely to be affected by irrigation.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 26

SITE SIZE (m^2) 4224

% DWARF SHRUB COVER 50 PROPORTIONS OF CALLUNA 0.95

TETRALIX 0.05

CINEREA 0.

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass, dwarf gorse.

SLOPE SLIGHT/MODERATE ASPECT SOUTH EAST. SHADING NONE.

MANAGEMENT OCCASIONAL CUT.

LOCATION Between tee and fairway on West Course hole 9.

TRAMPLING MODERATE LANDSCAPE RATING HIGH.

COMMENTS Site lies across a small valley with a stream at the bottom. There is a single path across the site which reduces trampling. The site is slightly wetter than ~~than~~ most on the course but is not likely to receive extra watering from the irrigation system.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 27

SITE SIZE (m^2) 3699

% DWARF SHRUB COVER 50 PROPORTIONS OF CALLUNA 0.80

TETRALIX 0

CINEREA 0.20

AGE OF HEATHER MATURE / DEGENERATE.

OTHER SPECIES Acid grass.

SLOPE FLAT ASPECT N/A SHADING NONE.

MANAGEMENT Part cut.

LOCATION Between railway line and 9th fairway on the West Course.

TRAMPLING MODERATE LANDSCAPE RATING MODERATE

COMMENTS A fairway edge site is likely to receive little extra watering. The site is partly cut this has maintained mature heather the uncut area being degenerate heather and tending to die out allowing acid grass to take over.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 28

SITE SIZE (m^2) 2245

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 1.00
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES acid grass

SLOPE SLIGHT ASPECT SOUTH SHADING PARTIAL

MANAGEMENT OCCASIONAL CUT.

LOCATION Between tee and green on West Course hole 10.

TRAMPLING HIGH LANDSCAPE RATING HIGH

COMMENTS Heathland area nearest Broomhall Heath it is unlikely to be affected by ~~the~~ extra watering but trampling by golfers may reduce the heather content of the vegetation.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 29

SITE SIZE (m^2) 1888

% DWARF SHRUB COVER 50 PROPORTIONS OF CALLUNA 0.95
TETRALIX 0
CINEREA 0.05

AGE OF HEATHER MATURE

OTHER SPECIES ACID GRASS

SLOPE NONE ASPECT N/A SHADING NONE.

MANAGEMENT OCCASIONAL CUT

LOCATION Between tee and fairway on West Course hole 13

TRAMPLING SLIGHT LANDSCAPE RATING HIGH.

COMMENTS Site may receive water from irrigation systems near green. There is a well maintained path that reduces walking on the heather.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 30

SITE SIZE (m^2) 2862

% DWARF SHRUB COVER 20 PROPORTIONS OF CALLUNA 0.80
TETRALIX 0
CINEREA 0.20

AGE OF HEATHER BUILDING

OTHER SPECIES Acid Grass.

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Regular cut.

LOCATION Edge of fairway on West Course Hole 7

TRAMPLING HIGH LANDSCAPE RATING LOW

COMMENTS Site is likely to receive some extra watering and this combined with the regular cutting and high level of trampling may reduce the heather content still further.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 31

SITE SIZE (m^2) 3251

% DWARF SHRUB COVER 20 PROPORTIONS OF CALLUNA 0.70
TETRALIX 0
CINEREA 0.30

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass.

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT OCCASIONAL CUT.

LOCATION Between holes 6 and 7 on the West Course.

TRAMPLING MODERATE LANDSCAPE RATING MODERATE.

COMMENTS This site has a low level of heather cover and may receive additional water from the irrigation system. The heather is likely to be reduced still further.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 32

SITE SIZE (m^2) 5451

% DWARF SHRUB COVER 30 PROPORTIONS OF CALLUNA 1.00

TETRALIX 0

CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass

SLOPE MODERATE ASPECT SOUTH EAST SHADING PARTIAL

MANAGEMENT OCCASIONAL CUT

LOCATION Edge of fairway on hole 11 of the West Course

TRAMPLING HIGH LANDSCAPE RATING MODERATE

COMMENTS Site is backed by Scots Pine woodland, it is not likely to be badly affected by ~~water~~ watering because of its slope but the high level of trampling will continue to reduce the heather content of the vegetation.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 33

SITE SIZE (m^2) 1990

% DWARF SHRUB COVER 65 PROPORTIONS OF CALLUNA 0·80
TETRALIX 0·20
CINEREA 0

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass. Scots Pine seedlings

SLOPE SLIGHT ASPECT WEST SHADING PARTIAL

MANAGEMENT Regular cut.

LOCATION Between tee and fairway on West Course hole 12.

TRAMPLING MODERATE LANDSCAPE RATING MODERATE.

COMMENTS Site is wetter than most others on the Estate it has a drainage ditch running across it. Extra watering may change the vegetation to wet/acid grassland.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 34. NOT RECORDED)

SITE SIZE (m^2)

% DWARF SHRUB COVER

PROPORTIONS OF CALLUNA
TETRALIX
CINEREA

AGE OF HEATHER

OTHER SPECIES

SLOPE ASPECT SHADING

MANAGEMENT

LOCATION

TRAMPLING LANDSCAPE RATING

COMMENTS

NO HEATHER NOT RECORDED.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 35

SITE SIZE (m^2) 1825

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 1.00

TETRALIX 0

CINEREA 0

AGE OF HEATHER BUILDING

OTHER SPECIES Acid Grass

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT OCCASIONAL CUT

LOCATION Between tee and fairway on West Course hole 13.

TRAMPLING SLIGHT LANDSCAPE RATING MODERATE.

COMMENTS Small area of heath likely to receive some extra watering.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 36

SITE SIZE (m^2) 803

% DWARF SHRUB COVER 55 PROPORTIONS OF CALLUNA 0.80
TETRALIX 0
CINEREA 0.20

AGE OF HEATHER BUILDING

OTHER SPECIES Acid grass

SLOPE FLAT ASPECT N/A SHADING NONE.

MANAGEMENT OCCASIONAL CUT.

LOCATION Between holes 12 and 13 on the West Course

TRAMPLING LOW LANDSCAPE RATING MODERATE

COMMENTS A patched in heather this small area of heath is likely to survive extra watering better than other sites because of its free drainage and low nutrient status soil.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 37

SITE SIZE (m^2) 1871

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 0.70
TETRALIX 0
CINEREA 0.30

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass.

SLOPE MODERATE ASPECT SOUTH WEST SHADING NONE

MANAGEMENT OCCASIONAL CUT.

LOCATION Between tee and green on West Course Hole 16

TRAMPLING SLIGHT LANDSCAPE RATING HIGH.

COMMENTS Despite the slope this area of heath contains a considerable amount of wet acid grasses that are likely to increase with spray irrigation.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 38

SITE SIZE (m^2) 1458

% DWARF SHRUB COVER 40 PROPORTIONS OF CALLUNA 1.00
TETRALIX 0
CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass

SLOPE FLAT ASPECT N/A SHADING PARTIAL.

MANAGEMENT Regular cut

LOCATION Between tee and Portnals Drive on the West course hole 16

TRAMPLING HIGH LANDSCAPE RATING HIGH.

COMMENTS High levels of trampling have reduced the amount of heather cover.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 39

SITE SIZE (m²) 2959

% DWARF SHRUB COVER 60 PROPORTIONS OF CALLUNA 1.00

TETRALIX 0

CINEREA 0

AGE OF HEATHER MATURE

OTHER SPECIES Acid grass

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Regular cut

LOCATION Between Portnalls road and fairway of the 16th hole on the West Course.

TRAMPLING MODERATE LANDSCAPE RATING HIGH

COMMENTS Just across the road from site 38 a single central pathway has reduced the amount of trampling on the heather.

WENTWORTH HEATHLAND SITES.

SITE NUMBER 40

SITE SIZE (m^2) 1354

% DWARF SHRUB COVER 10 PROPORTIONS OF CALLUNA 0.70
TETRALIX 0
CINEREA 0.30

AGE OF HEATHER MATURE

OTHER SPECIES Gorse and acid grass

SLOPE FLAT ASPECT N/A SHADING NONE

MANAGEMENT Regular cut

LOCATION Between tee and fairway on West Course hole 4.

TRAMPLING MODERATE LANDSCAPE RATING LOW.

COMMENTS Very little heather remaining on this site

WENTWORTH HEATHLAND SITES.

SITE NUMBER 41 NO HEATHER NOT RECORDED.

SITE SIZE (m^2)

% DWARF SHRUB COVER PROPORTIONS OF CALLUNA

TETRALIX

CINEREA

AGE OF HEATHER

OTHER SPECIES

SLOPE ASPECT SHADING

MANAGEMENT

LOCATION

TRAMPLING LANDSCAPE RATING

COMMENTS

WENTWORTH HEATHLAND SITES.

SITE NUMBER 42

SITE SIZE (m^2) 2165

% DWARF SHRUB COVER 75 PROPORTIONS OF CALLUNA 0.95
TETRALIX 0
CINEREA 0.05

AGE OF HEATHER MATURE

OTHER SPECIES Oak, Birch, mixed grass.

SLOPE FLAT ASPECT N/A SHADING PARTIAL

MANAGEMENT OCCASIONAL CUT.

LOCATION Edge of fairway on East Course hole 11.

TRAMPLING SLIGHT LANDSCAPE RATING MODERATE.

COMMENTS Good area of heathland not likely to be irrigated, trees need controlling. Not recorded on the 1990 Environmental Audit ~~to~~ map.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE B Dukes Copse

SIZE OF PROPOSED RESERVOIR (m^2) 5000

VEGETATION TYPE Oak/Birch woodland with alder, beech and some conifers. Understorey mainly Rhododendron.

WATER SOURCE BOURNE STREAM.

SITUATION Within mixed deciduous woodland near to Wentworth Pond.

SHAPING FULL

COMMENTS. Reservoir is small in comparison with the area of woodland in which it is to be situated. It could therefore easily be screened from the golf course, Wentworth Pond and adjoining houses.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE C Broom Hill

SIZE OF PROPOSED RESERVOIR (m^2) 3750

VEGETATION TYPE Mixed woodland mostly birch with alder round the pond area. The understorey is dense Rhododendron.

WATER SOURCE BOREHOLE AND SURFACE WATER.

SITUATION Natural depression backing on to houses and next to Wentworth Drive.

SHADING FULL.

COMMENTS. Retaining a screen of trees and Rhododendron to ~~with~~ hide the reservoir. Opening up the habitat may improve the diversity of the ground flora.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE D Shrubs Hill

SIZE OF PROPOSED RESERVOIR (m^2) 10,000

VEGETATION TYPE Scots Pine and Birch woodland with Bracken understorey.

WATER SOURCE MIXED BOURNE STREAM AND WENTWORTH INTERNAL SOURCE

SITUATION Between Estate boundary and fairway of the 13th hole on the West Course.

SHAPING FULL.

COMMENTS. Area marked on the map is outside the Estate boundary as defined in the 1990 Environmental Audit. The above applies to the area inside the Wentworth boundary, however the size of the reservoir may need to be reduced to allow for sufficient screening.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE K N. 12T WEST.

SIZE OF PROPOSED RESERVOIR (m^2) 12500

VEGETATION TYPE Scots Pine woodland with Birch and an understorey of Bracken.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

SITUATION Within woodland next to track near 12th Tee on the West Course.

SHADING PARTIAL.

COMMENTS: Site is naturally screened from the golf course.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE E Longcross

SIZE OF PROPOSED RESERVOIR (m^2) . 7500

VEGETATION TYPE Young Birch woodland with bracken ground cover / Fairway grass and heather.

WATER SOURCE WENTWORTH INTERNAL SOURCE.

SITUATION Next to the railway line and across part of the fairway of the 8th hole on the Edinburgh Course.

SHAPING PARTIAL.

COMMENTS. Part of the proposed reservoir site includes heathland site 11 and runs across part of the golf course. Because of the large fluctuations in ~~levels of the~~ water levels in the reservoir this site may be rejected for landscape reasons.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE J Nat Res. 2

SIZE OF PROPOSED RESERVOIR (m^2) 30000

VEGETATION TYPE Mixed deciduous woodland includes Birch oak and Rowan.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

SITUATION WEST WOOD

SHADING FULL

COMMENTS. Within a large area of woodland therefore easily screened. This site is of conservation interest and is subject to a management agreement with the Surrey Wildlife Trust.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE F West Drive SE.

SIZE OF PROPOSED RESERVOIR (m^2) 7500

VEGETATION TYPE Wet woodland of Birch and Alder carr.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

SITUATION Within Woodland between ~~tee~~ hole 11 of the East Course and hole 16 of the Edinburgh Course.

SHADING FULL

COMMENTS. Site is similar to Site G and is also ~~a~~ managed by the Surrey Wildlife Trust.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE 9 West Drive SW

SIZE OF PROPOSED RESERVOIR (m^2) 7500

VEGETATION TYPE Wet woodland of Birch and Alder carr with a diverse ground flora.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

SITUATION Within woodland between hole 10 on the East course and hole 3 on the Edinburgh course.

SHAPING PARTIAL / FULL

COMMENTS. This valley site has sufficient woodland around it to provide screening for a reservoir However the area is managed for conservation purposes by the Surrey Wildlife Trust, it is floristically quite rich and plants of interest include Tussock Sedge, Water Horsetail, Yellow Loosestrife and a number of fern species.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE I West Drive N

SIZE OF PROPOSED RESERVOIR (m^2) 5000

VEGETATION TYPE Deciduous woodland mostly mature Birch with oak. ~~and~~ Rhododendron understory with Bracken and Bramble.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

SITUATION Where West Drive is crossed by the Bourne Stream.

SHADING FULL

COMMENTS: Some Specimen trees on this site, most near the road and golf course. Screening from the road Bourneside house and Hole 2 of the Edinburgh course may require a reduction in size of the reservoir.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE H Fish ponds

SIZE OF PROPOSED RESERVOIR (m^2) 10,000

VEGETATION TYPE Little aquatic ~~vegetation~~ or marginal vegetation (Typha in lower pond).

WATER SOURCE WENTWORTH INTERNAL SOURCES.

SITUATION Set amongst scattered broadleaf trees, surrounded by tees and greens.

SHADING PARTIAL.

COMMENTS. The steep banks and large rise and fall in water levels of the proposed reservoir does not lend itself to producing a feature that is of conservation interest or a landscape feature.

WENTWORTH PROPOSED RESERVOIR SITES.

SITE L Clubhouse

SIZE OF PROPOSED RESERVOIR (m^2) 12000

VEGETATION TYPE Birch woodland with oak. Recently thinned and some of the Rhododendron understorey removed.

WATER SOURCE CHOBHAM COMMON SURFACE WATER.

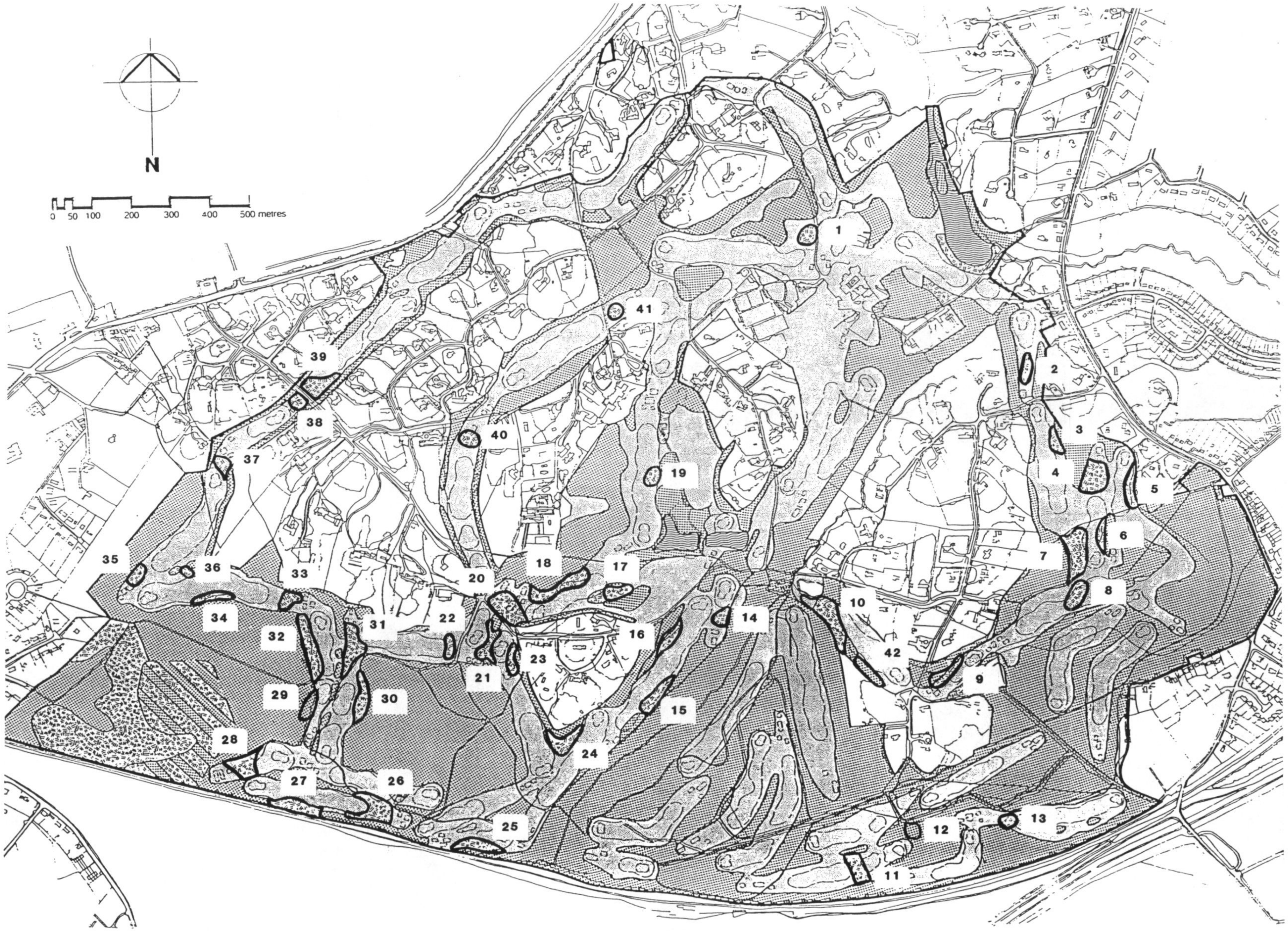
SITUATION Edge of fairway of the 18th hole on the Edinburgh course.

SHADING PARTIAL.

COMMENTS: Area appears to be outside the Wentworth Estate boundary, there is insufficient room to put reservoirs on the golf course side of the woodland.

WENTWORTH CLUB

HEATHLAND SITES



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