St Catherine’s Hill and Town Common Management Plan

HYDROLOGICAL APPRAISAL

Client: St Catherine’s Hill and Town Common Management Plan Steering Group
c/o Robin Harley, Countryside Officer
Christchurch Borough Council, Christchurch, Dorset
Site: Land at St Catherine’s Hill, Town Common, Christchurch
Project: Hydrological Appraisal
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Contents

Fig. 1 Pine woodland at St Catherine’s Hill

EXECUTIVE SUMMARY

Introduction

The purpose of this hydrological appraisal is to bring together such information as is available and to develop conclusions about the hydrology of St Catherine’s Hill so that the Management Plan Steering Group can advise on site management in such a way as to reduce the risk of adverse hydrological effects given a scheme of heathland restoration.

NB. Since the issue of our 5 August 2010 Consultation Draft, a meeting was held with the Steering Group on 30 September 2010 and this revised report takes account of matters raised during that meeting.

Note that this report is for guidance only and in the absence of any management proposals for the site, cannot offer detailed proposals

We have undertaken an extensive desk study of available maps and published information (including that on plant communities, geology, soils, hydrology and landform and the water relations of trees and heathland) and have visited householders where there are current drainage problems. We have walked much of the Hill itself making visual appraisals of the landform, geology and vegetation and looked for evidence of past erosion or landslipping.

Given this information, we have undertaken a careful analysis of what is known about the likely hydrology of the hill and used this to estimate the potential hydrological effects (changes in surface and groundwater flows) of different management scenarios in relation to the reduction in tree cover and heathland regeneration. Our analysis has taken account of the geology, slope and vegetation of a series of contrasted sample areas.

While we have drawn conclusions from our work, it is important to point out that there are many unknown factors in relation to the precise geological and soil conditions on the site and to the condition and vigour of the trees (which will be different to those in published studies).

While (and because of these uncertainties) we have had to make many assumptions, it is our opinion that given a range of scenarios and levels of mitigation, a limited and phased scheme of tree removal could be undertaken on slopes given careful consideration to the size, positioning and monitoring of any felling areas, and especially learning from the results of each felling and heathland restoration operation.

Landform

The site comprises a linear hill with a summit area (partly quarried) and sides with slopes of varying angles and containing a number of small valleys and gullies cutting back into the hill side. The hill side also has a number of historic banks and ditches. Mapping these features allows the plotting of a series of sub-catchments.

Geology and soils

The hill has a capping of gravels (Terrace Deposits) containing flint stones in a medium and coarse sandy matrix but also containing clayey layers; the gravels therefore are of varying permeability. Over a broad part of the western slope, these gravels extend down the valley side forming a layer of unknown thickness.

Below the gravels are stoneless sands (Branksome Sand) comprising both finer and coarser sand grains and locally cemented into sandstone and also with clayey layers. These deposits also have variable permeability but are likely to be less permeable overall than the gravelly deposits. Below the sands is a far less permeable clayey layer (Parkstone Clay) and which has only a very small ability to transmit water downwards.

Soils vary from very droughty nutrient poor soils on gravels and droughty soils on sands through to peaty soils affected by high groundwater and to clayey soils affected by perched groundwater and surface water.

There is thus a wide range of geological and soil conditions.

Hydrology

Given gentle rainfall, water passes either down between the trees to reach the ground or is intercepted by branches and passed down the tree stem where it is absorbed by leaf litter and passes into the soil. Some of the water is taken up by the tree roots and passed up within the stem to the leaves where it is evaporated to the atmosphere. Some of the water is evaporated from the soil surface while other water is retained in the soil and some passes downwards to reach the water table. Once the water reaches less permeable layers, and especially the Parkstone Clay, the water sits on these layers and builds up a perched water table, the water flowing sideways to emerge as springs and seepages on the hill side. The rate at which water flows through the hill and sideways to emerge on the sides depends upon the permeability of the different layers and the extent to which water is intercepted by pine woodland and heathland vegetation.

Given heavy rainfall or storm conditions, the surface soil layers rapidly become saturated and water will flow downhill over the surface of the land rather than sink into the ground. Such flows can remove the soil surface pine litter later and cause surface erosion.

Effect of vegetation

Generally, pine trees intercept more water than both grassland and heathland and so it would be expected that felling trees would result in more water reaching the water table. However, it should be noted that there is considerable overlap in water use values between pines and heathland and the relatively old maritime pine and Scots pine trees at St Catherine's Hill are growing mostly on droughty nutrient poor soils and appear to be of low vigour with much more open canopies than actively growing forest crop pines for which research data exists. Because of this, the water relations of the pines at St Catherine's Hill may not be that much different from well developed heathland.

The assessment

In our assessment we have taken a precautionary approach and assumed that the pine trees have a greater water use through the year than heathland. Our assessment also takes account of the complex geology and slope features of the site and we find that taking down large areas of trees at one time can significantly increase the flow of water to the ground and this amount increasing with the land area involved. The amount of water increase will depend upon the density of the trees, the vigour of the trees, the slope of the ground, and the complexity and water holding capacity of the subsurface geology.

General conclusions

The risk of adverse hydrological effects is thought to be greatest from tree felling on lower slopes close to the junction with the Parkstone Clay, especially in areas of complex geology such as where there are nearby thin gravels on the slopes over the Branksome Sand. There is a more intermediate risk when felling trees on thin gravel spreads on slopes, and least risk given felling on the Branksome Sands. It follows that areas with higher risk require greater levels of mitigation to reduce that risk to acceptable levels.

The risk of adverse hydrological effects on downslope urban areas is reduced by:

1. Avoiding felling on lower slopes adjacent to the urban boundary or on, or close to, the Parkstone Clay;
2. Felling small areas initially and restricting these areas to a. the top of the hill and uppermost slopes, to b. areas remote from housing and also c. locations where excess water can be more easily drained off-site;
3. Restricting felling so that only one area is felled initially within any one subcatchment and no more than five to six areas initially;
4. Avoiding felling on the steepest slopes where they occur close to housing;
5. Thinning trees in critical areas such that a more open woodland canopy can allow heathland to develop on the woodland floor (wood heath);
6. Using appropriate mitigation to reduce surface flows and encourage evaporation;
7. Closely monitoring the effectiveness of the heathland regeneration and any hydrological effects and proceeding with further phased felling when an assessment of the first phase felling confirms that it is safe to do so; and
8. Ensuring that all drains and ditches around the site, and any leading offsite, are maintained and functioning.

We recommend that initial first phase fellings on upper slopes should be on the restricted to five or six small areas of about 750sqm, equivalent to strips of about 10m x 75m. If larger areas are to be restored to heathland, these should be restricted to the plateau surfaces or consideration given to thinning rather than clear felling (or a mixture of both). The results of these initial fellings should be closely monitored, compared to control areas, and the results of such monitoring carefully considered prior to any further phased fellings.

Appropriate mitigation should be used to cope with the open ground situation in the time between felling and heathland establishment.

We have seen no evidence of past slumping or landslipping, the hillside having had many thousands of years to stabilise since the end of the last ice age and especially since the Bronze Age (or earlier) when woodland would have first been removed and heathland established. Given the precautionary approach to felling discussed above, landslipping would not be expected.

We have seen some evidence of the effects of surface washing below the existing pines leading to a slightly lowering of the sloping land surface; also the accumulation of material (such as upslope of tree stems). We assume that this slight erosion may arise when heavy storms have washed away leaf litter and exposed the sandy soils to surface washing. Heathland establishment would give better ground cover and reduce the potential for such erosion however, care would be needed to prevent such erosion in the time period between felling and heathland establishment.

We have noted that many of the tall mature pines have stems sloping back towards the hillside and that slight erosion on the downslope side of the tree stems may be destabilising some of the trees. We recommend that an assessment of their health and safety should be undertaken. Removal of any unsafe trees may provide opportunities for heathland regeneration in those locations.

1.0 INTRODUCTION, BRIEF, METHODS AND SUMMARY

1.1 INTRODUCTION

Christchurch Borough Council own and manage land at St Catherine's Hill (**Figure 1**), part of Town Common in Christchurch. In order to gain agreement about management, a Steering Group has been established comprising all interested parties with the objective of guiding Christchurch Borough Council about the most effective way of managing the Common.

St Catherine's Hill, part of Town Common, is situated to the north west of Christchurch, Dorset, and has significant nature conservation, geological and archaeological interests.

The land is part of Town Common Site of Special Scientific Interest (SSSI) and which land forms part of the Dorset Heaths Special Area of Conservation (SAC), Dorset Heathlands Special Protection Area (SPA) and is also an important recreational resource for the local and wider community. Land within the study area (western side of the Hill) is owned by Christchurch Borough Council; adjacent land (on the eastern side of the Hill) is owned by the Malmesbury Estate and leased to the Herpetological Conservation Trust (now the Amphibian and Reptile Conservation Trust). SSSI unit information on the Natural England website (see **Appendices**) in relation to the condition assessment of the nature conservation features indicates that the Christchurch Borough Council land is partly graded as 'Unfavourable no change', and partly graded (in the south) as 'Unfavourable Declining'.

The main reason for the unfavourable nature conservation condition of the SSSI is the extent of tree cover that has replaced heathland habitat with the implication that management should include a reduction in the tree cover.

Understandably, tree removal raises concerns with some in the local population, not only because of the loss of the locally valued wooded landscape but because of the perception that tree felling on the slopes present could in turn lead to adverse effects in relation to erosion, landslipping and changes to site hydrology.

Because of these perceptions, the **Friends of St Catherine's Hill** was established in 2008 to promote a greater understanding and involvement of the local community. It rapidly became clear that the management of the site was a locally contentious matter and so in 2009 a **Management Plan Steering Group** was established with representatives of the main stakeholders.

> <u>Unfavourable no change</u> This means the special interest of the SSSI unit is not being conserved and will not reach favourable condition unless there are changes to the site management or external pressures. The longer the SSSI unit remains in this poor condition, the more difficult it will be, in general, to achieve recovery.
>
> <u>Unfavourable declining</u> This means that the special interest of the SSSI unit is not being conserved and will not reach favourable condition unless there are changes to site management or external pressures. The site condition is becoming progressively worse.

In addition, the West Christchurch Residents Association, along with other existing representative bodies, wishes to ensure that the concerns of local residents are fully considered in any proposals to manage the Hill.

There is general consensus between the landowners, conservation organisations, statutory bodies and the local community, about the need for a management plan. To progress such a plan, an independent facilitator has been appointed to oversee the development of the plan and ensure that it takes into account both statutory and local issues including **flooding and landslip and the implications on groundwater and drainage**.

No decisions as to the nature of any proposed management have yet been proposed.

Ron Allen visited the site with Robin Harley on 21 December 2009 to appraise the general situation and later, 21 April 2010, visited a number of representative householders who had particular concerns about the hydrological implications of management on their properties and especially the potential for enhanced spring action and flooding. David Hall and Ron Allen have undertaken further site visits.

1.2 BRIEF

Because of local concerns, the Management Plan Steering Group is pulling together all relevant information such that informed decisions can be made as to the site's management. An important consideration is to have regard to the public's concerns over potentially negative hydrological impacts.

The brief for this study is therefore to assess the current hydrological situation including an indication of the likelihood of landslip, flooding or erosion as a consequence of management.

The objective is to prepare a well informed written report, in plain English and illustrated with photographs and diagrams that will be readily understood by all members of the Steering Group whatever their background and specific interest and of clear use in developing a management plan that avoids adverse hydrological effects on the local environment.

1.3 METHODS

We have undertaken a desk study of available information including:

- Landform maps and plans;
- Geology and soils (review of published information, geological mapping and any borehole/section information);
- Published or otherwise available papers discussing soil, water and vegetation relationships; and on
- Plant communities and tree cover.

We have also undertaken field appraisal to examine the site's hydrological features, both by walking most of the site and by using a number of representative study areas so as to:

- Assess the current, topographic, hydrological and drainage features;
- Assess catchments;
- Examine soil and geological types in sample areas;
- Look for current signs of wetness and erosion;
- Assess the habitat types in sample areas using available information; and
- Selected inspection of adjacent gardens with known drainage concerns.

Given the desk study and field data we have prepared illustrative cross sections of the sample areas showing the (as far as is possible within the scope of the project) different hydrological characteristics and used the data to consider:

- Catchment characteristics;
- Soil water regime and soil substrate characteristics;
- The dip and characteristics of the sand/clay junction;
- The current situation in relation to rainfall, precipitation, interception, percolation into soil and direction of groundwater flow;
- The likely impact of tree removal and heathland restoration on hydrology.

Given this information, David Hall has developed a spread sheet to analyse the various slopes, geology and vegetational components of the study focus areas and so estimate the likely changes in run-off and infiltration under the following scenarios:

1. Existing conditions;

2. Conditions with the removal of all woodland and gorse scrub and their replacement with heather heath; and
3. Conditions with the removal of woodland and gorse scrub over 50% of the study catchment area and their replacement with heather heath. In most study areas this could be assumed to relate to woodland in the higher reaches of the catchment area.

NB. With regard to item 3, the 50% removal percentage was taken as a convenient but arbitory value with which to explore the hydrological effects of tree removal.

As a result of these desk and field studies and the resulting analysis, conclusions have been drawn on the likely effects of any necessary tree thinning or other tree management necessary to restore the heathland and risks involved in so doing.

This process provides an indication as to whether felling or thinning can be undertaken without risk to erosion, landslipping and flooding, and if not, the level of risk appropriate associated with felling.

1.4 LIMITATIONS OF THE STUDY

In undertaking the analysis we are conscious that there are many unknowns that would require an extensive research project to resolve.

In particular, we have had to make assumptions (based on limited published data) about the way in which pine woodlands on the site interact with rainfall and the changes that would occur given felling and heathland restoration.

We have made other assumptions about how much water currently falls through the pine woodland to the woodland floor (and which may not be comparable to other areas), and also about how much rainfall is taken up by the pines and passed back up the trees and returned to the atmosphere by evapo-transpiration (because these trees appear to be of poor vigour and may not be comparable to commercial Corsican pine forests).

We have made further assumptions about how much water will be taken up by the heathland once established as this will depend upon the way the heathland develops and resulting mosaic of different growth stages. There will be a time between tree felling and the development of mature heathland when open ground will slowly convert to heather cover. The water relations will depend on how quickly and successfully mature heathland becomes established.

We assume that some water will fall direct to the ground and infiltrate downwards to groundwater. In the absence of data we have made assumptions about the amount and rate of such infiltration because we have no data on the permeability of the different substrates (Terrace Gravels, Branksome Sand and Parkstone Clay). We do know that the permeability of these deposits is likely to be variable because of their varied character; the gravels for instance are known to contain clayey bands, and the Branksome Sand is known to be of variable fine and medium sand grade size and to contain clayey layers and layers of harder sandstone.

Similarly, we had to make assumptions about the groundwater conditions on the site and the way in which groundwater may be intercepted by the hill sides and emerge as springs and seepages supporting areas of wet heathland and mire and also exiting towards areas of housing.

Despite this lack of site specific data, we have undertaken a study making what appear to be reasonable assumptions in the circumstances of the site.

1.5 GENERAL CONCLUSIONS, RECOMMENDATIONS AND SUMMARY OF RESULTS

1.5.1 General conclusions and recommendations

The following sections draw together our conclusions based on our examination and analysis of the study areas. While the data limitations mean that the detailed analysis remains somewhat tentative, the exercise does provide some guidance as to the likely effects of unconstrained tree removal on steep slopes in different parts of the site.

Given the data available to us, it appears that removal of pine trees and replacement with heather would lead to enhanced surface and subsurface water flows with potentially enhanced surface erosion and spring flow. Unfortunately, it is not possible to fully quantify the extent of this effect. We have attempted to provide some tentative guidance as to the possible extent of such increased flows in different areas based on our knowledge of the present vegetation, geology and slopes and the calculation of likely changes in flows.

The level of risk of increased flows given felling on steep slopes is impossible to quantify but the order of risk without mitigation is thought to be as follows:

Lowest risk:	sloping land on the Branksome Sand
Intermediate risk:	sloping land on the Terrace Deposits
Highest risk:	sloping land where there is a range of gravelly, sandy and clayey deposits in close proximity.

The lowest risk of enhanced surface flows affecting properties is in the north of the site away from properties and where excess water can be channelled down valleys and out of the site. Clearly, the highest risk to properties would result from clear felling large areas from slopes immediately above properties where the Parkstone Clay is in the close vicinity and in these areas felling should be considered very carefully and restricted to small areas high on the site.

We have considered what we mean by 'small' areas and suggest that on slopes such areas should be of the order of between 0.05 and 0.1 hectare depending on site conditions; ie about 750sqm equating to an area of about 10m x 75m, the precise shape depending on local topography. This size could be increased on the summit areas.

These areas could be increased in size if the density of trees were reduced (rather than clear felled) such that a cover of heather could be established below an open tree canopy and so producing 'wood heath'.

The consequence of this risk assessment is that areas with higher risk would require greater levels of mitigation if their risk class was to be reduced and potentially adverse hydrological effects avoided. The risk is reduced for the more level areas at the top of the hill where surface erosion would be less and the risk increases nearer to lower slopes where excess water cannot be easily removed.

The overall message is that the preferred approach would be to ensure that any proposed tree felling is phased and initially restricted to small areas and that active regeneration of heathland cover encouraged. All felling on slopes should be accompanied by a scheme of monitoring of any hydrological effects where necessary and an assessment made before any subsequent felling phases. Felling on the higher plateau areas would be less risky than on slopes.

Given no adverse hydrological effects from felling within the smaller areas, these smaller areas could be extended so as join and create larger and more connected heathland units. The larger the area felled at any one time, the more intensive should be the mitigation measures considered such as by using biodegradable matting, cut heather stems (brash), contour laying of cut tree stems or branch bundles, use of cutoff trenches and, in the vicinity of valleys and areas of seepage increasing areas of water storage and slow release or by thinning rather than clear felling. The mitigation methods used would depend upon the conditions in any one felling area.

We understand that there may be a pipe taking spring water off site via culverts below housing in the vicinity of Hillside Drive. We recommend that this pipe be researched and its effectiveness established.

We further recommend that an arboricultural assessment of the leaning trees should be undertaken and should these be dangerous that heathland regeneration should be encouraged quickly in any areas of safety felling.

1.5.2 Summary of results

<u>Slopes on Terrace Gravels</u>

Because of the higher hydrological risk in these areas, any tree removal in these areas should be limited to small phased areas along edges or as small clearings and on upper slopes so as to reduce the risks associated with increased flows. An alternative would be to thin trees so that heathland would establish between the trees. With greater tree felling, cut off ditches and possibly underground barriers could be installed (where there is space), to limit impacts on properties.

Large areas of tree removal/heathland restoration on steeper slopes on terrace gravels is not recommended because it could very likely result in large areas of open erodible sandy soils prior to heathland establishment and a significant increase in both surface water and ground water volumes and which could impact significantly on residential properties at lower levels.

However, by removing woodland in small phased areas and replacing with heather only above the 40m contour, these increases in flow are reduced, especially if 'wood heath' were to be the objective.

<u>Slopes on Branksome Sands</u>

Tree removal in these areas involves less hydrological risk than on the spreads of gravels and which can be more easily mitigated. However, it remains important to phase the works and to monitor the results and hydrological effects.

Our analysis indicates that large areas of tree removal/heathland restoration on slopes on Branksome Sands could increase surface water and ground water flows but with reduced velocities (compared to on the gravels) both for surface water and ground water leading to slower acting effects. Valley features could be extended to limit impacts on residential properties.

More limited mitigation would be required given the removal of up to 25% of pines in the south of St Catherine's Hill. Our calculations suggest that without mitigation, this felling could significantly increase surface water flows although the increase in ground water flow would be small. Such removal could be as small clearings or equivalent thinning of the woodland coupled with other mitigation to improve heathland regeneration and measures to reduce surface erosion. Depending on slope, cut off ditching could provide adequate mitigation together with an extension or modification of the valley landforms to provide surface water attenuation storage and enhanced evaporation.

In the central area, removal of woodland above the 35m contour could increase surface water flows such that cut off ditching may be necessary, perhaps coupled with the option of extending valley features giving greater attenuation storage. The extent to which such mitigation could be undertaken would depend upon any other adverse ecological or archaeological effects.

In the north, the land has predominantly heathland cover with a belt of woodland adjacent to the residential area and a valley taking water away from the houses and towards the River Stour. In the absence of mitigation, thinning the woodland by 50% to create small glades or wood heath would likely cause only a small increase of surface water and ground water flows such that only limited mitigation measures would be necessary such as cut off ditches along the boundary of the residential area and taking flows directly into the outfall valley.

It may be possible to place flow barriers across the valleys to retain water on site, encourage wetland creation and evaporation and so reduce discharge off site.

<u>Areas with mixed geology</u>

The northern part of St Catherine's Hill and some areas just above housing, have varied geological substrates from terraced gravels through Branksome Sand and onto the Parkstone Clay. There is a significant outfall valley in the north that takes flows away from the main residential area and eventually into the River Stour to the west. The area has woodland cover for much of its middle and lower reaches with heathland on upper slopes.

Any increase in seepage/spring flows resulting from felling in the northern area could be directed down the existing deep valleys directing water away from residential areas. By this means, removing tree cover on upper slopes initially (above the 25m contour) and replacing with heathland (especially if combined with other mitigation) could be achieved with less risk.

In the absence of mitigation, or felling in other areas, there could be increases in surface water and ground water flows resulting in an enhanced seepage /spring water flows and which would need careful mitigation if adverse effects were to be avoided.

<u>Slope Stability</u>

It is important that only small areas of trees should be removed on slopes over Terrace Gravels or Branksome Sand in order to avoid adverse hydrological effects. Removal of trees, especially on lower slopes, could (without mitigation) cause increased erosion until heathland became established. While the effects of tree removal remain unknown, there is a risk that if thin gravel beds on slopes became saturated, the gravels could very gradually move downhill (over tens if not hundreds of years). Accordingly, only small felling areas should be considered in these locations.

Having discussed the risk, it is notable that we saw no evidence of such movement bearing in mind that the area would have been heathland prior to the development of the pine woodland. It would appear that the slopes have long been stabilized under the previous heathland regime. However, only small phased areas of trees should be removed at any one time and the effects monitored and felling should not occur close to the sand/gravel and clay boundary unless monitoring has indicated that it is safe to do so.

At the interface of the Branksome Sand/Parkstone Clay where it lies close to the boundary of the residential area, there is risk that felling could result in increased seepage and spring water flow which could result in very slow movement of the sandy slopes. Cut off ditches up slope of the housing areas could assist in reducing these effects. Any felling in this area should be very carefully monitored.

The situation at St Catherine's Hill is very different to that on the coast. The coastal situation is such that there is a much greater catchment area and also thick areas of clay that when saturated become liable to rotational landslips. In addition, along the coast, stabilizing of such slipping is prevented by constant wave erosion that keeps the slips active. This is in contrast to St Catherine's Hill, where the geology and hydrology is different and wave action absent and the land has stabilized over many thousands of years.

Effects of the trees

Many pine trees on slopes exhibit signs of instability with leaning stems, soil deposition around the upper sides of the stem bases and areas of erosion around the lower sides of the stem bases. Reasons for this remain speculative, and could result from groundwater pore pressure causing downward movement of soils which, along with possible sheet and localized erosion and the predominantly westerly winds could result in tree instability. In addition, the very weight of the trees themselves could cause the trees and their immediate substrates to move downslope by perhaps 1-2m. This effect could increase as the trees increase in weight and height and so alter their weight distribution.

We recommend that further investigation of these trees should be undertaken on health and safety grounds and an assessment of their likely life span as healthy trees. Removal of any dangerous trees could result in small areas of heathland establishment within the pine woodland areas creating 'wood heath'. Given small areas, the resulting changes to surface and ground water flow would be small.

Managing the risks

We recommend that any tree felling should be staged in a series of phases and on a small scale so as to reduce risks of enhanced surface and ground water flows and also the risk of erosion and ground movement.

Tree root systems should be retained in situ to maintain soil stability and consideration should be given to contour laying of tree stems and or branch bundles and the use of cut heather brashings or biodegradable matting (in more extreme situations) to stabilise the initially bare sandy soils. The work should be undertaken by hand wherever possible to prevent compaction and downward forces on the soils and rutting that might be caused by vehicles.

Initially, small scale felling areas should be assessed for their soil and geological conditions and the means of measuring and monitoring any resulting surface water flow and enhanced groundwater flows.

Prior to works a site assessment should include information about slope, geology, micro topography and general terrain, extent of litter cover (area and depth) and tree stem density. This would allow an evaluation of effects against conditions

Monitoring methods could involve placing boards or tree trunks across the direction of flow and assessing any build up and by installing sequences of standpipe type dipwells to regularly measure the depth to groundwater. Such dipwells could be installed on footslopes, especially in areas close to the clay interface, and possibly also in gardens.

Monitoring changes in water levels in comparison to rainfall events would provide information not only about soil and ground water levels but also about the lag time between rain and rises in groundwater. Monitoring should also occur outside of any felling areas (as 'controls') so that comparisons can be made.

Should such areas be successful in avoiding adverse hydrological effects, the felling programme could be increased as long as lessons are learned from the initial felling areas and consideration is given to appropriate mitigation such as use of biodegradable matting, laying of tree stems or branch bundles, use of cut heather brash and the installation of interception ditches and possibly using valley features to retain water and reduce flows.

Monitoring and assessment of felling should be ongoing in order that best practice mitigation is established and measurements of performance and improvements to mitigation can be made based on continuing experience.

2.0 CONCERNS OF LOCAL RESIDENTS

2.1 SITE VISIT

First and foremost has been the need to address the concerns of local householders and this matter has been in the forefront of our minds while preparing this report. Accordingly, on 21 April 2010 Ron Allen visited a number of properties selected by the West Christchurch Residents Association. The addresses and names of householders have been omitted.

I understand that the properties were likely to have been constructed in about 1959.

Following these visits, I was able to walk St Catherine's Hill in the company of several members of the Association.

I should express my gratitude to the members of the Association and the householders for so helpfully showing me the conditions at their properties and I appreciate their concerns that management of the Common above their properties should not be such as to exacerbate the water problems evident in their gardens.

2.2 NOTES ON INDIVIDUAL PROPERTIES

2.2.1 Site 1

The householders were concerned that removal of trees would enhance the existing erosion down the main Hill access track that was used mostly by dog walkers but also by CBC contractors, and a few cyclists.

The garden has water rising through ground at the top of the garden (adjacent gardens have land drains) and which I am informed has steadily worsened over the past 25yrs. I was shown where water seeps out of tarmac pavement in places along Hillside and we looked particularly at the pavement nearby where water seeps out of a retaining wall, and also where water had spread over the pavement for a sufficiently long time to develop a growth of filamentous algae.

2.2.2 Site 2

The householder has expressed the view that the property has a water problem and excess water flows into an adjacent property.

There is a drain across the gateway and water seeps out of base of the drive. This steeply sloping garden is cut into terraces with brick retaining walls. The garden tends to be drier towards the top and has continued seepage half way up the garden. Water also seeps into and out of a small pond.

2.2.3 Site 3

A steeply sloping garden and which has had an underdrainage scheme installed. I saw water rivulets coming down the garden and understand that even in summer there is always a trickle of water and the garden is always moist, and saturated in places. Excess winter water flows down to the road. Residents are worried that the problem could get worse and suggest that there are already signs of subsidence.

2.2.4 Site 4

This property is set on a terrace above Hillside and I understand that the wetness has become steadily worse over the past ten years. The garden is terraced and upper terraces retain wet. Water from the garden has been channelled into an ornamental pond, the flow, I am told, being continuous through the year.

2.2.5 Sandy Lane

I was informed by residents that Sandy Lane has a water problem with water flowing down the road, all houses along the lane having water problems. The detailed sourcing of the water is not understood

2.2.6 Site 5

This property has seepage onto the road and has a stream flowing below an outbuilding.

I am informed that there is a problem along Fairmile where trickles can freeze in winter giving safety concerns.

2.2.7 Site 6

Water can pour down the drive and flows through a crack in tarmac. A works excavation in the pavement had water in the base.

2.2.8 Site 7

This is a relatively level garden and which was clearly very moist during the visit. I understand that large areas of the garden flood in wet periods and I later saw a photograph that confirmed the extent of the flooding.

2.3 SUMMARY

Residents have reported a range of hydrological effects on their gardens and those that I have seen are consistent with ground conditions nearby, especially in relation to the sand / clay interface.

3.0 BACKGROUND TO THE SITE

3.1 LOCATION

St Catherine's Hill, a part of Town Common, is located to the north of Christchurch and occupies part of the high NNW to SSW trending ridge that forms the interfluve (watershed) between the valleys of the River Avon in the east and the River Stour in the West.

The land occupies the west facing slope of the ridge to the northeast of housing along the B3073 Hurn Road between the A338 in the north and Fairmile in the south. The land studied is that in the ownership of Christchurch Borough Council and the Amphibian and Reptile Conservation Trust (the latter area being leased from the Malmesbury Estate). The area is broadly land on the west facing slope between an area of housing and up to the summit of the ridge.

3.2 LANDFORM AND LANDUSE

The site comprises the west side of a distinctive ridge rising from about 10m to just over 45mAOD and which is managed for both nature conservation and for public recreation. On much of the lower southwest side, housing development has occurred up to about the 30m contour.

The Hill is divisible into three topographic sections all rising to just over 45m AOD. The larger southern part has two large water storage tanks located on the summit. Two small areas, attaining much the same height occur to the north and are separated from each other by low-ways or landscape saddles.

While the long southwest face appears to be fairly even, closer examination shows that there is a considerable variety of slope from almost level areas to slopes approximating to 40-45 degrees. The slope is further divided by small re-entrant valleys, with an especially large and steep sided valley towards the north of the site. Individual slope facets also vary in the micro-topography resulting in an often rather irregular topography.

The landform is further complicated by historic features include barrows on the summit, various historic bank and ditch systems running across the site, and a broad footpath at about 30m AOD which appears to have been created by cutting and filling along the valley side.

3.3 GEOLOGY

3.3.1 Information from the 1:50 000 scale geological map and memoir

The geological map (**Figure 6**) shows the following succession:

Drift deposits
12 River Terrace deposits

Tertiary Eocene deposits
BrkS Branksome Sand
PkC Poole Formation
- Parkstone Clay
- Sand
- Interbedded clays and sands.

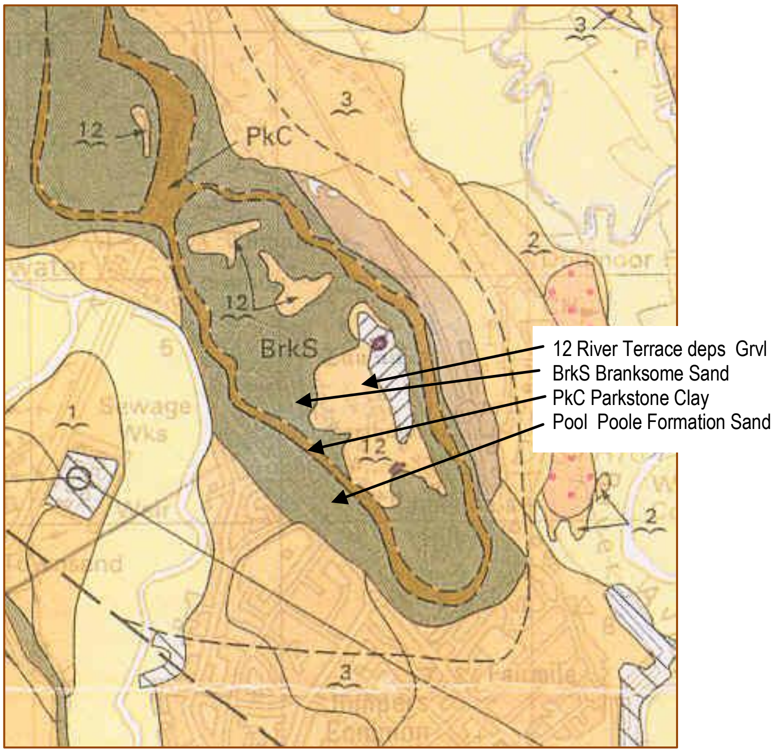

Fig. 6 Extract from the 1:50 000 scale geological map

The Parkstone Clay is indicated as about 12m thick in the general area.

A detailed description of deposits from the quarry at the summit of St Catherine's Hill is provided in **Figure 7** and which also describes two other nearby pits.

The 10m Branksome Sand succession in the quarry showed the following profile:

1m sand, fine to medium.
0.1 – 1.5m clay.
4m sandstone, mostly fine-grained, some coarse-grained, often cross bedded
1.5m sand, fine to coarse grained.
1.2 to 2.5m clay, thickens eastward and including up 1m of sand.

The pit 350m to the south revealed a 12m section in the Branksome Sand mainly of fine or medium grained sand.

Another pit nearby revealed a 6.7m section in the Branksome Sand of fine or medium grained sand but including a 1m band of clay passing down to clayey fine sand.

	m
Branksome Sand	
Sand, fine- to medium-grained, reddish brown, with some harder ferruginous beds	seen 1.0
Clay, pale lilac to bluish grey, with 10 cm of brown sandy clay at top	0.1 to 1.5
Sandstone and sand, fine-grained, brown, with some cross-bedding	up to 2.0
Sandstone, fine-grained, pale brown, thinly bedded	0.2
Sandstone, fine- to coarse-grained, hard massive, patchily red-stained	0.7
Sandstone, fine-grained, locally very coarse-grained, red-stained, cross-bedded, with ferruginous layers	1.2
Sand, fine- to coarse-grained, red-stained	1.5
Clay, white to pale grey; thickens eastwards within 20 m to include up to 1 m of brown sand, which itself thickens to the east	1.2 to 2.5

Some 360 m to the south, a large pit [SZ 1449 9523] reveals a succession, beneath 1 m of flinty gravel, that occurs lower in the formation than those given above:

	Thickness m
Branksome Sand	
Sand, fine- to medium-grained, pale to dark brown, iron-cemented in part, with thin (1 to 5 cm) white pipeclay seams	3.5
Sand, fine- to medium-grained, pale brown, locally cross-bedded, with harder clayey ferruginous beds	2.2
Sand, fine- to medium-grained, with bright red patchy staining; staining dies out below top 1.5 m	2.5
Sand, mainly fine-grained, but with very coarse-grained patches, brown, planar bedded; the base truncates the underlying beds where they are folded	1.0
Sand, mainly fine-grained, brown, with sandstone and ferruginous beds; bedding contorted and displaced by small-scale penecontemporaneous folding and faulting	3.2

BJW

In another old pit nearby [SZ 1453 9502], about 7 m of brown, fine- to medium-grained sand, with some coarse-grained patches, and thin ferruginous beds and locally contorted bedding are exposed. Traces of grey clay are seen at the top of the section. These strata lie below those of the previous pit. Another old pit hereabouts [SZ 1465 9494] shows the following section:

	Thickness m
Branksome Sand	
Sand, medium-grained, brown, with ferruginous cement at top	0.2
Clay, grey, passing down into clayey, very fine-grained, sand; probable palaeosol	1.0
Sand, medium-grained, brown to yellow, well-laminated at the top, with some cross-bedding; coarse-grained sand layers in the lower 1.5 m; erosional base	4.0
Sand, fine- to medium-grained, yellow to orange, with irregular silty clay areas; laminated silt at top	1.5

Fig. 7 Geological Section descriptions

3.3.2 Information from the 1:25 000 scale geological map

The Institute of Geological Sciences *Sand and Gravel Resources, Mineral Assessment Report 51 SU00 North of Bournemouth, Dorset*, provides information on the geology of the Town Common area and includes a map (see extract in **Figure 8** below) and a cross section (**Figure 9** below).

This map shows St Catherine's Hill capped by a large spread of the high level 8th Terrace Deposits associated with the River Avon (shown in pink), some of which has been worked (diagonal lines). Unlike other areas, the gravel resources were not assessed on the hill. These high level terraces are described as well-bedded gravels with occasional thin interbedded sand units.

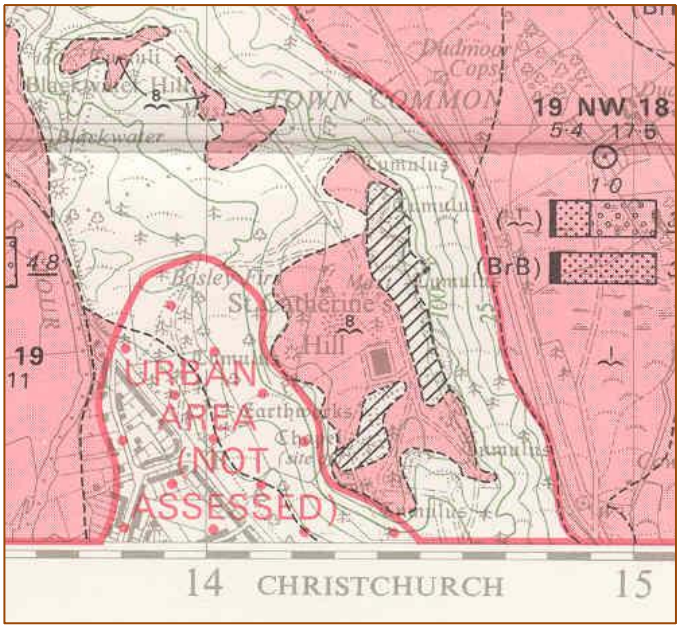

Fig. 8 Geological map; showing gravel deposits (pink) and extent of excavated land (hatched)

Cropping out on slopes around the gravels are Tertiary Deposits here identified as BrB Bracklesham Beds described as ranging from stiff, dark greyish brown, lignitic laminated sandy clays, to lignitic, fine and medium quartz sands with occasional thin flint pebble beds.

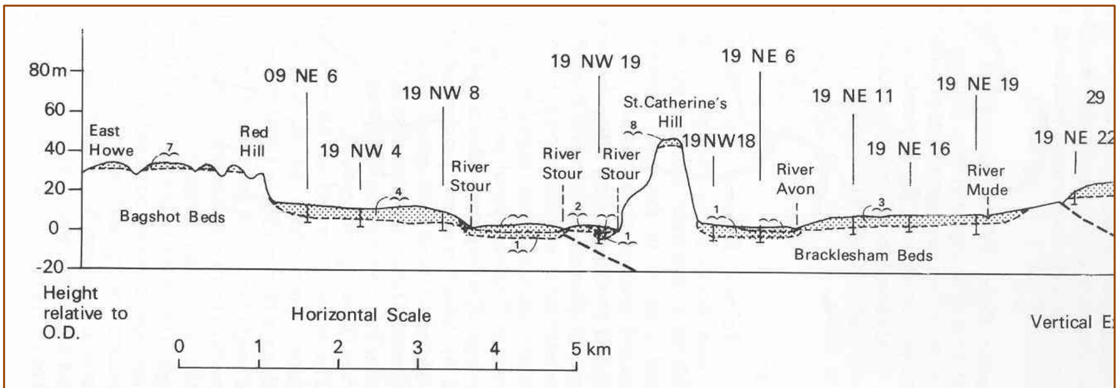

Figure 3 Geological cross-section of the Bournemouth sheet

Fig. 9 Cross section across the Stour and Avon valley showing the geological relations of St Catherine's Hill

3.3.3 Information from the 1:10,000 scale geological map

A portion of the 1:10 000 geological map is shown in **Figure 10a** and descriptions of four sections and a borehole (158) are provided in **Figure 10b**.

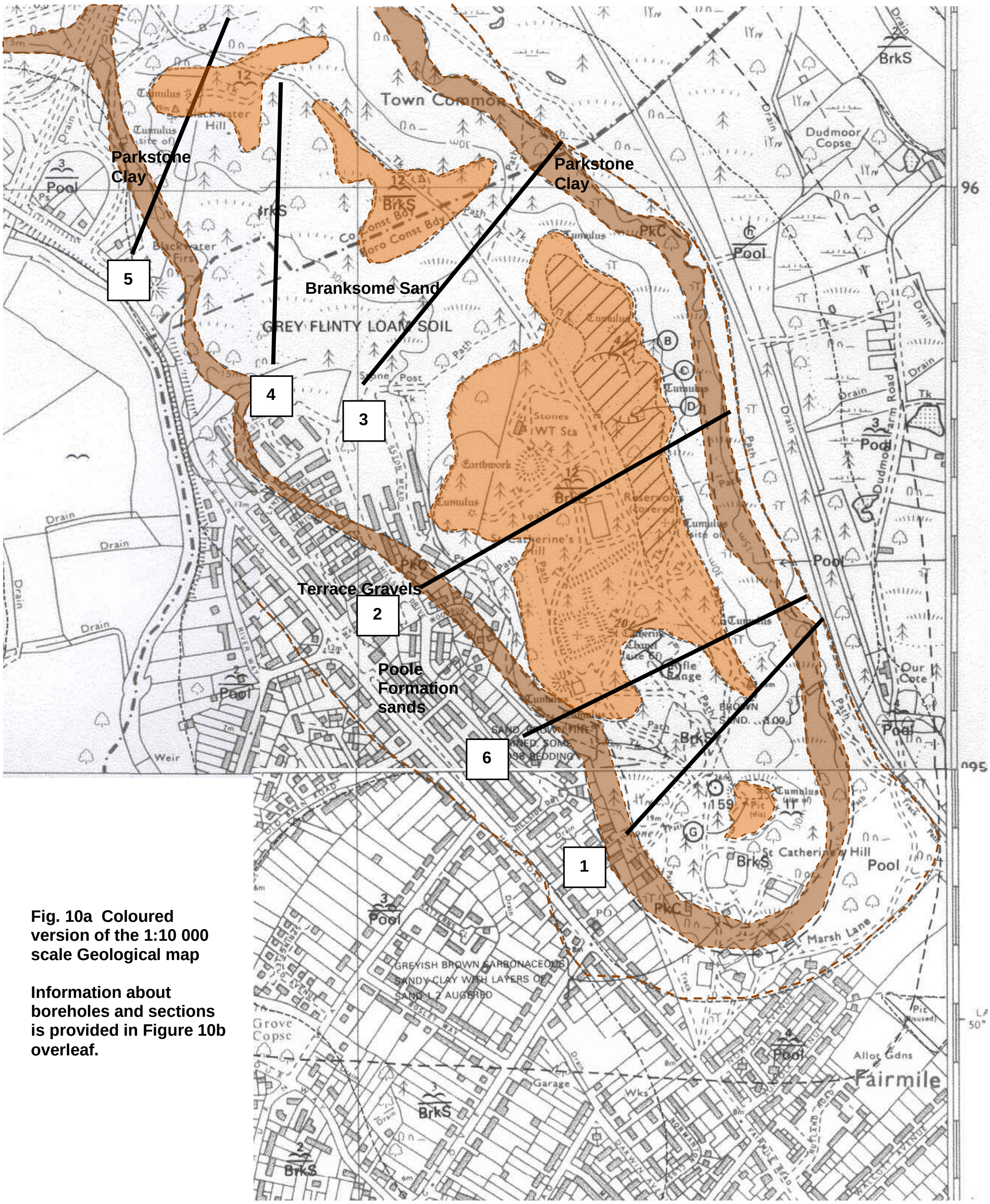

Fig. 10a Coloured version of the 1:10 000 scale Geological map

Information about boreholes and sections is provided in Figure 10b overleaf.

(B) ST. CATHERINE'S HILL GRAVEL PIT, NORTH END.
(1435 9569)
BOURNEMOUTH GROUP, BRANKSOME SAND
SAND, REDDISH BROWN, FERRUGINOUS LAYERS 1.00
CLAY, LILAC TO BLUISH GREY, 10cm, BROWN SANDY CLAY AT TOP .... 1.10 to 1.50
SAND AND SANDROCK, BROWN, SOME CROSS-BEDDING 2.00
SANDROCK, PALE BROWN, FINE-GRAINED, WELL-BEDDED 0.20
SANDSTONE AND SANDROCK, HARD, MASSIVE, FINE-TO COURSE-GRAINED, PATCHILY RED-STAINED 0.65
SANDROCK, BROWN, FINE-GRAINED WITH VERY COARSE PARTS, FERRUGINOUS LAYERS, CROSS-BEDDED 1.20
SAND, FINE-TO COURSE-GRAINED, RED STAINED 1.50
CLAY, WHITE TO PALE GREY, EXPANDS EASTWARDS TO INCLUDE 1m SAND WEDGE .... 1.20 to 2.50

(C) ST. CATHERINE'S HILL GRAVEL PIT, EAST SIDE.
(1451 9567)
RIVER TERRACE DEPOSITS
GRAVEL 2.50
BOURNEMOUTH GROUP, BRANKSOME SAND
SAND, BROWN FINE-TO MEDIUM-GRAINED, COARSE LAYERS, VARIABLY CEMENTED WITH FERRUGINOUS RIBS 1.75
CLAY, WHITE SILTY 2.50

(D) ST. CATHERINE'S HILL GRAVEL PIT, SOUTH END.
(1447 9559)
RIVER TERRACE DEPOSITS
GRAVEL 2.50
BOURNEMOUTH GROUP, BRANKSOME SAND
CLAY, WHITE, WITH PIPE CLAY SEAMS 1.00
SAND AND SANDROCK, BROWN, PATCHILY RED-STAINED 2.95

(E) ST. CATHERINE'S HILL NW SIDE OF RIFLE RANGE QUARRY
(1449 9523)
RIVER TERRACE DEPOSITS
GRAVEL, FINE TO FAIRLY COARSE, LITTLE SAND, DARK BROWN AND IRON-CEMENTED IN PARTS. IRREGULAR BASE 2.00
BOURNEMOUTH GROUP, BRANKSOME SAND
SAND, PALE TO DARK BROWN, IRON-CEMENTED IN PARTS. THIN (1 to 5cm) WHITE PIPECLAY SEAMS SEPARATE SAND BEDS UP TO 0.80m 3.50
SAND, PALE BROWN, OCCASIONALLY CROSS-BEDDED, WITH HARD CLAYEY FERRUGINOUS BEDS 2.20
SAND, BROWN, PATCHILY BRIGHT RED-STAINED IN TOP 1.50m 2.50
SAND, BROWN, PLANAR BEDDED, MAINLY FINE-GRAINED BUT VERY COARSE IN PARTS. BASE TRUNCATES UNDERLYING BEDS 1.00
SAND, MAINLY FINE-GRAINED, WITH SANDROCK BEDS, BEDDING CONTORTED BY SMALL-SCALE PENECONTEMPORANEOUS FOLDING AND FAULTING ... 3.20

(G) 1465 9494
SL c. + 33
RIVER DEPOSITS
GRAVEL, FERRUGINOUS .... MORE THAN 1.0
BRANKSOME SAND
SAND, BROWN MEDIUM-GRAINED WITH FERRUGINOUS CEMENT AT THE TOP 0.2
CLAY, CREAMY GREY, COARSENING DOWN IN TO CLAYEY VERY FINE-GRAINED SAND. POSSIBLE PALAEOSOL 1.0
SAND, BROWN TO YELLOW, MEDIUM-GRAINED WELL LAMINATED AT TOP. SOME CROSS-BEDDING COARSE-GRAINED SAND LAYERS IN LOWER 1.5m. EROSIONAL BASE 4.0
SAND, YELLOW TO ORANGE, FINE TO MEDIUM-GRAINED WITH IRREGULAR SILTY CLAY LAYERS. LAMINATED AT TOP .... MORE THAN 1.5

159 1460 9496
SL c.+26
BRANKSOME SAND
SAND, FINE, BUFF, WITH SOME BROWN LAMINATED CLAY LAYERS c.2.80
PARKSTONE CLAY
CLAY, BROWN TO BROWNISH GREY, LAMINATED WITH VERY FINE-GRAINED SAND .... OVER 5.75

Fig. 10b Information about boreholes and sections shown in Figure 10.

There are four described sections from the north eastern part of the main excavation, one from the southern gravel pit and a borehole description

Section B is the same section as quoted in 2.3.1 above:

1m	sand, fine to medium.
0.1 – 1.5m	clay.
4m	sandstone, mostly fine-grained, some coarse-grained, often cross bedded
1.5m	sand, fine to coarse grained.
1.2 to 2.5m	clay, thickens eastward and including up to 1m of sand.

NB. The angle of dip on the strata here is shown on the map as 4 degrees, this is taken as the dip on the Terrace Gravels.

Section C shows:

2m	river terrace gravel.
1.75m	Branksome Sand with fine to medium grained sand variable cemented.
2.5m	clay, white silty.

Section D shows:

2.5m	river terrace gravel.
1m	Branksome Sand clay.
2.95m	sand and sandrock.

Section E adjacent rifle range shows

2m	river terrace gravels, little sand, partly cemented.
3.5m	Branksome Sand, sand cemented in parts with thin pipe clay seams.
8.9m	sand with hard clayey layers over sand and sandrock.

NB. The angle of dip on the strata here is shown on the map as 20 degrees, this is taken as the dip on the Terrace Gravels.

Section G in southern gravel pit shows:

>1m	River deposits, gravel.
6.7m	Branksome Sand, variously medium and coarse grained sand including 1m sandy layer and irregular silty clay laminated layers towards base.

Borehole 159 shows:

2.8m	Branksome Sand, sand with some laminated clay layers.
5.75m	Parkstone Clay, clay laminated with very fine-grained sand.

3.3.4 Geological cross sections

Cross sections across each study area are shown in **Section 4**. These sections show the arrangement of the strata as far as can be ascertained from the geological maps and in the absence of borehole data.

The sections show the capping of Terrace Gravels and which in places spread down the hillside. The nature of the boundary to the underlying deposits is not known but we assume that the gravels have been redeposited on hillsides by slipping or by slumping during melting phases of the last ice age (solifluction) and may not be very thick on the slopes.

The Branksome Sands occupy the mass of the land.

The nature of the boundary to the Parkstone Clay is not known and could be planar or wavy and could also be sharp or gradual. The thickness of the Parkstone Clay is variable.

The dip on the surface varies from nearly level to nearly 2 degrees and also appears to change direction from place to place. Values for the angle and direction of dip based on six map measurements from south to north are:

Section 1 (in south)	1.8 degrees to the southwest
Section 6	0.66 degrees to the east
Section 2	0.87 degrees to the east
Section 3	0.04 degrees to the northwest
Section 4	0.26 degrees to the south
Section 5 (in north)	0.18 degrees to the south.

Note. Section 6 was measured later and is located between sections 1 and 2.

3.3.5 Information from site visits

The gravel sequence can be viewed from sections in the worked out quarry. In particular is an upper layer of reddish iron rich stoneless sands forming steep faces below which appears a layer of very pale silty clay (pipe clay) with an undulating surface. It appears that the flint gravels occur below the pipe clay and comprise mostly subangular and angular flint stones in a coarse sandy matrix.

An irregular junction of the gravels to the underlying Branksome Sands can be seen in the south of the site and in what may have been an eroded old access track to the quarry. Where the Branksome Sands can be seen in sections and along path surfaces, they appear to comprise mainly fine sands and fine-grained compact sandstone.

The Parkstone Clay has not been seen in outcrop and is likely to be covered in thin Head deposits that have accumulated from one-time erosion of the upper slopes.

3.4 SOILS

The 1:250 000 scale soil map of England and Wales does not show the area of St Catherine's Hill in detail but indicates the presence of two soil associations in the area. Soil associations are the units used on the soil map and indicate areas where similar ranges of soil types occur together (small areas of soil are not shown on the map because of scale). At St Catherine's Hill, these associations are:

634 SOUTHAMPTON ASSOCIATION on glaciofluvial drift (terrace deposits)

These are described as well drained very acid, very flinty sandy soils with bleached subsurface horizon, with some very acid sandy over clayey soils with slowly permeable subsoils and slight seasonal waterlogging.

These soils broadly equate with those on the terrace gravels. From sections along the quarry, we have seen that the soils here, while mostly coarse textured and freely draining do include more poorly drained soils where the pipe clays occur and stoneless soils on bedded sands.

641b SOLLOM 2 ASSOCIATION on Tertiary sand

Deep often stoneless and very acid, humose sandy soils, with bleached subsurface horizon, affected by groundwater. Well drained very acid sandy soils on slopes. Some sandy over fine loamy soils with slowly permeable subsoils and slight seasonal waterlogging.

These soils broadly equate to those on the Branksome Sand and where the soil conditions seem quite varied.

3.5 HYDROLOGY

3.5.1 Surface hydrology

The site is a hill top and has no running water such as rivers or streams. Two ditches above gardens intercept water from seepages and transmit the water around the housing and down a channel along an access track and whence to the sub-road drainage system. Standing water is restricted to:

1. a pool with the main quarry; and to
2. several minor pools associated with small excavations in wet heath areas.

Most of the land is below maritime pines and Scots pine trees or dry heathland vegetation and appears to be well drained. There are some areas of wet heath and mire plant communities reflecting locations where seepages occur at the land surface, often valley slopes.

Steep slopes allow surface flow of surface water once the underlying soils have become saturated.

Wetlands occur in several places and are expressed at the surface as areas of wet heathland and thought to reflect areas of perched groundwater, held over less permeably substrates below. Strong spring action and seepages occur in association with the Parkstone Clay seam that runs around the hillside with a dip towards the southwest towards the housing area.

Fig. 11 The pool in the summit quarry

The ridge line of St Catherine's Hill provides a hydrological divide or watershed whereby surface flows will move in opposite directions down the slopes either side of the line. Given the west facing slope with which this study is concerned it is possible, using topographic (contour) information to divide the area into sub-catchments. These are shown in **Figure 13**. Catchments in relation to geology are shown in **Figure 14**.

Fig. 12 Thick layer of 'pipe clay' within the gravels in the quarry

3.5.2 Hydrogeology

Because of the layered nature of the rock strata and their variable permeabilities, the hydrogeology of St Catherine's Hill is likely to be complex.

Rain falling on the Terrace Gravels will infiltrate quickly where the gravels are coarse sandy with a high permeability. However, pipe clay layers (**Figure 12**), finer sandy and cemented layers will affect the rate of downward percolation and the extent to which any perched water tables will occur (where water sits upon an impermeable layer).

Rainwater falling into the main quarry appears to be retained initially as a pool and which reduces in depth during the summer (**Figure 11**). We assume that this water is perched over pipe clay layers or perhaps over the underlying less permeable Branksome Sand. Water in the quarry will eventually soak downwards into the Branksome Sand or may move sideways emerging as springs and seepages on valley sides.

The gravels are shown on geological maps as capping the hill top and also spreading down the west facing valley side in places. It is likely that on the hillsides, the gravels are relatively thin and represent downwash or slippage during the later stages of the ice ages.

The Branksome Sand is thicker and occupies the mass of the hill below the gravels. Little is known about the permeability of these materials, but the presence of fine sands and sandrock suggests that the permeability may be only moderate.

Water passing into the Branksome Sand will percolate downwards presumably forming a water table whose surface broadly reflects the slope of the land surface.

The Parkstone Clay forms a layer below the Branksome Sand and appears to give rise to perched water tables at the base of the Branksome Sand and also affects the way in which water flows in the lower part of the Branksome Sands. This process appears to support some at least of the wet heathland vegetation on the site.

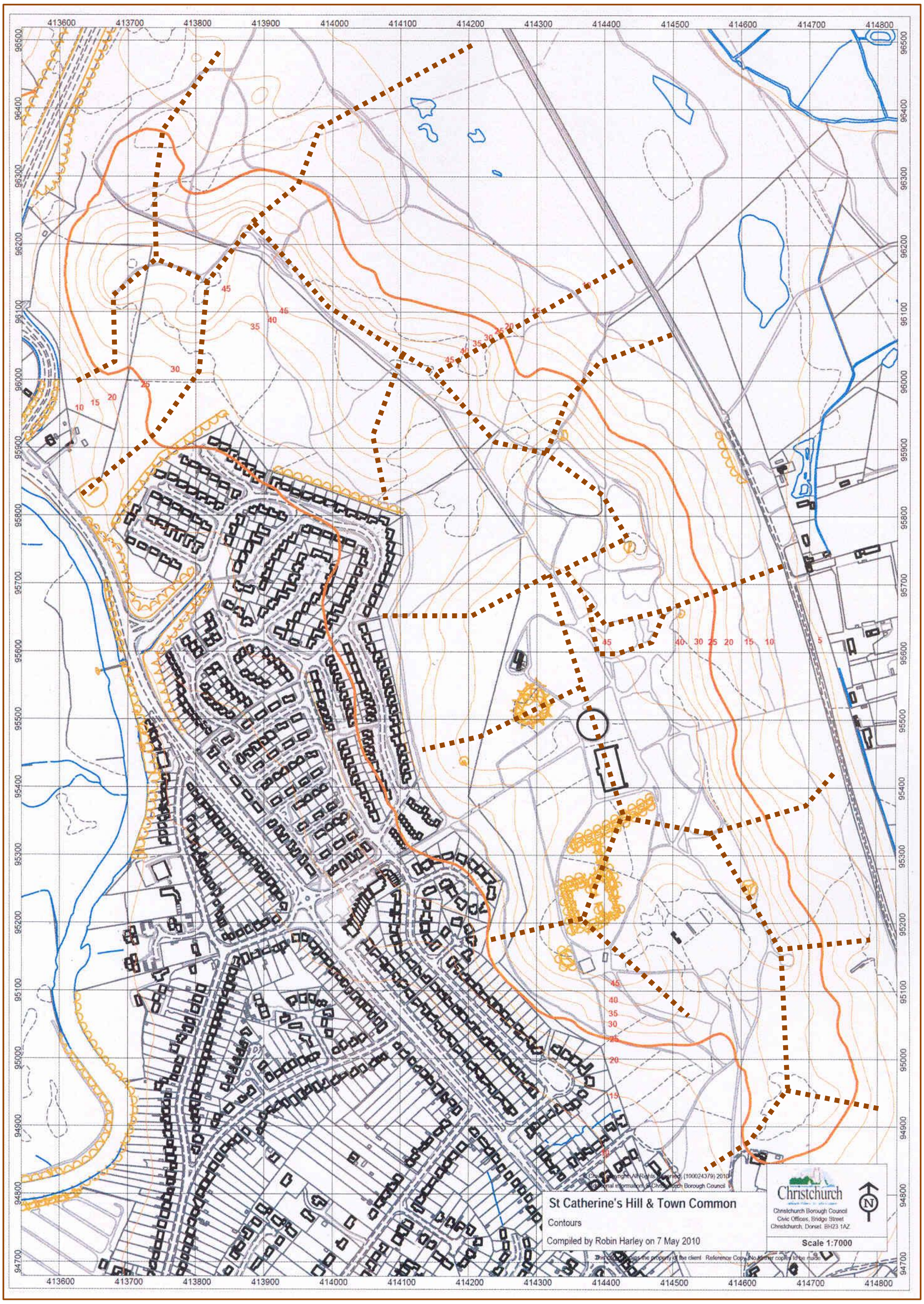

Fig. 13 Topographic survey with catchment interfluves (ridge lines) superimposed
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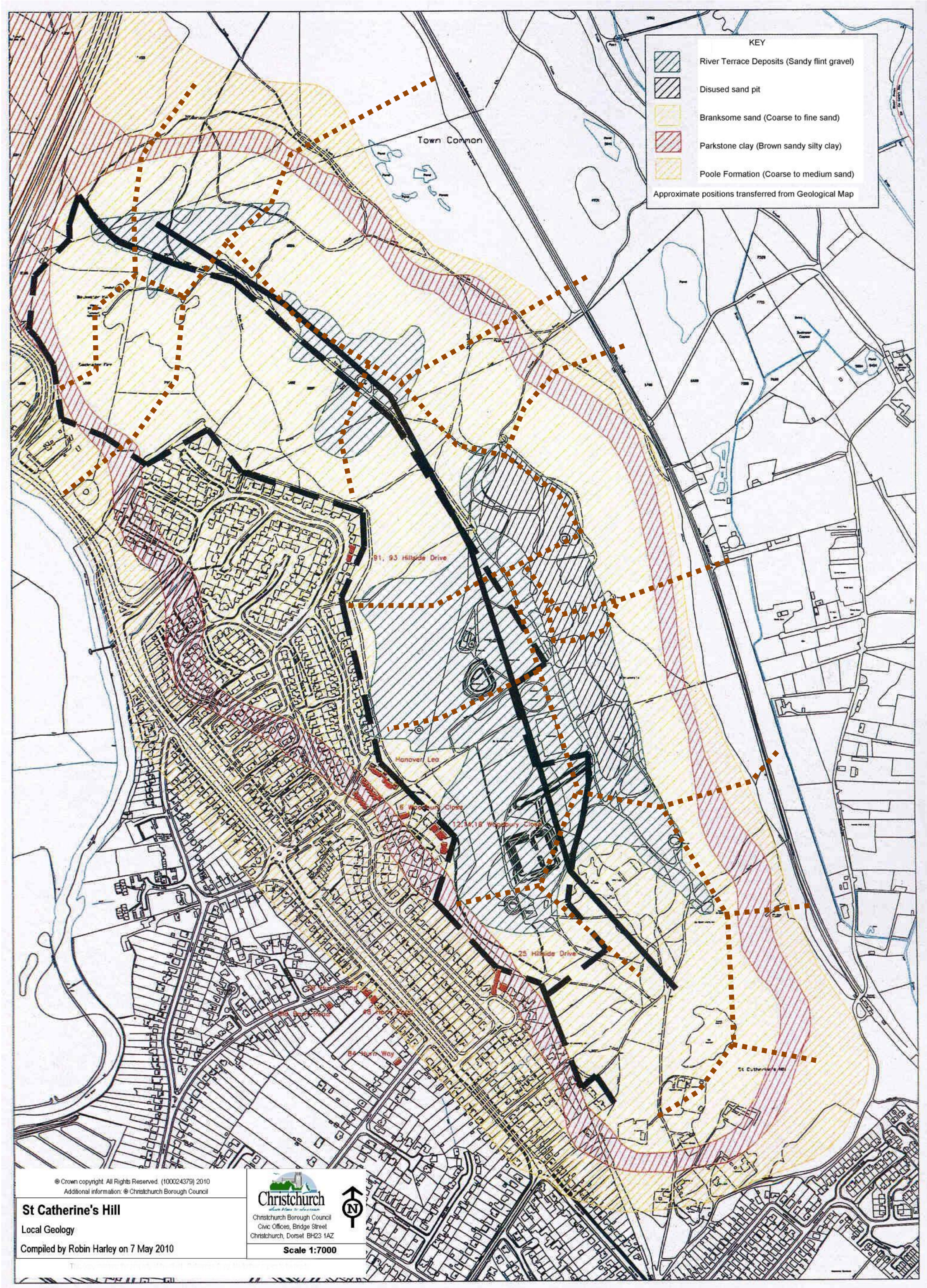

Fig. 14 Geological Map (compiled by Christchurch Borough Council) with catchment overlay

3.5.3 Factors affecting the water relations of the site

A key factor is the 'rate of infiltration', the rate at which rain water enters the ground surface, passes down through the soils and infiltrates into and through different geological substrates down to groundwater. This depends on a range of factors including:

Rainfall

Rainfall events will:
- vary in number through the year,
- vary in the amount of rain falling (intensity) at any one time, and
- vary in duration.

Soil permeability

The ability of the soil layers within the upper 1m of the ground to transmit water downwards will depend upon:
- seasonality of rainfall events,
- the permeability of the different soil layers,
- the depth to any slowly permeable impeding layer,
- the depth to any perched or rising groundwater table.

Substrate permeability

The ability of the geological substrate to transmit water downwards and/or laterally will depend upon:
- the permeability of different geological materials, especially of the Terrace Gravels (with included pipe clay seams), the Branksome Sand (the extent to which the material contains loose or lightly compacted sand and/or cemented sandrock), the characteristics of the Parkstone Clay and any included sandy seams and the boundary conditions between them.

Groundwater

Groundwater within the hill is thought to be perched above slowly permeable substrate layers and will vary according to:
- the presence of perched water tables within strata (such as over pipe clays in the terrace gravels);
- the presence of perched water tables between strata, such as that between the Branksome Sands and the Parkstone Clay.

Slope

The amount of groundwater that enters the soil will be affected by the slope of the land:
- the shallower the slope, the more likely water will infiltrate downwards,
- the steeper the slope, the more likely that a proportion of water will flow overland rather than soak directly into the ground,
- overland surface water flows may well soak into the ground downslope of where it fell.

3.6 TREES AND HYDROLOGY

Different trees growing in woodland will affect the way rainfall infiltrates into the ground and this will vary according to:
- the type (conifer or broadleaved);
- the species;

- seasonal growth patterns;
- the vigour and age of the tree;
- the planting density or spacing of the trees;
- the extent to which the canopy closes.

The use of water by trees is described in the Forestry Commission Information Note on *Water Use by Trees* 2005.

In outline, trees take water up through their roots to leaves where it is evaporated into the air (transpiration). Trees also intercept water by the surfaces of leaves, branches and trunks during rainfall and its subsequent evaporation. Taken together these processes are referred to as 'evapo-transpiration'. Some water passes directly to the ground (throughfall).

In a woodland, rainfall hits the tree canopy, some water passes onto leaves and along the branches and then flows down the tree stem into the ground (stem flow); some passes through the canopy directly reaching the ground. Some water will remain on leaves (interception) and be evaporated directly back into the atmosphere.

Once water has entered the ground, a proportion will be drawn back up by the roots and pass to leaves to again pass into the atmosphere (evapo-transpiration). The remainder of the water will either be held in the soil or passed downwards to groundwater.

Evergreen conifers tend to have greater water use than broadleaves across the year.

The extent to which water is passed back up the tree will depend on the availability of that water to the tree from the soil and the rooting pattern of the tree. Trees will have difficulty extracting water from well-drained sandy soils (that hold very little water) unless there is groundwater within rooting depth, and also from heavy clayey soils (that retain water between the clay particles). Conifers tend to be shallow rooted compared to broadleaved trees and so extract water mainly from surface soil layers. Broadleaved trees are in general, able to extract water from greater depths.

Discussion on changes in rates of evaporation are discussed in section 3.7 of the SSSI Restoration Project – Work Package 3: Update of EIA (RSPB and Footprint Ecology 2008). The report quotes references indicating that the rate of evaporation and interception losses decline in a range of conifers as they mature implying that tree removal will reduce evapo-transpiration rates and interception levels so that more precipitation reaches the ground and less is lost through vegetation.

From this it is concluded that removal of the older trees at St Catherine's Hill would have less effect than if the trees were younger. It also suggests that as the trees have aged, the rate of interception and evaporation may have decreased such that water flows could be greater now than when the trees were younger. From bare ground through establishment, maturity and aging, the rate of water interception from pine trees rises to a maximum and then declines. At St Catherine's Hill, pine establishment was into pre-existing heathland and so the hydrological impact would be less than would be expected from the bare ground situation.

Allen and Chapman (2001) discuss impacts on groundwater resources from forestry in Ireland and quote field investigations indicating that afforestation leads to a reduction in runoff by as much as 20% (in upland areas) mainly due to interception of rainfall by forest canopies. Clear felling has the opposite impact. Also that recharge rates under forests can be reduced to one tenth that under grass or heathland.

Trees on sandy soils such as at St Catherine's Hill are most likely to experience water stress (especially in summer) leading to reduced vigour and dieback unless located on seepage zones.

At St Catherine's Hill, the main trees are maritime pines and Scots pines (types of conifer) but with some areas having more open pine with a broadleaved tree understorey of willows, birches and oaks. The tree stands also vary in their ages with several generations being seen in some places.

Looking up towards the maturing pine canopy, the branching is seen to generally be quite sparse and taking up perhaps 75-80percent of the sky (**Figures 20 and 21**). This probably reflects the poor vigour of the trees that are growing on droughty impoverished soils.

Root uptake and transpiration by coniferous trees will be at a maximum during the spring and early summer growing season and continue through the year at a lesser rate, while that of broadleaved trees will reduce following leaf fall.

Evapo-transpiration from conifers will be greatest in the spring and early summer and continue at a reduced rate through the rest of the year, while that of broadleaved trees will be reduced following leaf fall.

Throughfall will tend to remain much the same for conifers, but will be greatly increased for broadleaved trees after leaf fall.

Felling of conifers will remove water use by the trees. Leaving brash on the ground will create up to 15% rainfall interception and there will be some evaporation from areas of bare soil. Evapo-transpiration and interception will start again as new vegetation (such as heathland) starts to develop but the extent will very likely be less than under the previous pine cover. In the absence of brash, heather cuttings could be used.

In the lowlands, total interception from conifers can be large and up to 75-100% of annual rainfall. This will however, vary considerably depending on the character of the woodland and this figure is perhaps more typical of managed productive conifer plantations rather than the impoverished conditions at St Catherine's Hill where the conifer woodlands have a rather open canopy. Total interception would be lower in the winter months when rainfall is high and growth levels low.

In conclusion from these studies, it would seem that:

- conifers tend to use water throughout the year than deciduous trees with a maximum uptake during the spring and early summer;
- conifers have shallow rooting which restricts the amount of water they can take up, especially on droughty soils;
- older trees may intercept and evaporate less water than younger trees.

At St Catherine's Hill, the pines on upper slopes and on the summit area likely to be on droughty soils remote from groundwater, and this, coupled with the trees age and reduced vigour means that these trees may be removing relatively little water from the system than would be expected from more vigorous trees on moisture retentive soils and perhaps more equivalent to that of heathland. The situation is likely to be different on lower slopes, where groundwater seepage may be supplying more water to the trees and which will then be taking more water out of the ground.

Areas with mixed pines and deciduous species, as well as areas of younger pines, are likely to lose more water annually from tree use than those areas of older pure pine.

Given this scenario, removal of older pines on the upper parts of the hill and replacing with heathland would have less risk of hydrological change than removing trees from the lower slopes.

3.7 HEATHLAND AND HYDROLOGY

Heathland is a complex habitat and typical dry heathland grows on droughty sandy soils in southern England. Heathland habitat comprises a mixture of open areas dominated by heather (*Calluna vulgaris*) but with areas of scrub, local trees and areas of bare ground. It is this complexity that makes heathland such a biodiverse habitat and that is promoted by heathland management.

Heather shrubs vary themselves in their growth stages. The following notes on the stages are for a site in Scotland (see Heathlands, Nigel Webb, The New Naturalist 1986 page 90).

NB. I understand that the growth stages following earlier pine removal at St Catherine's Hill have been much quicker than indicated below, perhaps reflecting the warmer climate in Dorset as compared to Scotland.

1. Pioneer stage
    - On first opening up heathland soils such as by pine felling or fire, the individual plants first grow as seedlings occupying about 10% of the vegetation cover with open soil around them and do little to intercept rainfall.
    - Throughfall is at a maximum in this stage which can last from 3 to 10 years.

2. Building stage
    - As the seedlings grow, the stems begin to branch and the canopy eventually closes over to cover perhaps 85-90% of the soil. The canopy now filters rainwater prior to reaching the ground and evapo-transpiration becomes more important.
    - Throughfall is at a minimum during this stage which can last from 7 to 13 years.

3. Mature stage
    - In time, the plants mature, the branches begin to lie back and the canopy opens letting light and rain into the central areas. The plants now occupy about 75% of the vegetation as other plants species, especially mosses, begin to increase their ground cover.
    - Throughfall remains low during this stage which lasts from 12-28 years.

4. Degenerate state
    - With greater time, the central branches of heather plants die off creating gaps in the centre of the bush in which heather seedlings may develop. Heather now contributes about 35-40% of the ground cover, the remaining 60-56% comprising other plants and mosses, seedlings or bare ground.
    - This stage can last from 16 to 30 years and during which throughfall increases to match that of the pioneer phase.

Dead stage

- Areas of dead heather can be common, either because the plants have simply died, or because of fire.

In practice any one area of heathland will comprise a complex mosaic of all growth stages according to the way the heathland has been managed. Thus the water relations of the any one area of heather are constantly changing.

The roots of heather plants growing in dry conditions are mostly (about 90%) in the upper 20cm of the soil, however they form a dense mat that becomes comparable to that of trees.

Humid, wet heath and valley mire form a sequence of different vegetation types reflecting the seasonality or permanence of soil wetness states. Dry heath tends to occur on well drained sandy soils, humid heath on soils with impeded drainage and seasonal wetness, wet heath on land that is mostly wet but dries out seasonally preventing the build up of peat, and mire habitats form where there is permanent wetness leading to the long-term accumulation of peat.

3.8 COMPARISON OF WOODLAND AND HEATHLAND HYDROLOGY

FC Information Note on Water Use by Trees 2005

The Forestry Commission Information Note on *Water Use by Trees* by Tom Nisbet April 2005 gives the following generalised information on annual evaporation losses from different land uses based on an upland rainfall of 1000mm.

Land cover	Total annual evaporation
Conifers	550-800
Broadleaves	400-640
Grass	400-600
Heather	360-610
Bracken	600-800
Arable (not irrigated)	370-430

It can be seen that there is considerable overlap in these figures especially for broadleaves, grass and heather.

Indeed, there is some overlap between conifers and heather suggesting that the difference in water use between pines at the lower end of the scale (as in those at St Catherine's Hill) may not be much different from vigorously growing heather. This would be especially the case if land at St Catherine's Hill was converted from pines of low vigour to wood heath where only a proportion of pines were removed allowing heathland to regenerate below them.

There are no figures for mire or wet heath as we find on lower slopes affected by groundwater at St Catherine's Hill.

(Note: St Catherine's Hill is within the Stour catchment and for which the Flood Estimation Handbook gives an annual rainfall value of 855mm.)

Studies at Clipstone Forest, Nottinghamshire and the TaDPole Project

The FC Information Note quotes work by Calder et. al. 2002 and 2003 which aimed 'to understand the potential impact on water resources of woodland expansion on sandy soils overlying the Sherwood Sandstone aquifer'.

The study area (Clipstone Forest in Nottinghamshire) was one of droughty soils over bedded fine to coarse-grained sand with layers of pebbles and thin beds of silty clay, the clays having a local impact on moisture retention and may be significant in causing local perching of drainage.

Groundwater below the site was at a depth of 20m, well below the rooting depth of the vegetation and so these trees were extracting from soil water. This may well be comparable to the hill top at St Catherine's Hill, but less so to the valley sides where groundwater is likely to be at shallower depth and in places giving rise to springs and seepages.

The pine woodland study area was a 32 year old stand of Corsican pine *Pinus nigra* var *maritime* (planted in 1968) and at a time of maximal growth stage during the study; this species is quoted as having high interception rates.

Note that our observations of the 50-100 year old self-sown maritime and Scots pines (*Pinus pinaster* and *P. sylvestris*) at St Catherine's Hill were that the canopies were relatively open.

The heath component of the study consisted predominantly of grasses (*Deschampsia flexuosa*, along with *Holcus mollis* and *Festuca rubra*) and heather (*Calluna vulgaris* and *Erica cinerea*), The authors indicate that it is difficult to predict accurately the water quantity impacts of UK lowland afforestation because:

1. water used by transpiration generally exceeds that by interception and is difficult to estimate because of the effect of tree physiology on transpiration losses and which can be lower or higher than shorter vegetation; and
2. information on evaporative losses for different tree species on different soils is limited or non-existent.

This study involved detailed measurements of soil moisture below different vegetation types and demonstrated the 'extreme sensitivity of recharge plus runoff to vegetation cover on drought prone sandy soils in a dry region of Britain'.

Calder et.al 2002 discuss the Trees and Drought Project on Lowland England TaDPoLE and, as a result of estimated recharge based on soil moisture measurements, ranked different habitats in the order of grassland>heath>oak>Corsican pine forest. Expressed as a percentage of rainfall, estimates of recharge are given as 25% for grass, 23% for heath, 17% for oak woodland and 8% for Corsican pine woodland. However, they indicate that 'While drainage beneath Pine is significantly less than that from the other land-uses, some of the models indicate that there is less certainty in distinguishing drainage rates beneath grass, heath and oak woodland due to the inter-annual variability of drainage in a period when rainfall has been significantly above the long-term average.'

This four year study involved complex instrumentation and measurement of the forest's water relations; however, this period was subject to high rainfall and conditions during drier weather were not obtained indicating the complexity of these types of studies and their limitations.

In general, it was considered that evaporation under forests is high, reducing groundwater recharge when compared with shorter vegetation such as grass and heath. This is because of increased tree transpiration during dry periods because of deeper rooting and increased interception losses in wet conditions.

Over an annual cycle, this study suggests that evergreen coniferous species such as pine exhibit higher interception losses than deciduous species that drop their leaves in winter. In this region (Clipstone Forest), the long term recharge plus runoff beneath pine forest will be approximately one quarter (25%) that under grass (considered to be similar to heath) and essentially only occurs in years of above average rainfall. The impact would be considerably reduced during drier periods. However, over a wider area, the impact on groundwater recharge (of planting pines) will depend upon the scale of planting, forest design and initial land cover.

In the worst case, new pine plantings that extended the area of woodland by 18% from 9 to 27%, could reduce recharge to the aquifer by between 10 and 14%.

The alternative scenario that removing a similar proportion of pine (18%), such as at St Catherine's Hill, would have the reverse effect seems likely; however; the extent remains unknown and would depend upon the vigour and age of the trees and the ability of the soils to retain water.

Removal of older less vigorous trees from areas with droughty soils and where groundwater is below rooting depth would be expected to have a smaller hydrological effect than removing vigorous trees from land with moisture retentive soils and access to shallower groundwater.

Forestry Commission letter in relation to proposed felling on east side

We have seen the March 2005 response by the Forestry Commission to the proposal to remove pines from the east side of St Catherine's Hill. This letter makes a number of very valid cautionary points that are also relevant to the west side.

- The effect of felling will be greatest [where trees are] on bare ground, but will also be marked where there is ground vegetation below the trees (note that apart from in the south, much of the pine woodland on the west side of St Catherine's Hill has either no ground vegetation or only a sparse layer of bracken).
- Run-off could be expected to increase from 20% of precipitation under pine to 30-40% for felled areas with a good cover of ground flora comprising heather or grass equating to a considerable rise in runoff or groundwater flow of between 50-100%.
- Data from TaDPoLE provides a good analogue to the site and gave annual drainage figures as a percentage of precipitation of 24% for heather and 6-8% for pine. Applying these to Town Common (east side) suggests that the proposed conversion of pine to heather would increase run-off by a factor of around three to four.
- The actual impact of the clearance will depend upon the scale of the felling with respect to the catchment areas of the local surface and groundwater systems. The surface water divide of the individual coombes would apply in the case of the former, while the assessment of the latter would depend on the local hydrology, including the stratigraphy and incline of the basal Parkstone Clay layer.

The letter expresses particular concern is expressed at felling in the south-western corner of St Catherine's Hill where there is older closed canopy pine woodland and the land drains to housing around Sandy Lane which may be at risk from the resulting runoff. The report continues 'There are two main threats. The first is the likelihood of greater surface runoff in response to periods of very heavy rainfall, this area appears to be prone to such events, linked to flow down the track and path. The second threat would be from increased flow/seepage of shallow groundwater along geological boundaries and in particular from existing springs so increasing the period of soil wetness around housing and possibly lead to more ponding/waterlogging'.

The letter indicates that 'As a general guide, the research literature suggests that if the scale of felling is less than10-20% of a catchment, then the effect on runoff is likely to be small and difficult to detect.

Recommendations are made to control the threat of increased runoff by regular maintenance and modification of existing drains at the main seepage points at the clay junction, also to trace and assess the condition of the main drainage pipe that is thought to take drainage from the principal spring and lead it underneath adjacent housing, possibly to the road drainage network. Another suggested countermeasure is to install shallow catch/interception drains down the main path/track to intercept any flows and divert these to side areas of vegetated ground and so reduce the speed of runoff and reduce erosion risk although the water may still pose a problem by enhancing shallow groundwater flows at the base of the hill.

3.9 OBSERVATIONS AND THOUGHTS FROM SITE VISITS

3.9.1 Quarry

The main quarry has been excavated into the Terrace Gravel deposits, presumably to extract the flint gravel. Sections in the quarry sides show areas of flint gravel, bedded coarse gravels and also seams of pale coloured pipe clay.

A feature of the quarry is a surface water pool (**Figure 11**) and which had signs of having had higher levels in the winter. We speculate that this water represents a location where the quarry base is located below the surface level of perched water retained either above a thick pipe clay seam or above the less permeable Branksome Sand, either situation could cause impedance of drainage water downwards resulting in a pool.

Bodies of open water tend to accumulate fine materials (silt and clay) on their pond floors. This has a sealing effect and can prevent downward percolation of water prolonging the life of surface pools.

3.9.2 Wet heath

Areas of wet heathland occur in several locations associated with valley sides, re-entrant valleys and low-ways with vegetation typical of acidic wetlands, including moor-grass, cross-leaved heath and, in places, *Sphagnum* bog-mosses and mire vegetation.

Wet heath is a community that develops on land subject to seasonal wetness usually through springs and seepages. The wetness is sufficient to support wet heathland vegetation including some *Sphagnum* bog mosses, but is insufficient to allow a build-up of peat deposits. Accumulation of organic matter during the winter and spring is generally lost by oxidation during the summer and autumn.

The origin of these areas appears to vary and could arise where springs and seepages occur through the following mechanisms:

- where downward drainage is impeded by less permeable layers within the Terrace Gravels,
- where downward drainage is impeded by less permeable layers within the Branksome Sand,
- where the Parkstone Clay is at shallow depth below the ground surface,
- where pore water pressure from areas of high groundwater causes water to emerge onto hillsides,
- where they have been historic mineral extractions.

The wet heath areas tend to be on gently sloping land and are likely to be supported partly by:

1. lateral seepage through the gravels,
2. high perched groundwater flowing through the Branksome Sand above sandstone layers or above the Parkstone Clay, and partly by
3. banks/excavations down slope which retain surface water against downward flow.

3.9.3 Surface erosion on slopes with heathland

We noted that on the break of slope just below the summit (close to a water company block structure or old water tank and a concrete platform) there was an area of exposed sand and gravel where rainfall appeared to have washed out the sand leaving flints at the surface. We speculate that while normal rainfall will vertically infiltrate the gravels directly and contribute to perched groundwaters within the Branksome Sands and above the Parkstone Clay, water falling during periods of higher intensity rainfall (such that the surface gravel soil layers are saturated) will escape as downslope surface flow.

Site observations of the exposed gravels suggests that surface water escapes down gradient in a meandering fashion passing between established clumps of heather and then reforming into distinct runnels of exposed gravelly substrate extending to about half way down the slope. At this point the heather forms a more continuous cover and water finally percolates into the ground preventing any further surface erosion.

3.9.4 Observations on the trees

While on site we noted that:

1. many of the pine trees on slopes were leaning back towards the slope,
2. many pines on higher lesser slopes appeared to be growing out of soil small mounds,

3. in the gravel areas, exposed flint gravel occurred on the downslope side of many of the tree stems,
4. many of the trees on the slopes had accumulations of soil and litter on the upside of the stem and had eroded soils on the downslope side.
5. the pine canopy was often very sparse (perhaps the result of poor growth resulting from droughty nutrient poor soils) allowing a high proportion of incident rainfall to directly reach the ground.

Water flows and surface erosion

It appears that light or moderate rain, falling through the sparse tree canopy, would first rebound against a carpet of the previous year's leaf fall (litter) absorbing impact forces and then soak into the litter layer. Some water would be retained within the litter, some would pass down into the underlying soil, and some would evaporate back into the atmosphere.

Fig. 15 Pine tree on mound possibly indicative of past surface erosion

Water reaching into the soil (especially spring and early summer) would be extracted by roots, passed up through the tree stems as transpiration flow and ultimately lost to the atmosphere by evaporation from the living needle surfaces (evapo-transpiration).

Fig. 16 Leaning pine trees

Heavy rain fall would result in rapid saturation of surface soil layers and cause water to move sideways by surface flow, especially on slopes. Given sufficiently heavy rain, sheet flow would result in the washing away of the leaf litter leaving the bare mineral soil liable to erosion. This process would explain why some trees, especially on the gravels, appeared to be grow out of small mounds about 10-25cm high, the surrounding soil having been washed away leaving a lowered land surface (**Figure 15**). Very often these small mounds would have flint accumulations on their downslope sides and we suggest that this results from water running down the tree stems (stemflow), exposing the gravel deposits and washing out of the flint stones from the adjacent soils.

Fig. 17 Exposed gravel and short erosive runnels on slopes with heather

We observed that (close to the old rectangular reservoir) the gravel soils lacked topsoil and that water runnels had developed running down slope and passing between heather plants. It appeared that sheet wash was being partly impeded by the heather plants and which partly concentrated the flows into bare flinty runnels (**Figure 17**). About half way downslope, these runnels ceased and we conclude that flow having lessened, that water could now percolate directly into the ground.

Downward washing of pine needles was observed along some re-entrant small valley/gully systems resulting in downslope accumulation of needles where water flows would be concentrated.

Effect of trees

We are concerned that loss of soil from around the downslope side of roots is leading to instability of the trees and making them liable to windthrow.

We also surmise that the leaning of many trees back towards the upper slopes (**Figure 16**), may be the result of the sheer weight of the maturing trees acting on the slopes. This may cause sheering of the soil in the shallow root zone pushing the tree root systems down slope a short distance resulting in the backward lean of the trees (perhaps enhanced by windthrow given a weakened root system). This could also be the result of pore-water pressure on slopes or a combination of factors.

Given this scenario, the maturing trees could (we speculate) be slowly moving soil material en-mass down slope and loosening the soil at the same time leaving the soil open to further erosion and trees further exposed to windthrow. As the trees become larger and heavier, the effect would likely increase and lead to enhanced risk of tree fall.

3.10 VEGETATION

A vegetation survey has been undertaken by R M Walls and J D Crew during February 2010 (**Figure 18**). Area 3 of that survey is of land owned by Christchurch Borough Council.

Key matters from the survey relevant to this study are:

Change

The predominant change over the years has been encroachment of pine and rhododendron onto the heathland. This has been actively tackled from the summer of 1999. Whilst there was good heathland regeneration on older areas, more recent clearances had little vegetation at the time of the survey.

Soils

The soils are mainly podzols supported by the sands of the Bracklesham Beds (Eocene) or thin peats in the wetter hollows. There are lenses of clay evident from the seepage lines. In the past the heath would have been grazed and used for gathering firewood. The current management is designed to optimise the conservation interest of the heathland, mire and associated wooded habitats.

Woodlands

The woodlands are all of recent origin, having developed over the last fifty to a hundred years from a few older trees on the heathland. Two exotic species responsible for the poor understorey in the woodland and loss of heathland are rhododendron and strawberry tree.

The wooded areas of Town Common are so recent that they have not developed the structure or ground flora that typifies established woodlands. The original generation of trees is still actively growing and due to the lack of gaps in the canopy from fallen trees the only substantial regeneration is on the open heathland.

The woodland habitats are summarised as follows:

W4 *Betula pubescens-Molinia caerulea* woodland
These are stands of recent woodland in damp patches where sallow (*Salix cinerea*) is common and purple moorgrass (*Molinia caerulea*) is sparse.

W16 *Quercus-Betula-Deschampsia flexuosa* woodland
Most of the woodland is a mixture of maritime pine and Scots pine - *P.pinaster* and *P.sylvestris,* maritime pine, being the dominant on St.Catherine's Hill and appears self-sown. Some stands are of a uniform age, whilst others contain a number of older trees. There are few trees visible in aerial photographs from 1960 except near the quarry and immediately north of the housing estate, confirming that the trees are very unlikely to be older than 60 years.

Where there is an understorey, it is often bracken or rhododendron, with very few other vascular plants or bryophytes. The poor diversity is usual in such recently established coniferous woodland. In places birch can be common and a few other deciduous species are patchily present.

<u>Heathlands</u>

The dry heathlands are Biodiversity Priority Habitats (lowland heathland) and are included in Annexe 1 as European dry heaths.

H2 *Calluna-Ulex minor* heath
Present throughout the area, except where there is extensive tree cover, is a species poor, dry heathland community.

H3a *Calluna-Agrostis curtisii* heath
Some of the heathland intermediate between the wet and dry would seem to fit better here than in H2.

Rhododendron *Rhododendron ponticum* stands
Dense stands of rhododendron. Substantial stands are present on some of the boundaries with negligible tree cover and over large areas of the woodland.

<u>Mires</u>

Wet heaths referable to M16 are classified as Biodiversity Priority Habitats (lowland heathland)

M1 and M2 *Sphagnum auriculatum* and *Sphagnum cuspidatum/recurvum* bog pool communities
The pools on the heathland are too impoverished to be reliably assigned to the correct community.

M3 *Eriophorum angustifolium* bog pool community
There are places where cotton grass is sufficiently dominant that it should be placed in this community.

M16a *Erica tetralix* wet heath, typical subcommunity

There is often, but not always, a sharp distinction between the H2 dry heath and a cross-leaved heath (*E.tetralix*) dominated community on a substrate of white sand thinly overlain by humus. The vegetation is dry for much of the year, but the water table is never too far below the surface. There are varying amounts of *Molinia* amongst the heather and the stands are species poor, probably as a result of fires. Most worrying is the absence of *Sphagnum* in some areas and these stands must be near the humidity limit of this community and are intermediate with H3 heaths.

M25 *Molinia caerulea-Potentilla erecta* mire
Tussocky *Molinia* occurs in a few very small areas as a near monoculture.

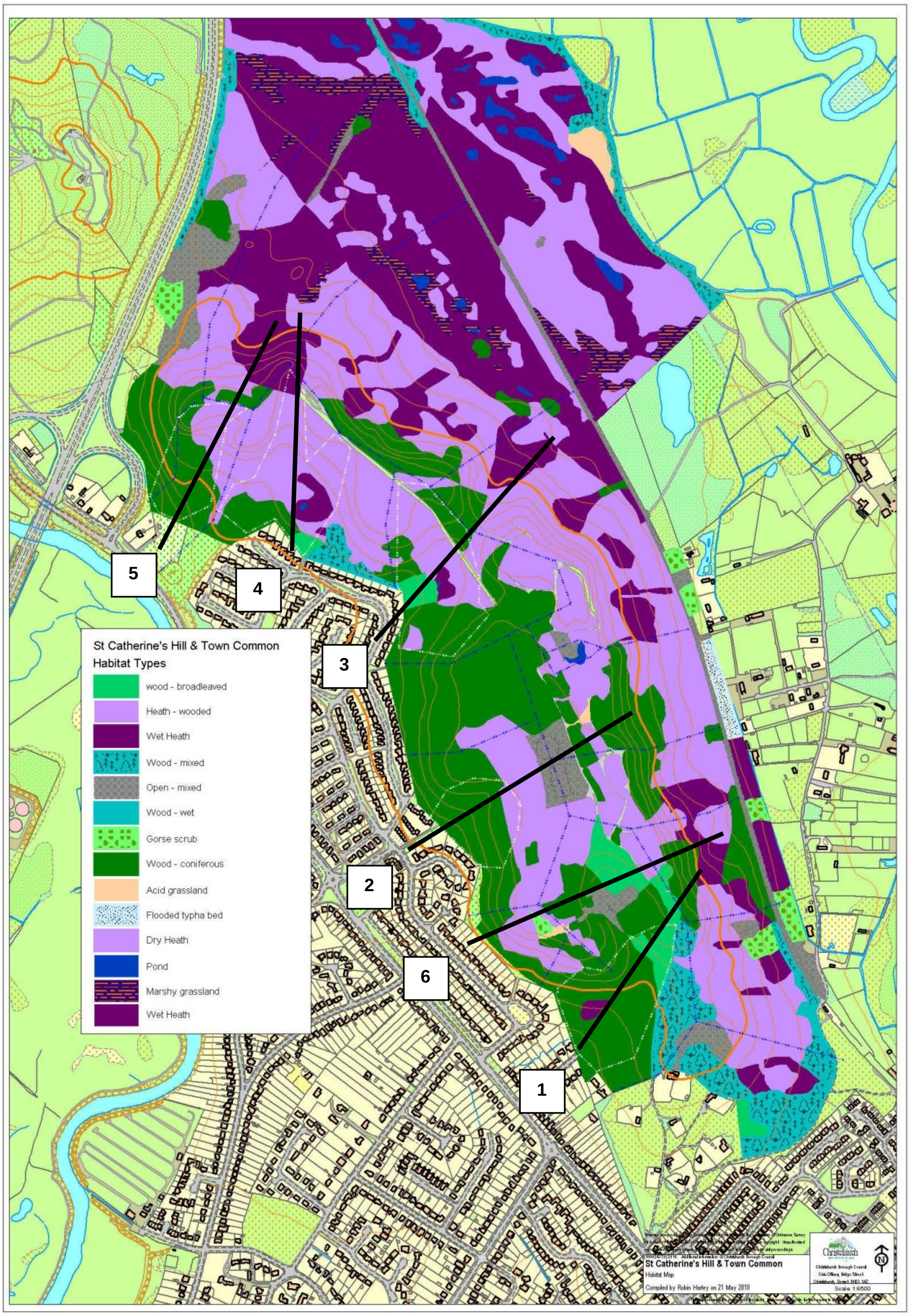

Fig. 18 Habitat types, also showing catchment boundaries and section lines (Plan from Christchurch Borough Council)

4.0 THE STUDY AREAS

4.1 THE STUDY AREAS

Following discussions with Robin Harley, it was decided to examine a number of focus areas representative of different parts of the site in order to assess a range of site conditions. These focus areas are shown in **Figure 19**.

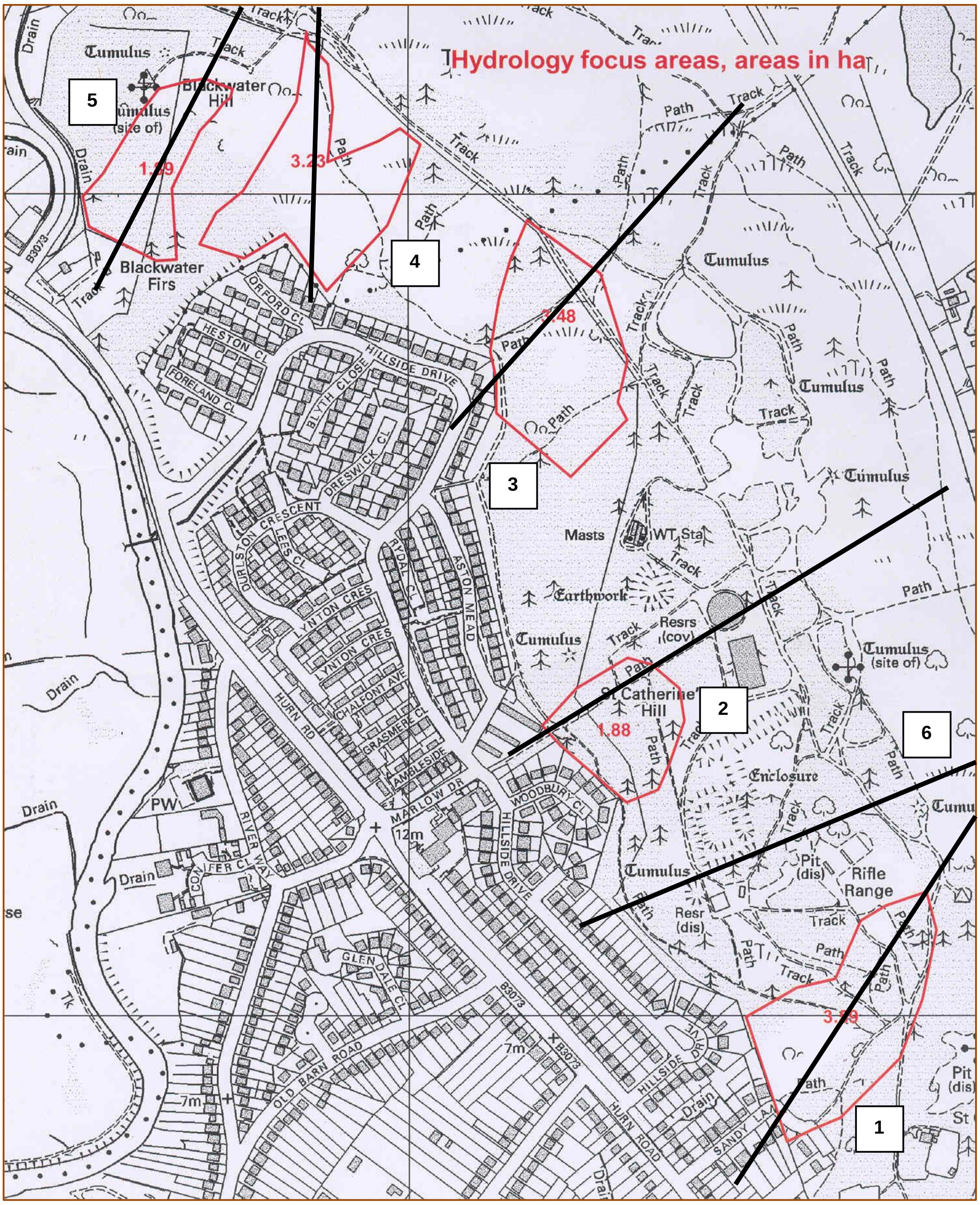

Fig. 19 Study focus areas, also showing lines of section
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4.2 AREA 1

This area in the southern part of the site opposite Sandy Lane (**Figure 20**) occupies a broad valley feature and has a large area of open coniferous woodland with an often dense broadleaved understorey on gentle slopes and with some pure pine woodland on smaller areas of steeper slopes. The pure pine woodland has only a sparse layer of bracken and some trees are seen to lean towards the valley side and have soil accumulation and erosion above and below the tree stems.

There is an area of wet heathland on the lower valley side and which may reflect the proximity of the Parkstone Clay at shallow depth.

This area is wholly on the Branksome Sands although the lowermost margin, where it abuts housing is close to the boundary with the Parkstone Clay.

The dip on the surface of the Parkstone Clay is 1.8 degrees to the south west.

See **Cross Section 1.**

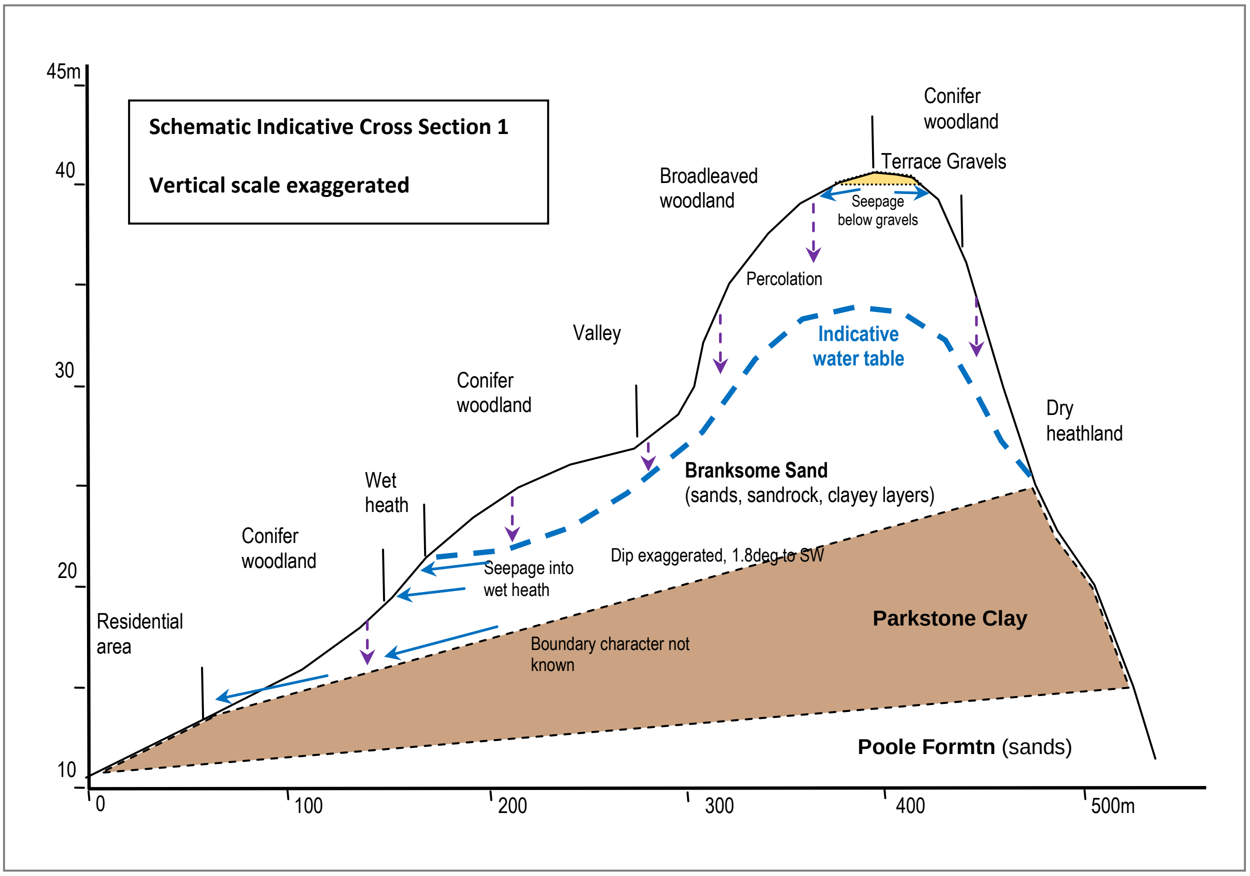


Fig. 20 Study area 1

Top left:	**Deciduous understorey to pine woodland**
Top right:	**Accumulation above and erosion below a leaning pine tree on upper slopes**
Bottom left:	**The area of wet heath**
Bottom right:	**Open canopy to pine woodland.**

4.3 AREA 2

This area (**Figure 21**) is approached via the track from the top of Marlow Drive and comprises a valley feature cut into the hillside with moderately sloping valley sides covered in pine woodland with only a sparse layer of bracken below. Many of the pines have a distinct lean towards the hillside with the typical signs of soil accumulation and erosion above and below the tree stems. The pine canopy is also very open and the branches only poorly leafed.

Higher land to the northwest has been cleared of trees and now comprises heathland with a mix of age classes and containing many areas of bare ground between heather plants.

The site is traversed up the slope by a track with concrete cross supports leading up to the Water Company reservoirs. It is likely that this track conceals pipes and which could be in a permeable bed.

Running broadly parallel to the contours on the lower slopes is a historic bank and ditch. Parallel to the valley feature is a pronounced gully.

This valley feature has been cut into the junction of the Terrace Gravels and the underlying Branksome Sands such that the upper slopes are on the gravels and the valley bottom and lower slopes are on the sands.

The dip on the surface of the Parkstone Clay is 0.9 degrees to the east.

See **Cross Section 2.**

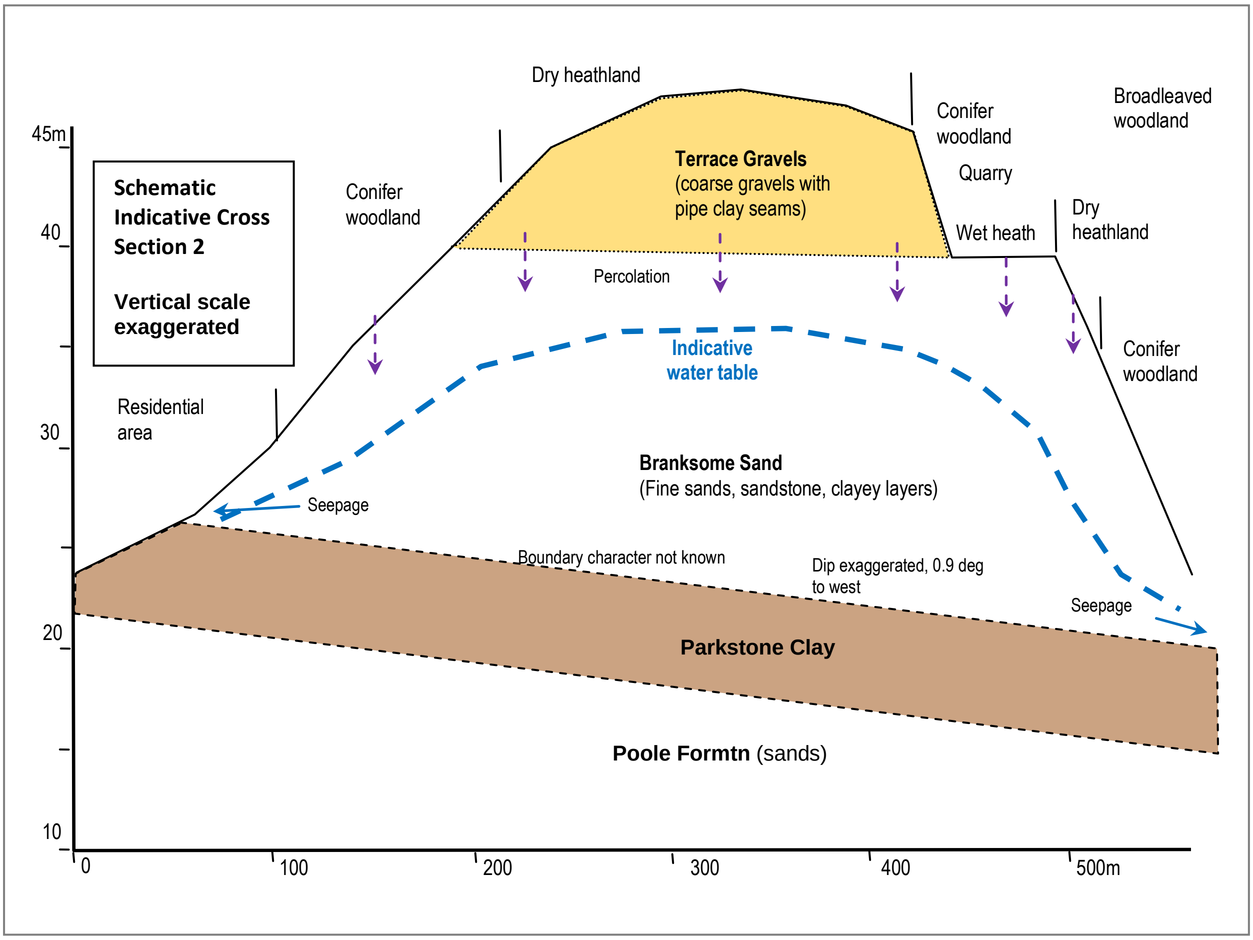


Fig. 21 Study area 2

Top left:	**Consistent slope to pine trees on slope**
Top right:	**Historic bank passing through pine woodland**
Middle left:	**Open canopy and spindly poorly leafed branches of pine woodland**
Middle right:	**Accumulation above and erosion below pine stem**
Lower right:	**Recently established heathland showing areas of open soil between heather plants.**

4.4 AREA 3

This is a complex topographic area sitting below the saddle in the ridge top. The landform is a broad valley form rising to the ridge top and comprises steeper slopes to the edges and lesser slopes within the valley.

Fig. 22 Pond and wet heath in study area 3

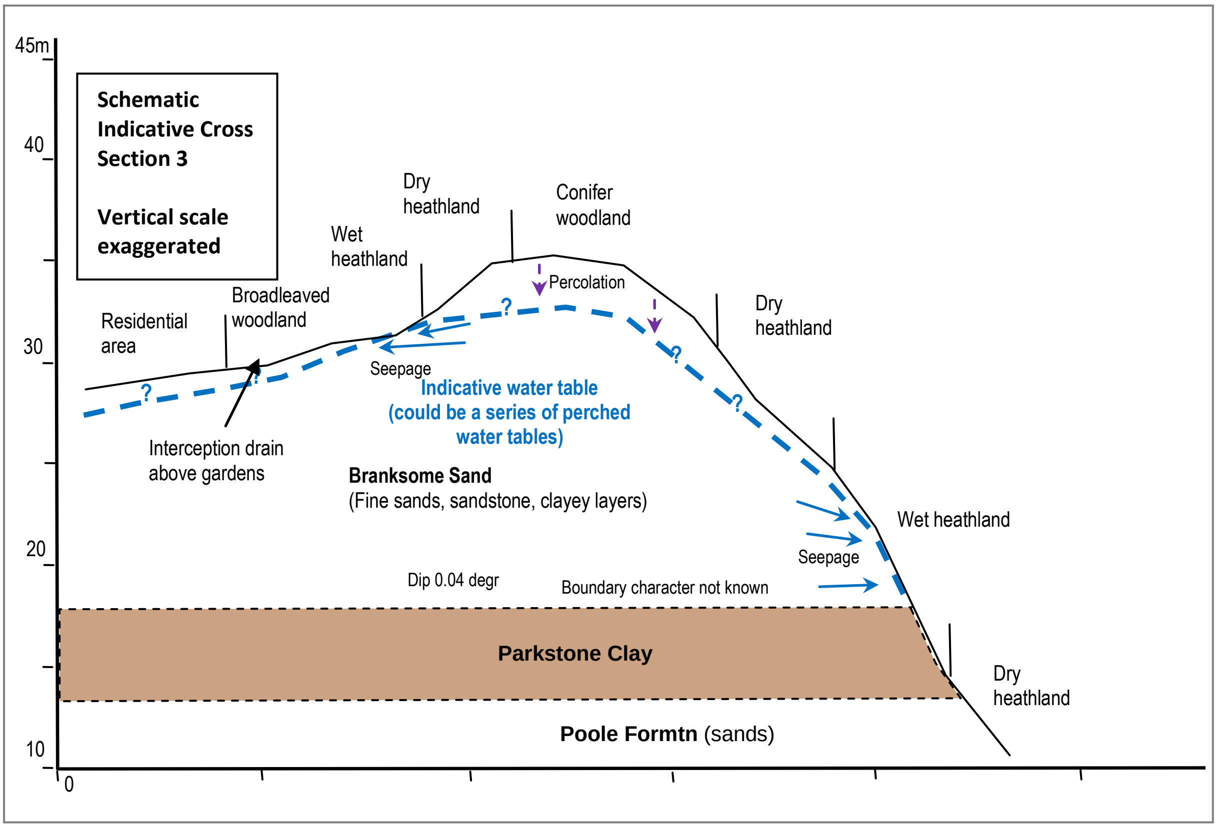
Parts of the slopes are covered in pine woodland and there is an area of wet heath / mire in the valley bottom. A pond has been cut into the wet heath area which was muddy at the time of the visit but appeared to have held water earlier (**Figure 22)**.

Upper slopes have been felled of trees and comprise areas of open mature dry heathland.

The land is almost wholly on the Branksome Sand with higher margins on the Terrace Gravels.

Dip on the upper surface of the Parkstone Clay is 0.04 degrees to the northwest (almost horizontal).

See **Cross Section 3.**



4.5 AREA 4

This is a complex area to the north of the Hill north of Orford Close and comprises a valley system with two valley heads re-entrant into the valley side.

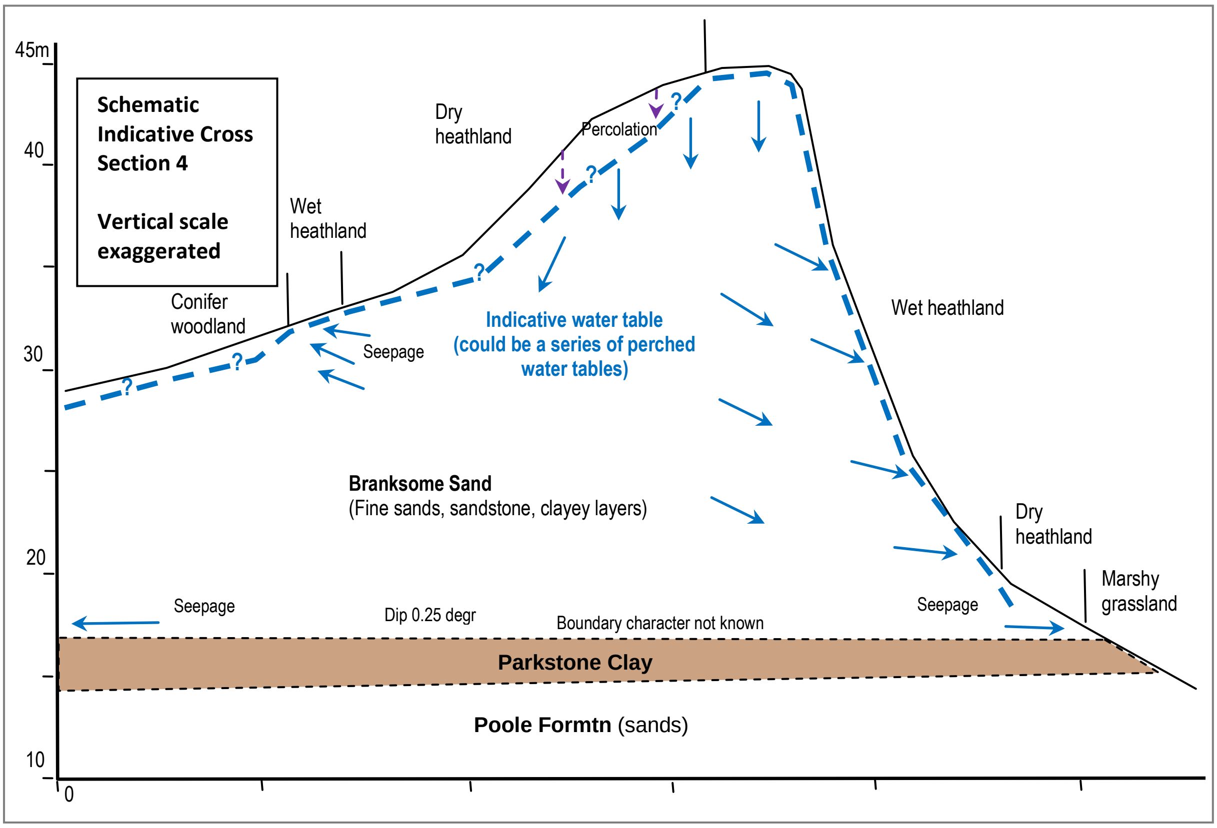
The western valley form arises high off the ridge top and a seasonal watercourse runs south down the valley to enter a very deep steep sided valley in the south. This area has been cleared of one time extensive rhododendron.

The eastern valley arm forms a broad low lying area containing an extensive area of valley mire thought (we speculate) to be supported by water seeping off the upslope gravels and retained in the valley by less permeable layers within the Branksome Sands. Much of the site is open heathland or wet heathland. Such woodland as is present is a mixture of pine and birch with some sallow below the wet heathland area.

This area is wholly on the Branksome Sands and the watercourses and wet heath habitats perhaps reflect variability in the permeability and water table within the sands.

Dip on the upper surface of the Parkstone Clay is 0.25 degrees.

See **Cross Section 4**.



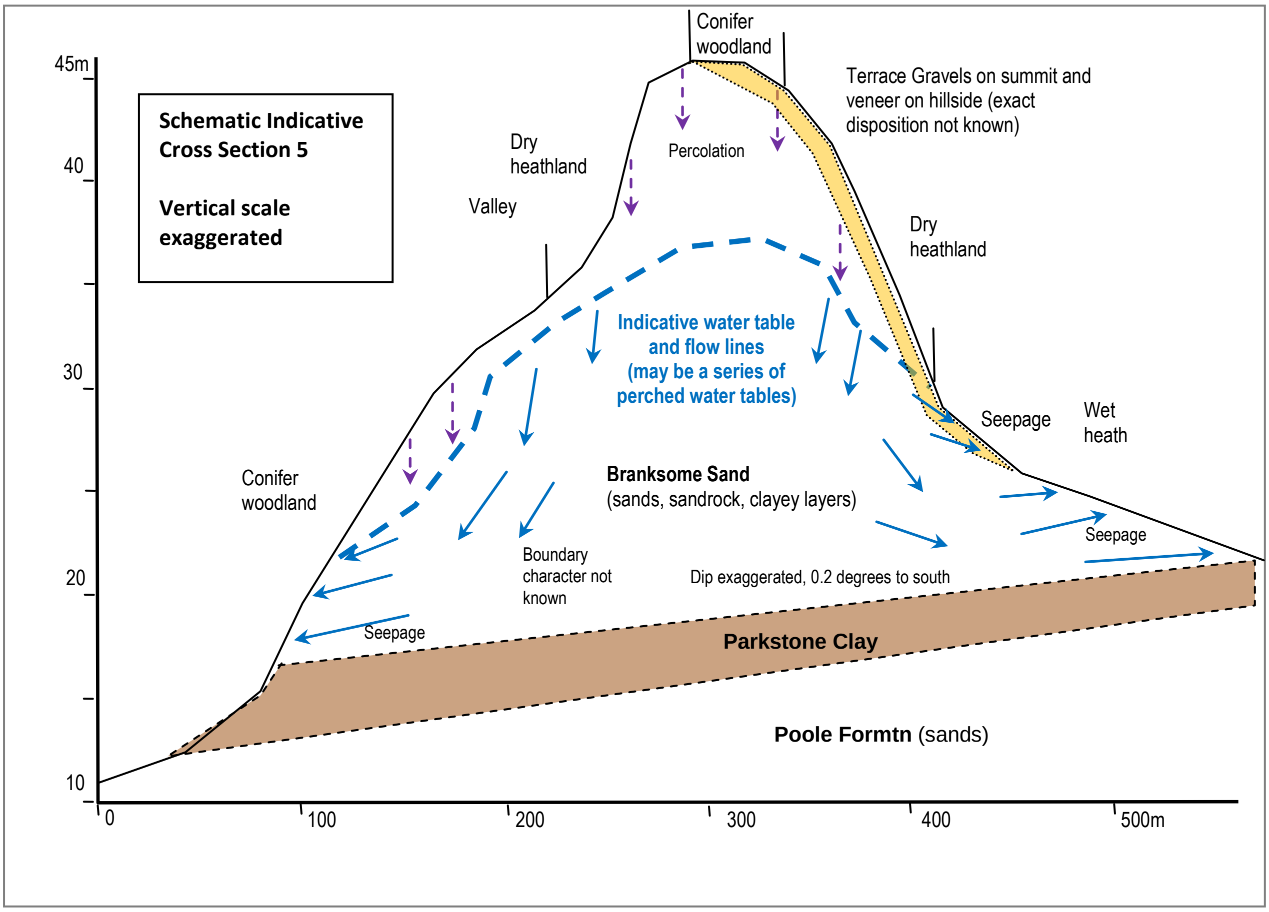
4.6 AREA 5

This is a smaller area in the north of the Hill and comprises the upper part of a valley feature with open heathland and scattered pines on slopes and areas of heathland and with some humid or wet heath in the valley bottom. Steeper slopes in the southwest have tall pine woodland.

The study site is mostly on the Branksome Sands but extends north onto the terrace gravels and south just onto the Parkstone Clay; the cross section taken through the study area has been extended to take in both sides of the hill and including the Parkstone Clay and the gravel outcrops.

See **Cross Section 5**.

Dip on the surface of Parkstone Clay is 0.2 degrees to south (almost horizontal).



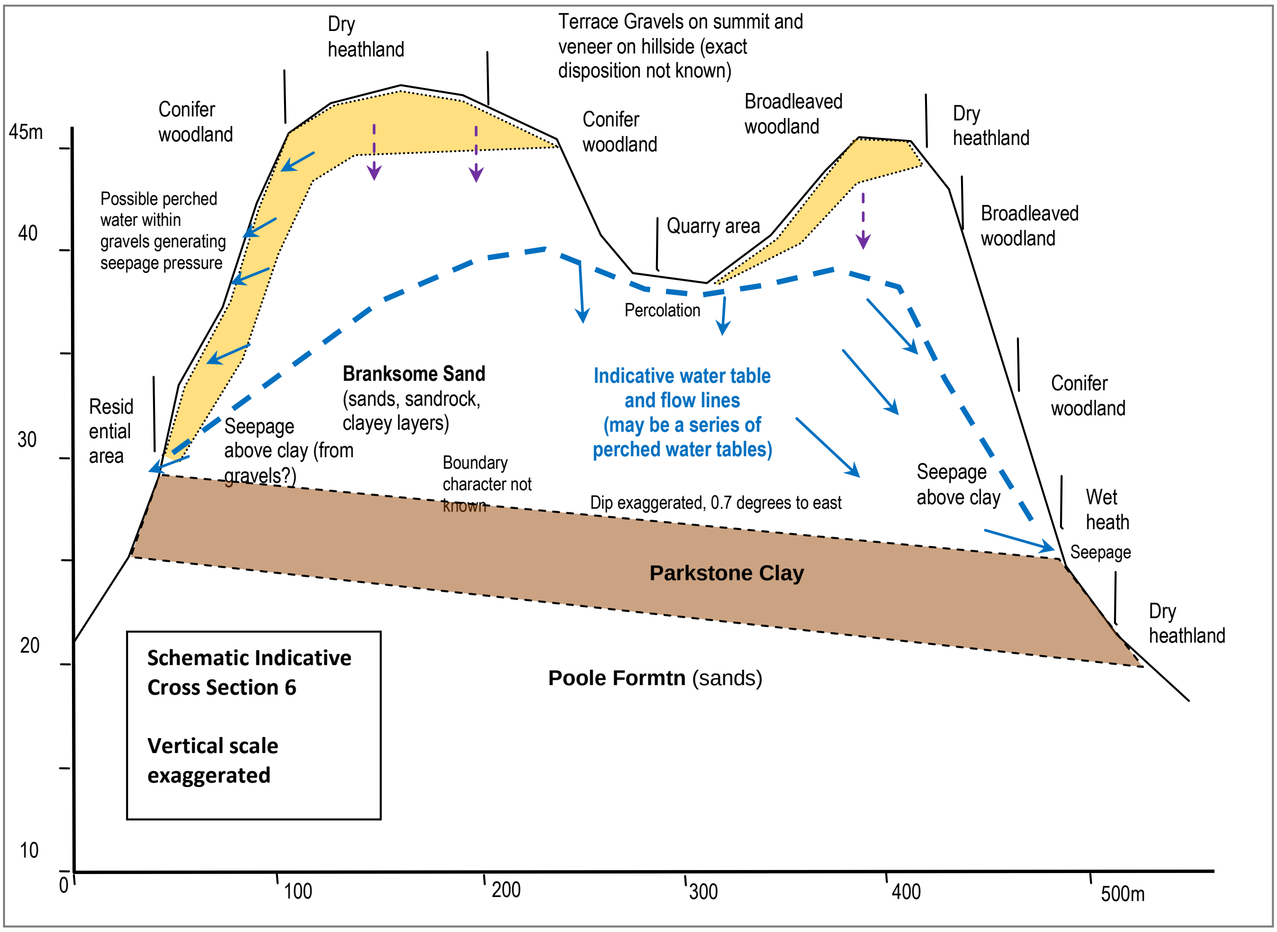
4.7 Area 6

This a further area examined where the Gravels extend down the west facing slope underlain by the Branksome Sand and butting onto the Parkstone Clay in the based adjacent to residential area. The geological map shows a wide spread of gravels here and which we assume comprises a thin spread downslope.

This is the area below the water company old reservoir showing erosion of the gravels and rill formation downslope between heather bushes and also where the ground surface appeared to have lowered between pine trees.

Dip on the Parkstone Clay is 0.7 degrees to the east

See **Cross Section 6**.



5.0 DATA ANALYSIS AND CONCLUSIONS

5.1 STUDY METHODOLOGY

5.1.1 Flooding and slope stability

It has been assumed in the study that flooding and slope instability problems arise as a result of water flows from two separate and different water flow conditions:

1. from above ground, surface water flows; and
2. below ground, sub-surface flows.

5.1.2 Flooding

The impact of flooding would arise as a result of:

- surface water flow with the worst case being under extreme storm conditions and when impacts are generally immediate.
- sub-surface flows that occur with the increase of water percolating into the ground, raising the phreatic (underground) water levels within the ground mass. These flows result in seepage at lower levels (generally at the interface between low permeable substrates e.g. between clays and overlying substrates with greater permeability e.g. gravels/sands). This seepage tends to occur over a much longer time scale and is less affected by "peaky" severe storm conditions than from increases in precipitation over a longer time period (e.g. a particularly wet year).

5.1.3 Slope Stability

It is assumed for the purposes of this study that without any impacts of water the ground slopes are stable. We have not taken into account any long term impacts of increased public use or extreme weather conditions such as ice/frost action.

Slope instability could result from:

- surface water flows following extreme storm conditions eroding ground surfaces, washing sand/gravel down to lower levels. Heavy rainfall falling from a great height and often under additional pressure from the wind builds up energies which have a great potential to disrupt the integrity of soil slopes. In addition heavy concentrated flows tend to form drainage channels within the soil surface which over time get deeper and wider accelerating erosion of the upper layers of the soil mass.

- increased percolation into the ground, raising phreatic water levels and increasing ground water flows. Particularly within sands and gravels these can create lateral pressures within the ground mass resulting in instability of embankment slopes. (Permeability along a bedding plane within a soil mass can be greater than permeability at right angles to the bedding plane).

- ground water seepage, particularly above a relatively impervious stratum. In this case significant (normally horizontal) associated seepage forces can occur which can cause instability in overlying strata.

5.1.4 Quantification of surface water flows

The 'rational method' (Land Drainage Design, Smedema and Ryecroft, Batscroft 1988) has been used to assess maximum peak flows under extreme storm conditions for various topography, soil and ground cover regimes. The catchment is divided into individual elements with differing topography or soil or ground vegetation cover descriptors.

Flow calculation have been carried out for each of these elements and then aggregated to get a total peak flow for the study area catchment as a whole.

By changing the descriptors for ground cover for any element (or elements) for example replacing woodland with heathland, relative differences in peak flow for the whole catchment can be recalculated. By this method differences in peak flow flooding under different ground cover criteria are identified.

For the purposes of this study the following conditions have been assessed:

- existing conditions
- conditions with the removal of all woodland and gorse scrub and their replacement with heather heath
- conditions with the removal of woodland and gorse scrub over 50% of the study catchment area and their replacement with heather heath. In most study areas this could be assumed to relate to woodland in the higher reaches of the catchment area.

(The Peak flow (Qp) is calculated from the formula Qp = CIA/360 cum/sec, where C is the discharge coefficient (descriptor) based on data supplied by US Soil Conservation Service for varying topography, soil and plant cover conditions. I is the average rainfall intensity over the time of concentration Tc and Tc =L/V where L is the length of flow and V is the flow velocity. For this study a 40mm/hr rainfall condition has been used. A is the area of the catchment/study area. The values used for C and V for various ground and ground cover conditions have been taken from LAND DRAINAGE by Lambert Smedema and David Ryecroft published by Batsford).

5.1.5 Quantification of water flowing into the ground to contribute to ground water flows

An average annual rainfall of 855mm has been taken as the basis of this analysis. This relates to the catchment of the River Stour and has been taken from Flood Estimation Handbook (CEH Institute of Hydrology).

A detailed quantification of the water that actually flows into the ground in an average year would be difficult to achieve without extensive field testing and this is outside the scope of this study.

Therefore, a broad based pragmatic approach has been taken. It is assumed that any rainwater that does not flow as surface water flow is either water that is taken up by transpiration and interception by ground cover trees/plants, or water that percolates into the ground. Equating storm water conditions with annual average rainfall conditions although not strictly correct, for the purposes of a general comparative study of volumes of water entering the ground under differing ground cover criteria is considered a reasonable assumption for this study.

Water entering the ground over an average year is therefore taken as the residual amount of water from the total rainfall that does not contribute to the surface water flow (1-C x total rainfall) less the annual evaporation losses for each of the varying ground cover conditions. The data figures for the latter have been taken from Forestry Commission Information Note: Water Used by Trees. Figures at the low end of the band have been taken on the basis that, at St Catherine's Hill, trees and other ground cover plants tend to be less closely packed together than in some managed woodlands and heathland areas.

Again, as for the surface water flow analysis, the following conditions have been assessed for each study area:

- existing conditions
- conditions with the removal of all woodland and gorse scrub and their replacement with heather heath

- conditions with the removal of woodland and gorse scrub over 50% of the study catchment area and their replacement with heather heath. In most study areas this could be assumed to relate to woodland in the higher reaches of the catchment area.

Although this analysis does not provided definitive volumes of groundwater that result in seepage flows or definitive rises and falls in ground water levels, it does give relative differences in rainwater volumes entering the ground under differing ground cover criteria on an annual basis. Short term high flows such as after storms are more likely to cause surface erosion, while longer periods of more gentle rain are more likely to contribute to groundwater flows.

While this data should be treated with a high degree of caution, it does provide pointers to the relative impacts on ground water conditions with changes in ground cover regimes. This in turn gives pointers to where and to what degree seepage and other potential ground stability issues might change.

5. 2 CONCLUSIONS IN RELATION TO STUDY AREAS

The analysis undertaken does not allow for any mitigation having been provided.

Study Area 1 represents a valley catchment with a relatively shallow gradient, much of which is covered by woodland.

With the removal of all trees and their replacement with heathland, surface runoff could double and water percolating into the ground increased by 40%.

With the removal of trees on the upper reaches of the catchment (stands 109,110, 228 and 228a) there would be a 36% increase in surface runoff but little increase in water percolating into the ground.

Recommendation:
Consider creating heath on stands 109,110,228 and 228a together with a widening of the wet heathland area if possible (stand 231e) to create improved storage for surface water attenuation.

Study Area 2 represents a steep valley catchment the majority of which is covered with woodland but has a heathland area at the valley head.

With the removal of all trees and their replacement with heathland, surface runoff could more than double and water percolating into the ground increased by 46%.

With the removal of trees above the 40m contour level, there would be a 17% increase in surface runoff and a similar increase in water percolating into the ground.

Recommendation:
This area needs careful consideration as to the likely effects and special consideration given to the creation of wood heath (open woodland with a heathy floor) and the use of an interception ditch along the pre-existing bank.

Study Area 3 represents a relatively flat valley area sloping down from a “saddle” break in the ridge line of St Catherine's Hill. Within the study area there is a significant area of mire and wet heathland. Present tree cover is restricted to the lower strip of the catchment area and to the valley slope on its south side.

With the removal of all trees and their replacement with heathland, surface runoff could increase by 44% and water percolating into the ground increased by nearly 80%.

A thinning out of the present woodland cover by 50%, particularly away from residential areas (leaving woodland along the residential edge in place), provides opportunities for opening up the woodland for some heathland habitats (up to 50%) concentrating on the valley side within the tree areas. By doing this there would be a 16% increase in surface runoff but only a 10% increase in water percolating into the ground. This means that there would be an increased risk of surface erosion during the heathland establishment phase which would require mitigation. The increased percolation is relatively small and further ditching along the residential boundary or around the wet heath may be required to slow down the groundwater flow. Existing ditches to the back of gardens appear to be functioning well and care should be taken to ensure that these are maintained and do not become blocked. A precautionary approach would be to clear only a maximum of 25% of the area, or thinning the trees, initially and monitoring the results.

It is possible that the area of wet heath could absorb some water, although the extent of any such effect remains unknown.

Recommendation:
Consider opportunities for extending the present areas of heathland by thinning out woodland cover. Mitigation of surface water flows could be achieved by creating greater storage/attenuation within or around the mire/wet heath area (stands 308a and 308b). Prevention of surface erosion during heather establishment could be by contour laying of tree stems and spreading of coir sheeting or cut heather stems (brashings).

Study Area 4 represents a catchment with a relatively shallow gradient with significant woodland cover only at the lower end of the study area. The majority of the area is heath.

There is a significant outfall valley downstream of the study area. For the purposes of this study it has been assumed that the valley and its associated conduits is capable of accommodating increased flows from changed ground cover conditions on St Catherine's Hill without affecting residential areas nearby.

With the removal of all trees and their replacement with heath, surface runoff would increase but not significantly - an increase of 11% for runoff and 7% for water percolating into the ground.

A thinning out of the present woodland cover by 50% provides opportunities for opening up the woodland areas for some heathland habitats within tree areas. There would be very small increases of surface runoff and in water percolating into the ground (6% and 4% respectively).

Recommendations:
Consider opportunities for extending the present areas of heath (especially in areas of wet heath) by thinning out woodland cover and directing increased flows along the deep valley leading off site to the west.

Study Area 5 represents a relatively shallow valley catchment but with steeper slopes on its upper and lower reaches. This includes gravel, sand and clay soil and substrate conditions within its area. Woodland cover is on the lower 60% of the area (a significant proportion of the woodland being on clay), heath on the remainder. Surface water from the catchment flows via an outfall valley downstream of the study area. For the purposes of this study it has been assumed that this valley and its associated conduits are capable of accommodating increased flows from changed ground cover conditions on St Catherine's Hill without affecting residential areas nearby.

With the removal of all trees and their replacement with heath, surface runoff would increase by a significant 89% and water percolating into the ground by again a significant 62%.

Alternatively by replacing the woodland above the 25m contour with heather an increase of 18% for runoff and 38% for water percolating into the ground would occur. In this instance, the presence of significant areas of clay within the lower reaches of the catchment would have an influence on the relative difference between these increases.

Recommendations
Consider opportunities for extending the present areas of heath by thinning out woodland cover in the higher areas.

Study Area 6 represents a steep catchment with tall conifer woodland predominantly on gravels in any area where slopes were showing signs of some erosion and possible instability. A ditch system/stream flowed from the catchment which had water flow following an extended dry period.

With the removal of all trees and their replacement with heath, surface runoff would increase by a significant 47% and water percolating into the ground by 22%.

With the removal of trees and replacement with heather only above the 40m contour there would be increase of surface water of 23% and of water percolating into the ground of 5%.

Recommendations
Consider opportunities for thinning out the tall conifers as they mature and replace with saplings with a view to managing the conifer woodland with less tall trees. Also consider the removal of woodland above the 40m contour (upper areas of stand 302 and stand 231b).

5.3 OVERALL CONCLUSIONS

5.3.1 Cautionary Notes

The following sections draw together our conclusions based on our examination and analysis of the study areas.

In the absence of a detailed site investigation (such as using trial pits, boreholes and soil water measurements) we have had to make substantial assumptions and value judgments on critical parts of the jigsaw, especially in relation to the permeability of the various soil conditions and geological materials.

While the following conclusions necessarily remain somewhat tentative, they do give an indication of the risks involved and possible means of mitigation.

5.3.2 Effects on Surface Water and Groundwater

5.3.2.1 Slopes on the Terrace Gravels

The effects of tree removal/heathland restoration on slopes on terrace gravels, which tend to be steeper than those on sand, could lead to a significant increase in both surface water and ground water volumes.

Where these slopes are adjacent to residential properties (for example study areas 2 and 6) these additional flows would impact significantly on residential properties at lower levels. By removing woodland and replacing with heather only above the 40m contour in each of these two study areas these increases in flow are limited to manageable levels. But even then could be as high as up to 23%.

Any tree removal in these areas should be limited to small numbers of trees along edges, thinning, or as small clearings so as to reduce the risks associated with increases in flow.

In order to limit impacts on property, mitigation measures such as cut off ditches and below ground barriers to ground water flows could be installed, but due to limited space this is only really feasible on study area 3. Some such ditches already exist.

In other study areas where there are terraced gravels present but remote from residential properties, the Branksome Sand at lower levels would provide a cushion to these impacts but mitigation measures on similar lines to those described above, but at a lower key, may be necessary.

5.3.2.2 Slopes on Branksome Sands

The effects of tree removal/heathland restoration on slopes on Branksome Sands, such as on study areas 1 and 3, would be increases in surface water and ground water flows but with the slower flow velocities both for surface water and ground water on and through the sands. The sand tends to be at shallower slopes than the terraced gravel and impacts would not be as immediate as for the gravel. Natural features such as the valley mires could well be extended to provide mitigation measures to limit impacts on residential properties.

In study area 1 the effects of removing woodland trees on stands 109, 110, 128 and 128a in the north eastern part of the area (roughly representing 25% of the total area), have been analysed. Surface water flow is increased by 36% but the increase in ground water flow is small. This suggests that cut off ditching could provide adequate mitigation together with an extension of the valley mire to provide attenuation storage for surface water flows and open water evaporation of ground water.

In study area 3 the removal of all woodland above the 35m contour, leaving a significant belt of woodland screening adjacent to the residential area has been analysed. Surface water flows would increase by 16% and ground water by 10% respectively. This would suggest that some cut off ditching may be necessary. But the extending of the valley mire area giving greater attenuation storage for surface and ground water flows would seem to be the most effective and appropriate mitigation measure. These existing wetter areas may extend naturally as a result of felling.

Study area 4 is largely on the Branksome Sand with predominantly heathland cover or at least heath with some isolated trees. There is a belt of woodland immediately adjacent to the residential area and there is a significant outfall valley alongside the houses to take water flows away from the houses and ultimately into the River Stour to the west.

Thinning out the present woodland belt by 50% to provide opportunity for some heathland regeneration within the tree cover (e.g. heathland glades) has been analysed. Increase in surface water and ground water flows are relatively small (6% and 4% respectively) and only limited mitigation measures would be necessary. Cut off ditches along the boundary of the residential area, taking flows directly into the outfall valley would prevent any significant impacts on people's homes. Some such ditches and some older ditches already occur.

5.3.2.3 Areas with mixed geology

Study area 5 extends from terraced gravels through Branksome Sand and onto the Parkstone Clay at lower levels so represents the range of soil conditions on St Catherine's Hill. As in study area 4 there is a significant outfall valley, parallel to that in study area 4 that takes flows away from the main residential area and eventually into the River Stour to the west. The area is at present under woodland cover for much of its middle and lower reaches and its upper reach is of heathland with a thin tree cover.

The impacts of removing tree cover above the 25m contour and replacing with heather cover has been analysed. Increases in surface water and ground water flows are significant under this condition (18% for surface water flow and 54% for ground water). This is largely due to the presence of relatively impermeable clay in a significant area of the study area's lower reaches. At this sand/clay interface the large increase in ground water would show in significant seepage/spring water flow.

Together with the increased surface water flow there would be increases in outfall flow in the valley. But this should not have impacts on residential areas. As mitigation to possible localized flooding within the valley, it may be appropriate to carry out clearance of vegetation in the valley bottom to prevent localised restrictions to flow.

5.3.3 Slope Stability

With the removal of trees and prior to the establishment of heather cover on the Terrace Gravels or Branksome Sand slopes, these slopes would be subject to some increased erosion, the extent of such erosion cannot be quantified in advance but the risk on the gravels may be higher than on the sands.

The slopes on the Terrace Deposits appear to be relatively stable, however there is evidence of surface erosion from the build up above tree stems and erosion below and surface materials get washed into a series of small re-entrant valleys.

It seems likely that where the Terrace Deposits occur on slopes (as opposed to thicker deposits on the summit), they do so as a relative thin cover over the Branksome Sands.

Increased surface and lateral subsurface flows following tree felling could lead to very slow "sheet" slippage with the whole gravel mass potentially gradually and very slowly moving down hill - the steeper the slope the greater the movement. We have seen evidence that downward surface flow of water sinks into the ground on slopes, but we have insufficient information about ground conditions to further appraise the situation. However, this slippage would be a very slow process and may occur over perhaps hundreds rather than tens of years.

The process could be initiated by ground water and surface flow changes consequent upon removal of large areas of trees (although I understand that this has never been proposed). The answer is to remove only small areas of trees at any one time, so restricting the generation of flows, and to monitor the results.

Within the Branksome Sand, the erosion mechanism on bare sloping ground would initially be the establishment of small flow channels which would gradually deepen and widen to form significant drainage channels with the locally concentrated water flows transporting sand downstream to form outfall fans. Given time, especially if heather establishment was poor, erosion could result in slight lowering of the land surface by continued small scale surface erosion.

A possible mitigation measure in order to provide temporary protection would be to lay the stems of trees cut down, or bundles of their branches, parallel to the contours of the slope in staggered rows to dam and slow down surface water flows. In addition, bio-degradable protective matting could provide further protection.

At the interface of the Branksome Sand/Parkstone Clay interface (which for study areas 1, 2 and 6 lies close to the boundary of the residential area and St Catherine's Hill), there is risk of increased seepage and spring water flow. For study areas 1 and 6 this is small (5%) but for study area 2 is more significant at 16%. Increase in seepage flow could create pressures that gradually wash out the overlying sand causing slow slippage in the sand embankment. Measures to mitigate groundwater flows such as cut off ditches further up the catchment might be considered. Should trees be removed, they should be done so in small areas or groups, rapid heather cover encouraged, and the situation monitored.

We have compared the situation at St Catherine's Hill with those of the coastal landslide areas at Highcliffe and Naish Farm on the coast and have been provided with information by M C Hinton at Christchurch Borough Council. The cliffs here comprise Barton Clay overlain by water bearing Barton Sand and in turn by gravels. Landslipping here is caused by external factors: undermining of the cliff by wave action, over steepening of the cliff by wave action, unloading of the cliff by removal of debris from the cliff toe and lowering of beach levels together with internal factors of: weathering, stress relief and swelling, strain softening, groundwater level changes and shrinkage. This process results in the breaking away of the cliff and slumping in a rotational fashion.

Further detailed information on coastal landslipping can be found on: http://www.soton.ac.uk/~imw/barteros.htm.

The coastal situation is very different to that at St Catherine's Hill where the slopes are not being undermined by wave action.

The conditions under which serious land slippage could occur at St Catherine's Hill would only arise if there were large increases in ground water flow near to the Parkstone Clay layer such as by large scale felling and removing all trees on lower slopes. Restricting felling to higher areas and to small areas only, coupled with monitoring, would prevent any such effects.

The conditions und which serious surface erosion could occur would be if large areas of felling were undertaken by machine and which could lead to adverse effects from soil compaction and rutting in some places and loosening in others.

It seems very likely that the slopes at St Catherine's Hill have had ample time to stabilize since the end of the last ice and especially since the likely establishment of heathland vegetation between the Neolithic and Bronze Age periods and therefore it is most unlikely that any catastrophic events would occur.

During our site visits we have seen no evidence of slope instability. Removal of trees would restore the previous heathland condition which we assume was present prior to the growth of the present trees over the last 100 years.

5.3.4 Effects of the trees

We are concerned that many of the trees on the slope exhibit signs of instability. Many have their stems leaning back towards the slope with areas of soil deposition around the upper sides of the stem bases and areas of erosion around the lower sides of the stem bases.

The reason for this remains wholly speculative. It could be that groundwater pore pressure is causing downward movement of soils in these layers which, coupled with erosion and the also the effects of predominantly westerly winds, could be causing the trees to lean back. The presence of soil accumulation behind the trees suggests that there may have been sheet erosion in the past, perhaps following heavy storms. This process could also lead to the lowering of soil levels down slope of the trees.

In addition to (or perhaps distinct to this effect), the very weight of the trees themselves could cause the trees and their immediate soils and substrates to move downslope. This effect could increase as the trees increase in weight. The amount of lean could also become enhanced as the trees gain height and their centre of gravity and weight distribution changes.

We recommend that further investigation be taken of this characteristic. If these trees are found to unstable and a danger to the public, removal of the more critical trees could result in small areas of heathland establishment within the pine woodland areas. Given small areas, the resulting changes to surface and ground water flow would be small.

5.3.5 Managing the risks

We recommend that any tree felling on steep west facing slopes, should, at least initially, be as small scale trials on the summit and upper slopes so as to reduce risks of enhanced surface and ground water flows and so reduce the risk of surface erosion and any ground instability. First phase felling should be restricted to five or six areas in the more hydrologically sensitive sub-catchments. In addition, larger areas could be considered on the plateau areas and areas where excess water can be directed away from housing such as through the deep valleys in the north.

We do not recommend that large areas of trees should be felled at any one time, rather small areas of trees would be removed and allowed to develop heathland cover before further felling was initiated. This would also give information about the rate that the heathland would recover after felling. More rapid encouragement of heathland could be encouraged by seeding with heathland propagules and/or spreading heather cuttings (brashings) rather than simple natural regeneration which might be slow and uneven. There is less concern on the plateau areas and slopes away from housing and where larger areas of trees might be removed depending on site conditions.

The shape of any felling areas should be carefully considered and where possible it would be advisable for felling areas to comprise linear zones more or less parallel to the slope contours and with irregular wavy boundaries or even split into small areas. This would both match in with the landscape and reduce further the risk of erosion

Tree root systems should be retained in situ to stabilize the soil mass and consideration should be given to contour laying of tree stems or bundles of branches (which would decay quicker) and use of biodegradable matting (or cut heather stems) to stabilise the initially bare sandy soils.

The work should be undertaken by hand wherever possible to prevent compaction and downward forces on the soils. Compaction of the soils could lead to greater surface flow on slopes increasing the risk of surface erosion by sheet flow and rill and gully development.

Initially, such small felling areas should be assessed for their soil and geological conditions and the means of measuring and monitoring any resulting sheet flow and enhanced groundwater flows should be assessed.

Monitoring methods could involve placing boards or tree trunks across the direction of flow and assessing any build up and by installing sequences of standpipe type dipwells to regularly measure the depth to groundwater. Similarly, the depth and seasonality of flows along existing drains adjacent to housing areas could be monitored.

It is important that monitoring of any areas affected by felling should be coupled with monitoring of areas not affected and so providing controls. Details of the monitoring can only be worked out when any felling areas have been selected. Monitoring should be a key component of any management plan.

Should such small scale felling and heathland regeneration areas be successful in avoiding adverse hydrological effects, the felling programme could be carefully increased as long as lessons are learned from the monitoring of initial felling areas and consideration is given to appropriate mitigation such as interception ditches, use of biodegradable matting and heather litter and possibly increasing the area of mire and wet heath to balance water flows.

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APPENDIX

Town Common SSSI citation and condition assessment

Taken from the Natural England website.

County: Dorset **Site Name: Town Common**
District: Christchurch
Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981, as amended. **Local Planning Authority:** Christchurch Borough Council, Dorset County Council
National Grid Reference: SZ 138966 **Area:** 256.75 (ha) 634.42 (ac)
Ordnance Survey Sheet 1:50,000: 1 9 5 **1:10,000:** SZ 19 NW, SW
Date Notified (Under 1949 Act): 1951 (part), 1971 (part)
Date of Last Revision: 1977
Date Notified (Under 1981 Act): 1985 (part), 1986 (part), 1994
Other Information:
This site contains St. Catherine's Hill Geological Conservation Review site. Most of the site is proposed as part of the Dorset Heathlands Special Protection Area (SPA) under the EEC Directive on the Conservation of Wild Birds (Directive 79/409/EEC). Large parts, including Town Common and Sopley Common, are managed as nature reserves by the Dorset Trust for Nature Conservation and the Herpetological Conservation Trust. There are several boundary extensions at this notification and adjacent parts of the Hurn Common SSSI (1986 notification) are also included. The site adjoins the Moors River SSSI and the Avon Valley SSSI which is also proposed as a SPA and as a Wetland of International Importance under the Ramsar Convention.
Description and Reasons for Notification:
Town Common SSSI covers an extensive tract of lowland heathland centred on a hilly ridge separating the floodplain of the Avon Valley from the Moors River. Exposures of the deposits forming this ridge are of special geological interest. The topography is diverse, and with variations in the underlying geology and drainage conditions, there is a varied mosaic of heathland plant communities. Areas of succession from open heath to conifer and mixed woodland add further interest. The heathland is especially valued for a wide assemblage of bird, reptile, dragonfly and other invertebrate species distinctive to this habitat, including several that are nationally rare or scarce. Further heathland, wet grassland and other wetland covered by the adjoining Avon Valley, Moors River and Hurn Common SSSIs place Town Common within an exceptionally large tract of such habitats for lowland Britain. This entire area has a national and international importance for its wildlife interest.
St. Catherine's Hill at the southern end of the ridge provides key evidence for reconstructing the geography of the area during late Eocene times, some 35 to 40 million years ago. Two disused pits expose a sequence of fine sands and silty clays containing plant debris, and the sediments show evidence of having been laid down in fluvial (river-lain) or estuarine conditions. The strata are the lateral equivalents of marine rocks ("Lower Barton Beds") seen at Hengistbury Head and Friar's Cliff on the coast to the south. They are the only known strata of this age in southern England to have been laid down in a fluvial or estuarine environment, all others having been deposited under marine conditions. If the determination of the age of the rocks seen at St. Catherine's Hill is correct, then the site is of critical importance in showing that the late Eocene shoreline lay in the area between Christchurch and Hengistbury
Head.
Lowland heathland has become much reduced in extent both in Britain and continental Europe. The loss in south-east Dorset has been about 86% since the mid 18th century but this remains one of the few locations in Britain where heathland has an extensive presence. The tract at Town Common is relatively little fragmented and includes one of the largest unbroken blocks. The heathland has developed on infertile and mostly sandy soils, which along the ridge are derived from the Branksome Sand and Poole Formation, with occasional clay layers causing impeded drainage on the slopes. A broad, low-lying plain extends along the eastern flank of the ridge on Head and River Terrace deposits, widely giving rise to poorly drained clayey sands. In places these deposits have a rather hummocky surface due to areas of blown sand. Gravely sands from an older river terrace cap parts of the ridge adding yet further diversity to the physical nature of the site.

The freely drained soils on the higher ground support dry heath. This is dominated by heather *Calluna vulgaris*, a dwarf-shrub which widely forms deep, mature stands. Bell heather *Erica cinerea* and dwarf gorse *Ulex minor* also occur, while bare areas of firm, sandy ground are important for the diminutive and nationally scarce mossy stonecrop *Crassula tillaea*. Cross-leaved heath *E. tetralix* becomes significant where conditions are less dry, forming a humid heath. In places this vegetation supports an abundance of *Cladonia* lichens such as *C. impexa*. On large parts of the ridge, particularly at St. Catherine's Hill, the heathland has been replaced by pine woodland. Other areas are at a transitional wooded-heath stage with invading Scots pine *Pinus sylvestris*, maritime pine *P. pinaster* and birch *Betula* species. This succession to woodland provides temporary niches for heathland edge animals, mostly notably some bird species, but causes a decline and eventual loss of the heathland interest.

Flushes on the slopes of the ridge give rise to a sequence of communities from the dry and humid heath to wet heath and valley mire. The wet heath occurs on seasonally waterlogged soils, with differences in soil moisture conditions leading to varying proportions of heather, crossleaved heath, purple moor-grass *Molinia caerulea* and certain bog-moss *Sphagnum* species such as *S. compactum*. Where the soils are permanently waterlogged small valley mires have developed on peat. These areas are more floristically rich. Among the characteristic plants are bog asphodel *Narthecium ossifragum* and cotton-grass *Eriophorum* species, including hare's-tail cotton-grass *E. vaginatum* which is very local in Dorset and further species of bog-moss such as the nationally scarce *S. pulchrum*. The insectivorous plants oblong-leaved sundew *Drosera intermedia*, round-leaved sundew *D. rotundifolia* and pale butterwort *Pinguicula lusitanica* are particularly associated with this community and also open patches of peat within the wet heath.

The broad plain on the eastern flank of the ridge extends from near the Moors River in the north to the floodplain of the Avon Valley. Wet and humid heath widely dominates the rather flat and poorly drained land, while occasional hummocks provide transitions to dry heath. Numerous pools are scattered across this plain. These support carpets of the aquatic bog-moss *S. cuspidatum*, and margins that include purple moor-grass, many-stalked spike-rush *Eleocharis multicaulis*, common cotton-grass *Eriophorum angustifolium*, white beak-sedge *Rhynchospora alba* and the nationally scarce brown beak-sedge *R. fusca*.

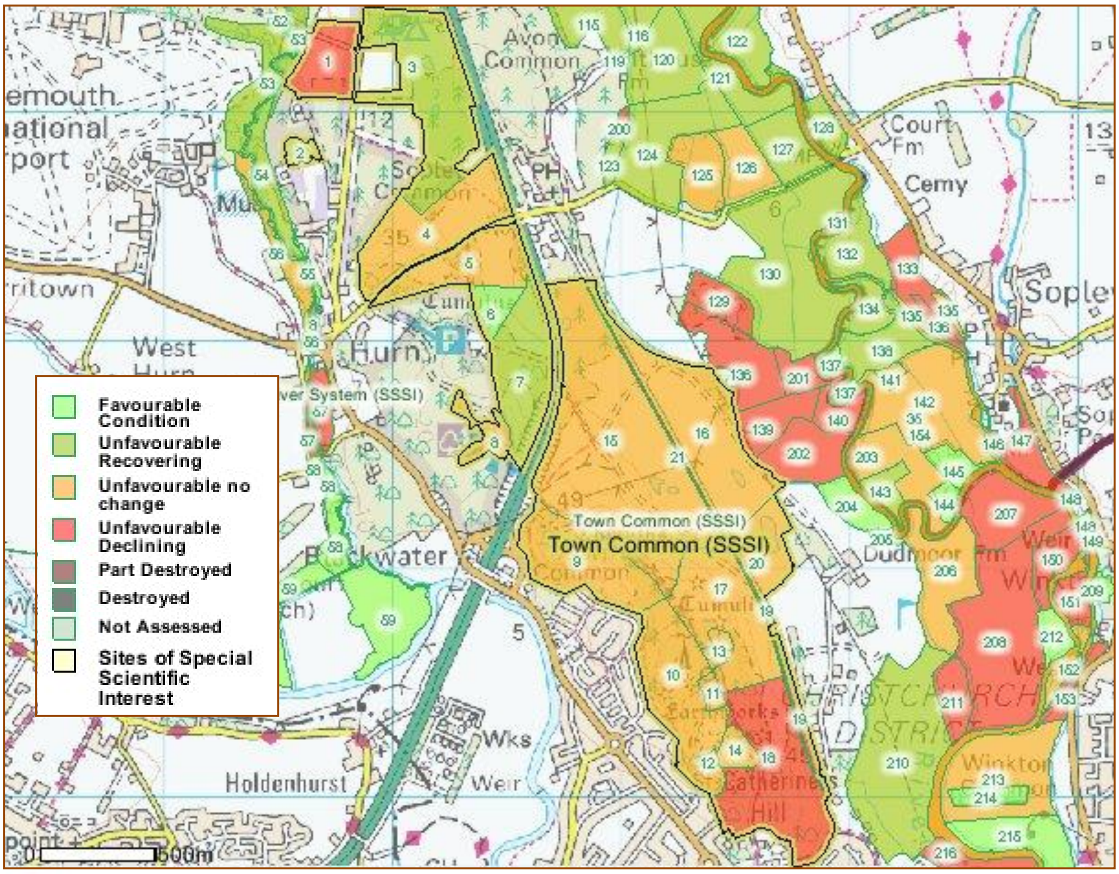
The heathland is used by a diverse assemblage of dragonflies and damselflies (Odonata), with some 24 species recorded in recent years. Some of these species occur as a consequence of the close position of the heathland with breeding locations along the Moors River and the wetlands of the Avon Valley. The scarce chaser *Libellula fulva*, a nationally rare damselfly, is an example. The many heathland pools support breeding populations of other species such as hairy dragonfly *Brachytron pratense* and downy emerald *Cordulia aenea*, both nationally scarce, and black-tailed skimmer *Orthetrum cancellatum*, another local species.

Other insect groups strongly associated with lowland heathland have been little studied at this site, but the available records indicate a significant interest. The assemblage of grasshoppers and crickets (Orthoptera) includes the nationally rare heath grasshopper *Chorthippus vagans* and the nationally scarce bog bush-cricket *Metrioptera brachyptera*. Suitable short heathland supports silver-studded blue butterfly *Plebejus argus*, also nationally scarce. The spiders (Arachnida) include many rare, scarce and local species such as the pirate spider *Ero aphana* presently recorded from only a few east Dorset heathlands, a jumping spider *Evarcha arcuata* and a crab spider *Thomisus onustus*.
The site has breeding populations of all six reptile species native to Britain. These include the rare sand lizard *Lacerta agilis** and smooth snake *Coronella austriaca** which are typically associated with the mature dry heath. This is an especially important stronghold for the sand lizard in Britain, with the many favourable heathland slopes supporting widespread populations.

The bird interest is substantial. The dry heath supports a large population of the rare Dartford warbler *Sylvia undata*§, with the number of breeding pairs reaching about 2% of the British total. Among the other breeding birds of the open heath are stonechat *Saxicola torquata* and the rare woodlark *Lullula arborea*§, while species of the heathland edge such as nightjar *Caprimulgus europaeus*§ and tree pipit *Anthus trivialis* also use the wooded-heath. The woodlands attract a further range of breeding birds including woodcock *Scolopax rusticola*, green and great spotted woodpecker *Picus viridis* and *Dendrocopos major* and siskin *Carduelio spinus*. There is also a mix of heathland and woodland raptors with the site being used during the breeding season by species such as hobby *Falco subbuteo*†, sparrowhawk *Accipiter nisus* and long-eared owl *Asio otus*.

The proximity of the ornithologically important wetlands of the Avon Valley and the extensive presence of wet heath and pools serves to attract a variety of wildfowl and waders. Small numbers of snipe *Gallinago gallinago* are often present, together in winter with teal and other wildfowl. The site has supported several of these wetland birds as breeding species including snipe, redshank *Tringa totanus* and Shelduck *Tadorna tadorna*.

*Species listed in Schedule 5 of the Wildlife and Countryside Act 1981.
†Species listed in Schedule 1 of the Wildlife and Countryside Act 1981.
§Species listed in Annex 1 of the EC Birds Directive.


Favourable Condition
Unfavourable Recovering
Unfavourable no change
Unfavourable Declining
Part Destroyed
Destroyed
Not Assessed
Sites of Special Scientific Interest
Town Common (SSSI)
Town Common (SSSI)
Hurn
Avon Common
Holdenhurst
Court Fm
Cemy
Wks
Weir
0 500m


Favourable Condition
Unfavourable Recovering
Unfavourable no change
Unfavourable Declining
Part Destroyed
Destroyed
Not Assessed
Sites of Special Scientific Interest

Town Common - Unit 9

back
View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006718
Unit area:	15.88 hectares
Main habitat:	Dwarf shrub heath - lowland
Condition:	Unfavourable no change
Latest assessment date:	08 June 2005
Reason for adverse condition:	Inappropriate cutting/mowing, inappropriate scrub control, public access/disturbance
Condition assessment comment:	The Borough Council has made noticeable progress on heathland conservation at this site, reducing tree invasion in surviving heath and expanding the heath into areas previously lost to dense pine and rhododendron. On large parts pine, especially Scots pine locally occurring with rhododendron, remains the dominant vegetation at the expense of potentially high quality heathland habitat and species interests. Further restoration of heathland has been set back with intervention of the Forestry Commission to bring the work within felling licensing procedures as public open space felling licences were not previously sought and to widen a resolution of local opposition to felling which has arisen on adjacent units. Where felling has taken place for heath restoration further management is needed to reduce tree re-growth, reduce the shading/leaf fall effect of retained trees as they expand (especially oak) and lessen competition from opportunistic colonising plants eg bracken and bramble. A widened programme of heath sward and gorse cutting or possibly patch burning is required to establish a mosaic of vegetation structures and species assemblages. Grazing with the wider heathland site, could increase the heathland quality, especially areas of wet heath.

Town Common - Unit 10

back View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006719
Unit area:	18.24 hectares
Main habitat:	Dwarf shrub heath - lowland
Condition:	Unfavourable no change
Latest assessment date:	08 June 2005
Reason for adverse condition:	Inappropriate cutting/mowing, inappropriate scrub control, public access/disturbance
Condition assessment comment:	The Borough Council has made noticeable progress on heathland conservation at this site, substantially reducing tree invasion into heath and expanding the heath into areas previously lost to dense pine and rhododendron. On large parts pine, especially maritime pine, remains the dominant vegetation at the expense of heathland habitat and species. Further restoration of heathland has been set back with intervention of the Forestry Commission to bring the work within felling licensing procedures as public open space felling licences were not previously sought and to widen a resolution of local opposition to felling which has arisen on adjacent units. Where felling has taken place for heath restoration further management is needed to reduce tree re-growth, reduce the shading/leaf fall effect of retained trees as they expand (especially oak) and lessen competition from opportunistic colonising plants eg bracken and bramble. A widened programme of heath sward and gorse cutting or possibly patch burning is likely to be needed to establish a mosaic of vegetation structures and species assemblages. Some dry heath on surface peat comprises almost single species carpets of poor growth and scrawny appearing Calluna. This may be due to insufficient sward management, but influences such as acidification also require investigation.

Town Common - Unit 12

back | View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006730
Unit area:	0.54 hectares
Main habitat:	Dwarf shrub heath - lowland
Condition:	Unfavourable no change
Latest assessment date:	10 June 2009
Reason for adverse condition:	Inappropriate scrub control
Condition assessment comment:	Some scrub removal has taken place but not at a sufficient rate. A pine tree stand to the east still needs pushing back. Bramble and piri piri are found over the redundant reservoir structure which would benefit from grazing.

Town Common - Unit 14

back View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006735
Unit area:	2.4 hectares
Main habitat:	Inland rock
Condition:	Unfavourable no change
Latest assessment date:	10 June 2009
Reason for adverse condition:	Inappropriate scrub control
Condition assessment comment:	Some management work has taken place with respect to scrub and pine and birch seedling removal and this has resulted in some heather regrowth to the north east of the site. The north and the west of the site have a dense covering of pine growth which if thinned out could result in a further extent of heather regrowth. Within the site a number of invasive species eg strawberry tree, evergreen oak, sweet chestnut and sycamore need to be removed. Further clearance of pine seedlings is required to expose the geological feature

Town Common - Unit 18

back View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006723
Unit area:	24.76 hectares
Main habitat:	Dwarf shrub heath - lowland
Condition:	Unfavourable declining
Latest assessment date:	08 June 2005
Reason for adverse condition:	Inappropriate scrub control, public access/disturbance
Condition assessment comment:	Heathland management on this unit (eg pine, birch and rhododendron scrub cutting, bare ground creation, mown firebreaks, erosion control) has yet to significantly reverse the scale of birch invasion into heath vegetation and the previous loss of heath to stands of mostly Scot's pine. As an example of the situation, the unit contains one of the most significant seepage mires on St Catherine's Hill but only the wetter communities survive within an area of dense pine and these are being squeezed down by rhododendron and pine growth from the edges. A felling licence application covering the unit and a much wider part of the SSSI attracted considerable local opposition and has failed to gain consent from the Forestry Commission. The impasse on felling needs to be resolved to turn this situation around. A widened programme of heath sward cutting or possibly patch burning is likely to be needed in the future to establish a mosaic of vegetation structures and species assemblages. Grazing with the wider heathland site, could increase the heathland quality, especially areas of wet heath and seepage mire. Some dry heath on surface peat comprises almost single species carpets of poor growth Calluna. This may be due to insufficient sward management, but influences such as acidification also require investigation.

Town Common - Unit 15

back   View Map

Staff member responsible for SSSI unit:	Helen Powell
Unit ID:	1006720
Unit area:	53.92 hectares
Main habitat:	Dwarf shrub heath - lowland
Condition:	Unfavourable no change
Latest assessment date:	28 July 2009
Reason for adverse condition:	Inappropriate scrub control, other - specify in comments
Condition assessment comment:	Large unit of both wet, dry heath and mire. Dense pine tree cover on part of the slope at St Catherine's hill and dense bracken where trees have been cleared also rhododendron present on the slope. Pine and birch seedlings widespead in parts. Nice open mire but whole area would benefit from grazing. Much of the heather on the heath was mature.

This document has been prepared by Ron Allen BSc Hons (Lond), ARSM, CEnv, CBiol, EurProBiol, MIEEM, MSB, MIEnvSc, MEWI Environmental Consultant and specialist in the soils of semi-natural wildlife habitats assisted by David Hall BSc Eng CEng MICE MIHT Consulting Engineer.

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