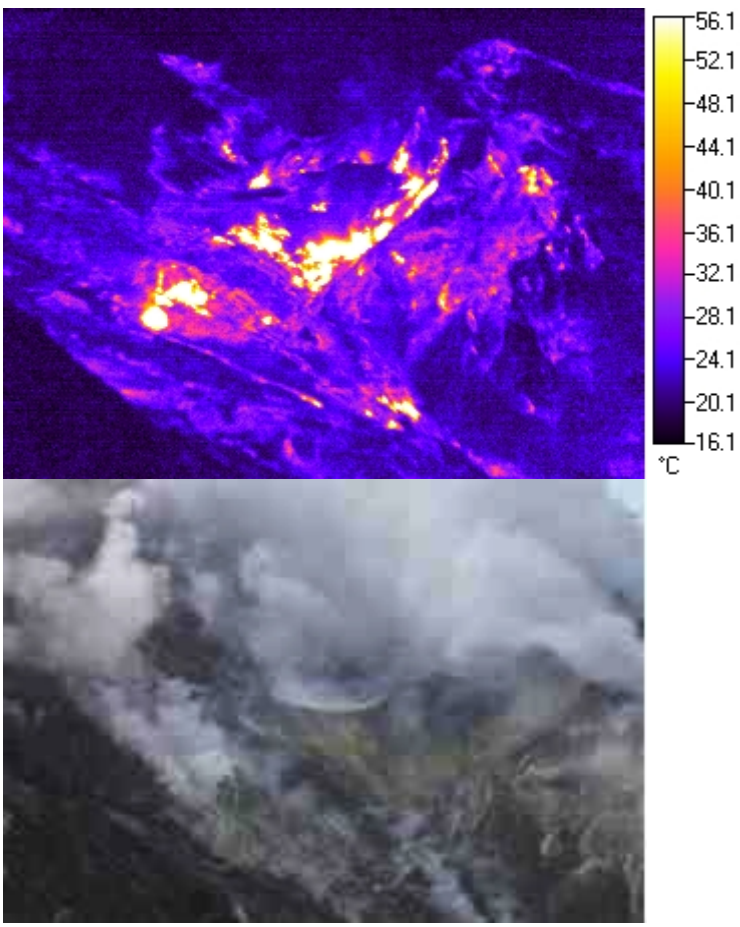
ASSESSMENT OF THE HAZARDS AND RISKS ASSOCIATED WITH THE SOUFRIERE HILLS VOLCANO, MONTSERRAT

Fourth Report of the Scientific Advisory Committee on Montserrat Volcanic Activity

Based on a meeting held between 4 – 6 April 2005 at the Montserrat Volcano Observatory, Montserrat

Part I: Main Report



Issued on 6 May 2005

Summary

(i) Surface activity at the volcano over the last six months has been minor, continuing the trend of the previous period. Exceptions to this were two periods of elevated gas flux, in October 2004 and February-March 2005, and an episode of strong gas venting through two new vents near the remnants of the lava dome starting on 15 April 2005.

(ii) Our procedure for evaluating whether the magma supply at depth has stopped, thereby ending the potential for immediate renewed eruption, has been refined and used again. When tested against the three criteria, the MVO measurements of gas flux, surface deformation and seismicity over the last year show that only the seismicity criterion is nearly met. We conclude that the activity of the volcanic system has not yet stopped.

(iii) We have re-analysed the probability that the volcano will resume magmatic eruptive activity during the next year and estimate that there is a 23% probability that this will happen. Should this happen, we consider it 10% probable that that such a restart will involve large explosions. Together, these two new evaluations reduce considerably the overall level of risk faced by the people of Montserrat from the volcano.

(iv) The individual risks faced by people in the former Daytime Entry Zone and for anyone in the Exclusion Zone are generally lower than during the last assessment. These risks are specified at the local level. Whilst the risks to an individual have fallen, we stress that the Exclusion Zone still remains a dangerous place in the event of an explosive resumption of activity.

Contents

Introduction

1. The fourth meeting of the Scientific Advisory Committee (SAC) on Montserrat Volcanic Activity took place at the Montserrat Volcano Observatory (MVO) from 4 to 6 April 2005. This report is the main product of that meeting. The Committee was commissioned by the Foreign and Commonwealth Office and operates under the Code of Practice for Scientific Advisory Committees issued by the Office of Science and Technology. The Terms of Reference for the Committee are presented in Appendix 1, and the agenda of the meeting is given in Appendix 2.

2. The meeting was attended by: Prof. G. Wadge (SAC-Chairman), Dr. W.P. Aspinall (SAC), Dr. S.C. Loughlin (MVO, SAC), Dr. R. Luckett (MVO), Dr. J. Neuberg (SAC), Dr. A. O'Mongain (MVO), Dr. R.E. Robertson (SAC), Dr. G. Ryan (MVO), Mr R. Saranathan (MVO), Mr. M. Strutt (MVO), Prof. B. Voight (SAC). Appendix 3 gives a list of participants and their affiliations. An apology for absence was received from Dr. K.C. Rowley (SAC).

3. At the time of the meeting Soufrière Hills Volcano (SHV) had shown very low levels of surface activity since the previous meeting of the SAC (28 – 30 September 2004). Many of the issues discussed at the meeting involved the risks within the Exclusion Zone and the probability of renewed surface activity. During the writing of this report, starting on 15 April 2005, the volcano began an episode of seismicity, including tremor, with increased gas and ash production. We have taken this activity into account in our deliberations.

4. There are two parts to the report: Part I contains the main findings and Part II contains the technical aspects of the assessment. Appendix 5 has a glossary of technical terms. A Preliminary Statement (Appendix 4) was issued on 6 April. An interview involving Wadge and Loughlin that discussed some of the preliminary findings of the risk assessment meeting was broadcast on ZJB Radio that same day.

Recent Volcanic Activity

5. The last six months have seen little surface activity at the volcano. The rainy season lasted well into January and triggered several mudflows in the Belham Valley and elsewhere. An incident occurred in which a tourist bus was caught by a mudflow at the Belham crossing and some tourists were washed away, though not seriously hurt. The expected erection of a bridge in the next six months should reduce the risk here. Earthquakes that correlated with the rainfall were thought to

be driven by near-surface fumarolic activity. There were two distinct periods of high gas output: 1-15 October 2004 and 9 February to 10 March 2005. The latter episode was notable in that it coincided with a period of clear weather with the plume being visible for hundreds of kilometres downwind and hydrogen sulphide being smelt on neighbouring islands.

6. On 15 April 2005, a week after the meeting, the strongest surface activity since the 3 March 2004 episode began. Vigorous gas and ash release from two vents to the north of the crater vent was accompanied by jet roaring noises. One of these vents is located at the remnant of the Northwest Buttress, a large part of which collapsed on 3 March 2004, and the other, further to the northwest, lies outside the current rim of the crater, but probably on the line of the old English's Crater which was marked by steaming early in 2003. Preliminary analysis of all the available data (in the Technical Report) suggests that this activity represents either interaction of the volcano's groundwater with shallow hot rocks to produce steam-driven explosions, or release of trapped magmatic gases. The episode does not indicate the imminent arrival of new magma at the surface.

7. The April 2005 episode produced a new steam vent outside the crater, below a remnant of the Northwest Buttress. We have considered the possibility that this activity might have made this mass of old dome material more likely to collapse outwards down either the Belham River Valley or Gage's Ghaut to Plymouth. Whilst this is possible, it is far more likely that any collapse, should it occur, would fall back into the crater, not away from it, and that any resulting debris flow would travel down the Tar River valley. We do not think that this situation merits any new precautionary measures.

Recent Monitoring Data

8. This period saw the continuation of the low levels of seismicity seen since May 2004, with small numbers of hybrid and volcano-tectonic earthquakes within the volcano, the former being most common in October and November 2004. There are also indications that a separate source of small earthquakes, localised between Garibaldi and St. George's Hills, was active in recent weeks.

9. The average rate of sulphur dioxide emission stayed within the 300-400 t/d range seen since May 2004 with the exception of two periods of elevated rate: 1-15 October 2004 and 9 Feb. – 10 March 2005. The former included a daily averaged measurement on 8 October of about 13,000 t/d, the largest measured value in the whole eruption. We see no reason to regard this result as spurious and conclude

that the volcano is occasionally capable of releasing a large volume of gas stored away from the main conduit. HCL values remain low, indicating no shallow degassing magma.

10. The surface of the volcano has generally inflated since June 2003, with occasional short reversals of this trend in April and November 2004. There is some indication that the inflation since November 2004 has slackened, without a longer period of evidence to the contrary we conclude that general inflation continues.

11. Thermal imaging of the crater and vent area was undertaken in November 2004 (see front cover). Surface temperatures of up to 350°C were recorded. On their own these values in themselves are not significant, but further measurements providing information on the long-term pattern could be. The initial measurements using this system were made during August 2003.

Current State of the Eruption

12. We reconsidered the criteria by which we previously judged whether the three main sets of measurements made by MVO over the previous year were consistent with stoppage of the underlying process powering the current eruption. This process involves the injection of basalt and interactions between basalt and andesite magmas. These criteria help us to decide when the eruption has ended rather than stalled. The criteria remain the same as last time but we have refined the way in which we use them jointly and how we express our confidence in them (see Technical Report for details). Our aim in using these criteria is to be able to declare the eruption over with the greatest confidence at the earliest opportunity, on the basis of the scientific evidence. However, any decisions that rely on such a declaration have to be judged for compatibility with public safety.

13. The criteria are:

Criterion 1.	The SO_2 daily emission rate averages less than 50 t/d.
Criterion 2.	An absence of low frequency seismic swarms and tremors associated with the magmatic system.
Criterion 3.	No significant surface deformation from a demonstrably deep source.

14. Applying these criteria to the measurements made by MVO during the last year: April 2004 – April 2005, we find that criterion 2 had nearly been met, from May 2004 to April 2005, but that the other two had not. Therefore, our interpretation is

that the volcano remains active at depth, and we think the likelihood that we have got this wrong to be less than 1-in-10.

15. Hence, the eruption cannot be considered over yet. This does NOT mean that the volcano will DEFINITELY start to erupt lava again in the next months to years. We consider that, although the volcano appears quiet outwardly, at depth it continues to show signs of being active and COULD re-start lava extrusion again in the next months.

Probable Future Behaviour

16. There has now been a pause in the extrusion of lava at the surface of twenty-one months; just longer than the previous longest pause from March 1998 to December 1999. We have looked closely at the behaviour of the volcano during this pause and at other volcanoes. We think now that it is less likely that the volcano will resume producing lava in the coming year. This is the converse of our thinking in the last report. However, there is still a significant probability, about 23%, of a resumption of lava effusion in the next year.

17. What of the longer term? Looking ahead 5 years and 20 years is helpful for strategic planning. In particular, planning policy may need to consider the potential effects of major eruptive events such as a repeat of a collapse event of the July 2003 or a large explosion as on 17 September 1996. We think that the chance of a huge collapse event is about 1-in-45 over a five-year period and about 1-in-20 over a twenty-year period. The likelihood of a single, large explosion (of the same size as the largest yet recorded on 17 September 1996) is between 1-in-10 per year over one year and 1-in-50 per year over twenty years. These likelihood estimates are conditional on the volcano continuing to be active, and would change significantly once the eruption is over.

Assessment of Volcanic Hazards

18. We focused our attention on the areas of the former DTEZ and the previously inhabited parts of the Exclusion Zone closest to the boundary. We were also asked by government to look at specific work- and tourist-related scenarios. As before in this regard, we consider the situation up to one year ahead.

19. When magma ascends the conduit to the surface there is always the potential for major explosions and their two attendant hazards: large rock fragments falling

from the ash cloud and pyroclastic flows created during the collapse of the eruption column. High flux rates and high gas contents increase the likelihood of such an explosive restart and the likelihood of pyroclastic flows being able to flow outside the crater. Such a restart could be preceded by clear and timely evidence of magma rise, giving MVO plenty of time to issue alerts and for government to act. However, there is the possibility that the restart could have few, brief and ambiguous precursor symptoms. In such a case, if people were to be within the Exclusion Zone, particularly living there, then they may not be able to move out of harm's way fast enough. The surges of ash from pyroclastic flows are also capable of travelling at high speed over the surface of the sea and putting boats in danger. We have clarified the relative severity of this risk within the Maritime Exclusion Zone.

20. There are two additional hazards that are not dependent on the resumption of a new lava production. The first is mudflows and the second is a debris avalanche created by the collapse of the remnant Northwest Buttress. Both hazards could threaten the Belham River Valley and Plymouth areas. Mudflows are inevitable for years to come. The likelihood of a major collapse outside of the crater is considered to be slight, however.

Assessment of Risks to People

21. As in the previous reports we take each hazardous process identified above, estimate the probability that they will occur in a given area of Montserrat and then calculate quantitatively the risk that a given number of people in that area will be exposed to. We use the Chief Medical Officer's (CMO) scale (Appendix 6) to convey a qualitative description of the scale of risk based on the numerical estimates. Details of the probability and risk calculations are presented in Part II of this report. These risk estimates have large uncertainties and so the reader should not attribute detailed meaning to small numerical differences in these values. The CMO scale categories, as reported here, better capture these differences.

22. We estimate that the overall risk to the people of Montserrat from volcanic activity over the next year is significantly reduced now compared to six months ago. This change comes from the combination of two judgements. We now think it more likely that the volcano will NOT restart magmatic eruptive activity in the next year, but if it does, then it is considered less likely than before that it will involve major explosions immediately.

23. Whilst this is good news for the long-term rehabilitation of Montserrat, we urge caution. Future evaluations may reverse this trend. As long as there is sound evidence, which there is at the moment, that the volcano is capable of quickly restarting from its current stalled state, then areas within the Exclusion Zone will continue to be associated with elevated risk, particularly for residents.

24. *Risks in the former DTEZ*

The potential hazards to people living in the former DTEZ are as before: sudden explosions with falling rocks and/or pyroclastic flows. The risk is in the VERY LOW category on the CMO's scale for the current state of activity of the volcano. If dome growth did recommence then, as before, the risk depends on the vigour of the magma flow. We expect that this rate would be low to moderate and that the risk exposure to an individual is LOW, but increasing to MODERATE to HIGH if the rate was high.

25. *Risks in the Lower Belham Valley*

The mudflow risks in the Lower Belham Valley have not changed since the last detailed report in September 2004. The risks from a debris avalanche due to collapse of the Northwest Buttress arelow.

26. *Risk exposure for St. George's Hill*

Under the present conditions, our current hazards model indicates that the risk exposure for a person returning to live full-time on St. George's Hill is VERY LOW on the CMO's scale.

27. *Risks within the Exclusion Zone*

We have studied, as we began last time, the risks in those areas of the Exclusion Zone that would be most likely to be re-occupied if the decision were taken to allow people to live within the Zone. The areas considered are: Harris, Windy Hill/Streatham/Dyers/Molyneux, Amersham/Kinsale, St. Patrick's, Plymouth, Trant's/Bramble airport. Our assessments do not include those risks if a person remains in the area after a restart of magmatic activity.

28. *Risk exposure in Exclusion Zone for Amersham area*

The risk exposure for a person returning to live full-time in Amersham under present conditions is assessed LOW to MODERATE on the CMO's scale.

29. *Risk exposure in Exclusion Zone for Streatham - Windy Hill*

The risk exposure for a person returning to live full-time in the Streatham – Windy Hill area would be MODERATE on the CMO's scale.

30. *Risk exposure in Exclusion Zone for Harris*

The risk exposure for a person returning to live full-time in Harris is MODERATE to LOW on the CMO's scale.

31. *Risk exposure in Exclusion Zone for St. Patricks*

The risk exposure for a person returning to live full-time in St. Patricks is MODERATE to HIGH on the CMO's scale.

32. *Risks to people working in and visiting the Exclusion Zone*

There has been a gradual increase in the number of people working in or visiting some areas of the Exclusion Zone for periods of an hour or two up to a full working day. To assess the risk exposure faced by these people we have made specific assumptions about their numbers and behaviour in the analysis presented in Part II.

33. *Risks to workers on Plymouth jetty*

The individual risk of exposure of a worker on the jetty is in the LOW category on the CMO's Risk Scale.

34. *Risks to people working at Thomson's Field*

The risks to individual workers involved in access to this area are approximately the same as those for working at the Plymouth jetty. The same qualifications about extended (i.e. 24 hour) working apply as in the last report.

35. *Risks to people working in the daytime at Trant's Quarry*

The risks to individual workers present in this area during normal working hours are judged to be in the LOW to VERY LOW categories.

36. *Risks to people using Bramble Airport as a diversion airfield*

If the Bramble Airport runway were to be operational no more than six times in a year, and for no more than two hours at any one time, the annualised risk for any individual who was in this area on such occasions would be NEGLIGIBLE for an 'out-of-the-blue' volcanic event.

37. *Risks to tourists and short-term visitors in Plymouth*

For a tourist or person who makes a single short visit to an area with elevated risk (say, a trip into the middle of Plymouth of about two hours in duration), their limited time at exposure would correspond to an annualised individual risk of death or injury in the category NEGLIGIBLE on the CMO's Scale. For taxi drivers or others who make regular short-term visits week-on-week, although the

chances of becoming a casualty would be higher, the individual risk can be expected to fall still in one of the categories MINIMAL, VERY LOW or LOW, depending on all the circumstances involved. However, it should also be recognised that whereas the risk levels involved are insignificant for any one individual, the chances of suffering two or more casualties in a 12-month period from repeated multiple visits by different groups involving several persons may be non-negligible. For the scenario of a sudden onset explosive eruption and associated hazards, the probability of suffering a number of casualties amongst tourist visitors to Plymouth is estimated to be about 1.5×10^{-4} per year - i.e. there is a chance of about 1 in 6600 of this happening under present conditions.

38. *Risk within the Maritime Exclusion Zone*

We have re-calculated the relative hazards faced by sailors just offshore from the volcano. The area offshore Tar River Valley is between ten and a hundred times more dangerous than the area offshore Trants (and the areas offshore Plymouth and St Patrick's). A proper risk analysis would require a detailed knowledge of visiting patterns but the equivalent full-time exposure offshore Trants is currently is currently in the LOW - MODERATE category, while that for the Tar River is in the upper part of the CMO's HIGH category. If any decision were to be made to relax the Maritime Exclusion Zone boundaries, then a logical new boundary would be one that recognised the above distinction around the Tar River area compared to the rest of the island.

39. All these risk estimates represent inferences from our best scientific judgement at the present time, given the past and present behaviour of the volcano and the information and observations that are available. There are limitations and uncertainties involved. If the levels of individual risk are to be used to inform public safety decisions then an analysis done on a more precautionary basis (i.e. incorporating some additional element to allow for the margins of uncertainty) could easily provide rankings higher on the CMO's Scale than those quoted above. Thus, given the limitations intrinsic in risk assessment, but mainly because of the potentially large range of risk exposures that is partly contingent upon the initial rate of supply of erupting lava, government authorities may wish to add a precautionary factor to any decision making concerning the long-term status of that area.

The Operation of MVO

40. As usual we were made to feel very welcome at MVO. The activity report to the SAC was excellent and staff were patient and forthcoming with additional requests for data and analysis. Most importantly, it is the ability to have a concentrated scientific dialogue with MVO staff that makes the meeting format a success.

41. The first six months of the new Director's term had gone smoothly and Dr Loughlin envisaged a smooth period of relative stability in staffing for at least the next six months. The new software engineer replacing Mr Silcott, Mr Saranathan, had settled in quickly and a term of office of at least two years was expected. Dr Loughlin assured the committee that any future gaps in staffing capability would be flagged as early as possible. Postgraduate level volunteers at MVO had been a particular success recently with some excellent contributions, less so for graduate level people.

42. Delays to the opening of the airport, now expected in August 2005, have meant an extension of the current helicopter contract. Three bids had been tendered for the new contract, which in the first instance would be for a period of about one year. The issue of single- or double-engined aircraft had still to be resolved and the CAA guidelines were important here. Almost certainly there would have to be a local fuel dump.

43. The seismic upgrade was now complete and the effort to improve the seismic data management by Dr Luckett was paying real dividends. A new seismic station on Fergus Mountain had been deployed, with a line of sight to Garibaldi Hill, to improve data quality compared to the old noisy instrument at South Soufrière Hills. It was felt that two hours of helicopter time per week would be sufficient to maintain the seismic network. However, the maintenance access trails around the southeastern side of the island that were advocated at the last SAC, as part of the anticipated reduced helicopter provision, have not yet been cut. With the imminent approach of the wet season it was important to get this work funded and done before then. The Committee agreed to write a letter to the Director, MVO stressing this issue. A new GPS receiver had been deployed and another was sought. The Leica 1100 Total Station was to be used for a new Windy Hill – Farrell's wall survey line. Whilst the Spectrascan sulphur dioxide monitoring technique was a major step forward it is not without its problems. The data retrieval rate was low and an improvement in the custom software could improve this. Synchronised video of the plume would help improve the plume velocity values used in the emission rate calculations. The reasons for the differences

between the two instruments was not clear. The initiative to monitor carbon dioxide and thermal anomalies within the crater was applauded.

44. The protocols to monitor collaborative research have worked well recently. Relations with the CALIPSO consortium are good but there are insufficient resources available to that project for them to extract their complex dilatometer signals and integrate them fully into the MVO data stream. New links with the Seismic Research Unit of the University of the West Indies should be encouraged. As access to the volcano becomes easier it may become more difficult for MVO to keep track of the activities of external research groups, though this is a long way from becoming a problem yet.

SAC Membership

45. This meeting involved two new members: Drs. Loughlin and Robertson. We considered whether we were lacking in a particular area of expertise relevant to the current state of the volcano. The petrology of magma supply and reservoir processes is one that could be strengthened and we agreed to explore potential candidates.

Next SAC Meeting

46. Given the rather low level of recent surface activity, we considered whether the SAC should meet annually rather than bi-annually. We feel that Dr. Loughlin, Director of MVO, would benefit from another meeting after six months, so that she becomes more familiar with the methods and support that the SAC can bring to MVO, before we, potentially, change to an annual cycle. Increasing the intervals between SAC meetings may add delay to the timing of the decision as to when the eruption can be reasonably considered to be over. We advise that the next meeting of the SAC be held on 26-28 September 2005.

Appendix 1: Constitution of the Scientific Advisory Committee on Montserrat Volcanic Activity

This document outlines the main responsibilities of the newly constituted Scientific Advisory Committee (SAC) on the Soufriere Hills Volcano, Montserrat. The document includes the terms of reference for the SAC and a membership template. The SAC is to replace the Risk Assessment Panel and is commissioned by the Overseas Territories Department (OTD)of the Foreign and Commonwealth Office (FCO). The SAC will work according to the Office of Science and Technology (OST) Code of Practice for Scientific Advisory Committees.

TERMS OF REFERENCE
The main responsibilities of the SAC are:

1. to carry out regular hazard and risk assessments of the volcano in co-operation with the Montserrat Volcano Observatory (MVO) and to report its findings to HMG and the Government of Montserrat; and

2. to provide scientific advice at a strategic level to HMG and the Government of Montserrat outside these regular assessments in co-operation with the MVO.

NB: The "Government of Montserrat" will normally mean, in the first instance, the Governor as he has the constitutional responsibility for the safety of the Montserrat population. The Governor will be responsible for ensuring appropriate dissemination of SAC assessments or recommendations to the Government and people of Montserrat.

The SAC is also required to perform these additional functions:

3. to provide independent advice on the scientific and technical operations of the MVO to ensure that the work matches the level of risk;

4. to provide scientific advice and assistance to the MVO as required by the MVO Director; and

5. to offer advice on new developments that were not foreseen when the TORs were set up, and if appropriate make recommendations for changes to the TORs.

The SAC will carry out its activities within the OST Code of Practice for Scientific Advisory Committees. The SAC will be responsible to the UK Government through the FCO (OTD). The SAC will not incur expenditure without prior FCO (OTD) authority.

These general terms of reference are supplemented with the following specific points:

(a) The work of the SAC concerns scientific assessment of the volcanic activity and related hazards and risks. This scientific work is an input to decisions made by the HMG and the Government of Montserrat related to the safety of the people of Montserrat (such as evacuation and extent of Exclusion Zones), to issues of planning and sustainable development of Montserrat and to the mitigation of external hazards (e.g. to civil aviation).

(b) The provision of scientific advice to the Governor and Government of Montserrat is the responsibility of the MVO and its Director. The SAC has the function of assisting the MVO in its major missions in all respects of its activities and to assist in matters relating to the provision of long-term and strategic matters.

(c) The MVO Director (or scientific staff designated by the Director) participate in all SAC activities except for ToRs 3 and 4.

(d) The SAC has the function of giving advice and assistance to MVO and the management contractor relating to scientific matters as required by the MVO Director. Such independent advice to the MVO may include appraisal of the technical expertise of staff, evaluation of the monitoring systems, assessment of proposed research projects by external groups, and advice on technical matters.

(e) With respect to ToR 3 the Chair of the SAC will be a member of the MVO Board of Directors and can provide independent advice to the Board as required. The Chair will be expected to attend MVO Board meetings (currently twice a year).

(f) Given the special circumstances of Montserrat as a United Kingdom Overseas Territory, reports of the SAC would be provided for both Governments. Reports would also be given to the MVO Management Board.

(g) The SAC will be required to present its findings in a manner suitable for release to the public. It will also be required to assist the Governments and the MVO in

explaining the activity of the volcano and the scientific information pertinent to decision-making by the authorities.

(h) The SAC will liaise with other relevant scientific organisations or committees as required, which might for example include regional scientific institutions and the Department of Health Committee on health hazards from volcanic ash.

(g) The Chair of the SAC will make an annual report to the MVO Board of Directors.

MEMBERSHIP

Membership of the SAC will be at the invitation of the FCO (OTD) and will cover the key areas of expertise required to assess the hazards and risks of erupting volcanoes. Expertise will include such areas as volcanology, volcano geophysics, and hazard analysis. The SAC will continue the approach of the former Risk Assessment Panel that was endorsed by the UK Chief Government Scientist in December 1997. Thus the Committee requires a facilitator as a member for applying expert elicitation methods to estimate volcanic risk. These considerations imply a minimum of four members, excluding the Director of the MVO. Additional experts can be invited to participate as required by the Chair, with prior agreement from the FCO (OTD), if a lack of expertise becomes apparent on a particular issue. As required by the Code the SAC is expected to consider external opinion. The membership will be considered on an annual basis with a view to regular changes and refreshment of membership.

MEMBERSHIP TEMPLATE

Members invited to serve on the SAC for the Montserrat Volcano are expected to attend all hazards and risk assessment meetings and to participate in the formalised elicitation procedure. Members have the responsibility to use their scientific judgement and expertise to meet the Terms of Reference. Opinions of the Members on scientific matters should be expressed through participation in the work of the SAC. Divergences of scientific opinion will normally be reported in terms of scientific uncertainty through the formal expert elicitation procedure. Differences that cannot be incorporated through the elicitation methodology should be included in the reports of the SAC as required by the OST Code. The Chair of the SAC, or his or her delegate from the Committee, will be responsible for presenting the findings of the SAC's work to the Governments of Montserrat and the United Kingdom and to the public in co-operation with the Director of the MVO. Any disagreement or divergence of opinion with the Director of the MVO that cannot be reconciled or incorporated through the elicitation method should be reported through the MVO Board of Directors.

SECRETARIAT

The FCO (OTD) will provide a Secretariat for the SAC, as set out in the Code of Practice. FCO (OTD) will reimburse premium economy travel costs, reasonable hotel accommodation, meals and professional fees (once agreed) in full. The SAC will not incur additional expenditure without prior FCO (OTD) authority. The Secretariat's main point of contact is Ann Birch, Desk Officer for Montserrat in OTD. Her contact details are as follows:

Email: Ann.Birch@fco.gov.uk
Tel: +44 20 7008 3123
Fax: +44 20 7008 2879

Appendix 2: Scientific Advisory Committee on Montserrat Volcanic Activity, Meeting 4 , 4 – 6 April, 2005: Agenda

1. Previous SAC report, plan for this meeting
2. Activity Report [*MVO Open File Report 03/05*]
3. The end of the eruption [*Criteria for assessing the end of the eruption*]
    a. Status of current criteria
    b. Uncertainty via Bayesian Belief Network
4. Long-term prognosis
    a. 1-5 years
    b. 5-20 years
5. Renewed eruption hazard scenario elicitation
6. Exclusion Zone Risks
    Harris, Windy Hill/Streatham, Amersham, Plymouth, St.George's Hill
7. Risks in Former DTEZ
8. Work/Visit-specific Risk Assessments
    a. Plymouth jetty working
    b. Plymouth tourist visit
    c. St. Patrick's
    d. Thomson's Field
    e. Trant's quarrying, gravel mining
    f. Bramble airport as diversion strip
9. Maritime Exclusion Zone
    a. Cruise ships 300m off Plymouth
    b. Fishing boats off Trants
10. MVO Matters
    a. Staffing
    b. Helicopter
    c. Monitoring
    d. Collaboration
11. SAC Matters
    a. Membership
    b. Frequency of meetings/next meeting

Appendix 3: List of Participants

Chairman

Prof. G. Wadge	Environmental Systems Science Centre, University of Reading, UK

Committee members

Dr. W.P. Aspinall	Aspinall & Associates, UK
Dr. S.C. Loughlin	Director, MVO
Dr. J. Neuberg	Leeds University, UK
Dr. R.E.Robertson	Seismic Research Unit, University of the West Indies, Trinidad and Tobago
Prof. B. Voight	Penn. State University, USA
(Dr. K.C. Rowley	Trindata Ltd., Trinidad & Tobago, unable to attend)

MVO Scientists present in an advisory capacity:

Dr. R. Luckett

Dr. A. O'Mongain

Dr. G. Ryan

Mr R. Saranathan

Mr. M. Strutt

Appendix 4: SAC4 Preliminary Statement issued 6 April 2005

The last six months has been one of the quietest periods since the volcano began to erupt nearly ten years ago. In this period there was no new dome growth, no explosions and no major collapse of the remnants of the old dome. Nevertheless, there were two episodes of increased gas release. Stronger pulses of gas emission occurred in early October 2004 and February/March 2005. Together with changes in the rate of surface deformation, this suggests that the deep parts of the volcanic system remained active. The established criteria for deciding whether the eruption has finished have not yet been fully met. The average rate of gas emissions has fallen slightly, but remains just below the 1995 – 2005 average. Surface deformation measurements have generally followed the trend of volcano-wide inflation seen since June 2003. However, it is now nearly a year since we saw seismic evidence of magma movement within the conduit. As a result, our expectation that the volcano will resume dome growth or explosive activity within the next year is reduced. We are re-assessing the risks faced by people in the Exclusion Zone, the DTEZ and the Maritime Exclusion Zone. The main risks faced by people in the Exclusion Zone would come from a sudden resumption of explosions, and mudflows and gas remain potential hazards. We are now analysing the reduction in risks and will present the full results in the Main Report.

Appendix 6: Glossary of Terms

Andesite: The name given to the type of magma erupted in Montserrat.

Basalt: The type of magma entering the magma reservoir below Montserrat.

cGPS: Continuously-measured Global Positioning System for repeated measurement of ground deformation.

Conduit: In a volcano magma flows to the earth's surface along a pathway known as a conduit. The conduit is usually thought to be a cylindrical tube or a long fracture.

Hybrid/LP Seismicity: Varieties of earthquake signal often indicative of magma motion in the upper part of the conduit.

Lava: Once magma gets to earth's surface and extrudes it can be called lava. Below ground it is always called magma.

Magma: The material that erupts in a volcano is known as magma. It is not simply a liquid, but a mixture of liquid, crystals and volcanic gases. Magma must contain enough liquid to be able to flow.

Magnitude: The magnitude of an explosive eruption is the total mass of material erupted.

Mudflow: A flow of rock debris, ash and mud that occurs on many volcanoes particularly during eruptions and after very heavy rain

Pyroclastic flow: These are flows of volcanic fragments similar to avalanches of rock in landslides and snow avalanches. They can be formed both by explosions and by parts of an unstable lava dome avalanching.

Pyroclastic surge: These are also flows, but they are dilute clouds rather than dense avalanches. A surge is a rapidly moving mixture of hot particles and hot gas and their behaviour can be compared to a very severe hurricane. Surges can be formed above pyroclastic flows or directly by very violent explosions.

Swarm: A large number of , in this case, earthquakes occurring in rapid succession with characteristics indicating they are generated from a similar region in the earth. Can merge into tremor.

Volcanic ash: Ash particles are defined as less than 4 millimetres in diameter. Respirable ash consists of particles less than 10 microns (a micron is one thousandth of a millimetre) in diameter.

Appendix 7: Chief Medical Officer's Risk Scale

Negligible: an adverse event occurring at a frequency below one per million. This would be of little concern for ordinary living if the issue was an environmental one, or the consequence of a health care intervention. It should be noted, however, that this does not mean that the event is not important – it almost certainly will be to the individual – nor that it is not possible to reduce the risk even further. Other words which can be used in this context are 'remote' or 'insignificant'. If the word 'safe' is to be used it must be seen to mean negligible, but should not import no, or zero, risk.

Minimal: a risk of an adverse event occurring in the range of between one in a million and one in 100,000, and that the conduct of normal life is not generally affected as long as reasonable precautions are taken. The possibility of a risk is thus clearly noted and could be described as 'acceptable' or 'very small'. But what is acceptable to one individual may not be to another.

Very low: a risk of between one in 100,000 and one in 10,000, and thus begins to describe an event, or a consequence of a health care procedure, occurring more frequently.

Low: a risk of between one in 10,000 and one in 1,000. Once again this would fit into many clinical procedures and environmental hazards. Other words which might be used include 'reasonable', 'tolerable' and 'small'. Many risks fall into this very broad category.

Moderate: a risk of between one in 1,000 and one in 100. It would cover a wide range of procedures, treatment and environmental events.

High: fairly regular events that would occur at a rate greater than one in 100. They may also be described as 'frequent', 'significant' or 'serious'. It may be appropriate further to subdivide this category.

Unknown: when the level of risk is unknown or unquantifiable. This is not uncommon in the early stages of an environmental concern or the beginning of a newly recognised disease process (such as the beginning of the HIV epidemic).

Reference: On the State of Public Health: the Annual Report of the Chief Medical Officer of the Department of Health for the Year 1995. London: HMSO, 1996.