The facilities on the eastern side are all within the Unsafe Zone and unconfirmed reports indicate that some have been buried as a result of recent pyroclastic flows

The pumping systems were built in the period 1972 to 1975 as part of the Canadian Aid project and are sized in relation to the storage and transmission systems constructed under that project Although recent augmentation of the system has increased available yield from the springs the pumping plant requirements have not been evaluated.

The pumps are controlled by switches and pressure cut outs for manual override. Pumping stations contain only duty pumps In the case of failure of the pump or motor, the affected unit has to be replaced with a new unit from the stores

The detailed information on pumping station equipment including pumps and switch gear has not been available, but it is understood that there has been some upgrading of pumps and motors and replacement in time. However, the switch gear and starting units which were installed required replacement due to redundancy.

The effects of Hurricane Hugo highlighted the susceptibility of the pumping stations to the loss of power. As a result, standby diesel generator units were provided for four of the pumping stations and one of the wells. Three of the units are installed adjacent to the pumping stations and the remaining two are transported to site and set up should there be a prolonged loss of power.

With unconfirmed reports of damage to installations in the eastern section and their location within the Unsafe Zone, pumping stations of significance at this time are the one which pumps from Lawyers towards Hope and the one at St Peter's which pumps to the higher elevations in the north.

With the transfer of population to the north, the pumping station at Lawyers in its current duty condition is redundant, since there is a need for a transfer of water north rather than south which is its present duty condition.

The St Peter's pumping station, which continues to operate, is significantly under capacity for current demands because of the shifting population.

It is understood that as part of the emergency aid by the British Government, pumping equipment is being imported to improve the supply conditions to the north. Details are however not readily available in the current circumstances

In order to relieve the demand for pumping to some extent and to place water into the area of greater demand, taking into account the higher level of storage currently at Hope, an option would be to reverse the duty of the pump at Lawyer's and bypass the Lawyer's and St. Peter's storage facilities and pump at least to Fogarthy, which would permit the transfer of a volume of stored water at Hope closer to the northern area of demand. The foregoing could be considered a first step in the process of alleviating the current pressures, especially when it was noted that Hope Springs and Reservoir overflow and reports are that it is a regular occurrence. As an indication of the demand to the north, Figure 13 shows the May 1996 distribution. The demand to the south would have been significantly diminished in more recent time, with an increase to the north despite the out migration.

Installation of new pumps, understood to be on their way, would allow for transfer of water from Fogarthy to the higher elevations. Additional storage within the area would be a subsequent step to bring a higher degree of security to the distribution system.

While the foregoing would reduce vulnerability in the current level of activity of the volcano, as well as the seismic activity related thereto, it does not remove the susceptibility of the northern area to loss of supply in hurricane conditions because of the previously mentioned location of sources, storage reservoir capacity and length of mains from Hope supplying to the north across a number of main drainage paths and areas subject to soil movements as a result of heavy rainfalls.

3.2.7 Distribution

In the current circumstances, the availability of detailed information on distribution systems is not readily available. Reference on this subject is therefore totally related to the revised May 1993 report on the Water Authority Planning Study by Howard Humphreys and Partners Limited. Figure 5 is a schematic layout of the sources, transmission and storage with an indication of the areas to which distribution takes place from the reservoirs

The system comprises over 100 miles of pipework ranging in diameter from 8 inch to 1 inch. Ductile iron pipes have been used for 8 inch, 6 inch and 4 inch mains and account for about 50 miles of lines. A further 45 miles of pipeline is in galvanised mild steel which accounts for the smaller diameter pipes although there are some 6 inch and 4 inch pipes also in this material

In recent years much more use has been made of uPVC and HDPE pipes, but to date these account for only 5% of the pipes in the system.

The distribution systems cover large variations in elevations and a number of pressure reducing valves are incorporated. It is known that some consumers also install pressure reducing valves in their pipework.

Repair programmes after 1986 indicate that the number of leaks attended per year has fallen The assumption is that there has been a reduction in water loss. However, the event of Hurricane Hugo in 1989 was included in the repairs, with the high numbers of 2 inch, 3 inch and 4 inch pipes reflecting the damage to the network resulting from Hurricane Hugo.

A considerable portion of the spring water has a pH value of less than 7 and therefore is acidic and is likely to cause corrosion particularly to the galvanised pipework.

Leaks continue to occur frequently in the small diameter service pipes and the method of repair is generally of a temporary nature requiring repeat visits.

With the possible limitation on supply and storage availability in the current circumstances, especially during dry periods, some closer control will be necessary for leaks of this nature.

In the early 1990's replacement of distribution mains and service connections progressed in the Old Town, Olveston, Foxes Bay, Woodlands and Richmond Hill areas, under the British Government's ODA project. The foregoing, along with improved practices, should have reduced leakage in the main distribution system However, there are no immediately available records although subsequent assessment and examinations of water requirements in the volcano Safe Zone by T B Kennedy, Chartered Engineer, does indicate a still relatively high volume of unallocated water

No hydraulic analyses of the transmission networks have been undertaken and the Montserrat Water Authority is not aware of exactly how the systems are functioning, or whether correct pressure zones have been established The period of this project does not permit these analyses, but during inspection it was noted that spring overflows were taking place as well as overflows from reservoirs, especially in the southern portion of the Safe Zone The foregoing is to be expected in the current circumstances and any analyses of the overall system must now be considered in the light of the new demand centres.

3.2.8 Metering

There is a network of bulk meters that measure flows in and out of service reservoirs and pumping stations from which readings have been taken frequently and recorded.

In the current project it was not practical to obtain and assess the extent of recorded information and no emphasis was placed on this in the light of the changing demand circumstances and the capacity of the system to satisfy such circumstances.

In the future planning of the system in relation to its vulnerability, it would however be useful to have background records and to institute methods of metering to satisfy what would be a changing demand situation in any resettlement process.

The metering at the sources has been inconsistent due to blockages on a periodic basis. Periods of outages and discontinuities have in the past led to inconsistencies in the totalling of flows In the current situation, with overflows in systems after metering, the records would not be of significance without measurement of the losses as well, and currently no means of measure is available and it is not considered a priority.

3.3 Water Quality

3.3.1 Historical

The aim of the Montserrat Water Authority is to supply water which falls within the World Health Organisation Guidelines for physical, chemical and bacterial standards, of which the levels for basic chemical quality are:-

- pH - 6 5 to 8 5
- TDS - 1.0g/l
- Fluorides - 1.5 mg/l
- Chlorides - 250 mg/l
- Sulphates - 250 mg/l

The Montserrat Water Authority does not have the laboratory facilities to undertake full chemical analyses and therefore samples required for analysis are sent to the Government Laboratory in Antigua However, they are able to carry out tests for chlorine residual, bacterial contamination, pH, total dissolved solids, fluorides, chlorides and sulphates, which are sufficient for the day to day control

Based on analyses carried out from December 1985, the spring water is generally of low total hardness and alkalinity with the corresponding low level of dissolved solids The water is also

acidic in nature, and from interpretation of the analytical results, this is due to a moderately high level of dissolved carbon dioxide. The consequence is that the water will be aggressive towards ferrous pipework.

The chemical oxygen demand was low, indicating only minimal contamination of the sources, though some determinations have been made recently which have indicated a slight increase. This may be readily controlled by dosing with chlorine as a disinfecting chemical. More recent chemical analysis, carried out in 1991 indicates some anomalies when compared with the earlier analysis, particularly regarding the pH, total dissolved solids and chlorides determinations at Lawyers and Hope Springs.

Based on the analyses, the water complies with the requirements of the World Health Organisation "Guidelines for Drinking Water Supply" published in 1984, for aesthetic quality. The pH of the spring source at Amersham and Mango Hill are slightly more acidic than the Guidelines recommend From the analysis of the water stored in Parsons Reservoir, it appears that the pH of the water had increased from previous testing, which could be as a result of the liberation of dissolved carbon dioxide.

The water from the two wells No. 4 and No 10 was slightly acidic in nature, although it is not possible from the results which were available to determine if this was due to dissolved carbon dioxide. The supply is of moderate hardness and alkalinity in considering the proximity of the sea, alkalinity as measured by chloride content is relatively low.

The values on nitrates and phosphates, which are indicative of contamination by fertilisers, were within the set guidelines. The result for the phosphate content of Well No 10 at 0 27 mg per litre is just within the European Economic Community Guideline of 0 4 mg per litre and well within the maximum admissible concentration of 5 mg per litre The Montserrat Water Authority would be well advised to check the supplies more frequently for concentrations of nitrates and phosphates in the future. In the current conditions however, this is not a priority but should be given significant consideration in the event of the use of these wells, and in the development of any service in the Belham Valley.

3.3.2 Rain Water

Recently, in addition to the chemical analysis of the water resources a similar analysis has been maintained for rainwater, to assist in a broader range of assessment of the impact of the volcanic activity.

The records available are from stations within the Unsafe Zone in the Weekes area, the Police Headquarters in Plymouth and the Amersham area.

The records indicated maintenance of low pH, as to be expected with the volcanic activity in the area and the formation of acid rain.

Total dissolved solids have been maintained at reasonable levels of acceptance, namely World Health Organisation Guidelines for Drinking Water, although there have been substantial increments at times, which are obviously due to localised impacts of rainfall.

Of the various monitors, the fluoride levels are the ones which would give some level of concern in that they are more frequently in excess of the 1.5 mg per litre Guideline level and in particular this exposes animals to risk, as piped supplies satisfy the human element.

Chlorides vary periodically outside of normally acceptable levels, but in general are within an acceptable range.

Sulphate levels have been the ones that have been maintained at lower than expected levels with a lower number of excess periods than the others monitored.

3.3.3 Spring Sources

The chemical analyses of the water sources do not reflect any significant change or impact from the variations in the rainwater analysis. In summary, pH levels have been maintained around seven (7) without any significant variations. Total dissolved solids have been maintained within acceptable WHO Guideline values as has been the case for fluorides, chlorides and sulphates, with a surprisingly low level of sulphate measurements and in most cases non detectable levels.

The bacteriological analysis of water sources does however give some degree of concern periodically, particularly the high faecal coliform counts in the springs in the north, with similar levels occurring along the west on a lesser basis. The foregoing are generally within the wetter periods, as to be expected, with significantly lower counts or zero during the dry period.

Recent spring and rainwater analyses are included in Appendix C.

3.3.4 Vulnerability

The vulnerability of water quality from the recent activities of the Soufriere Hills Volcano does not seem to be significant, but it has only been in recent time that significant ash falls have taken place within the Safe Zone area. Hence the need for more regular monitoring of the sources. This testing procedure will be of greater significance especially as the rainy season continues and leachate from settled ash penetrates the formation into the springs.

In the rainy season and for hurricane conditions, while the impact may be adverse on other sectors, such as vegetation, high rainfall may be beneficial to the long term water quality by flushing of ash from the catchment areas, if it was indeed having any impact, in particular on the acidity of the spring waters.

None of the source waters receive treatment other than disinfection by chlorine. The system is such that contamination can occur at a number of points, and for a number of reasons, between source and consumer. These include:-

- Surface runoff entering spring catchments.
- Improper or ill-fitting chamber covers;
- Unrestricted access for small animals;
- Low or no pressure in transmission and distribution mains.

Some spring flows are said to produce turbid water after very heavy rain and this is probably due to surface runoff finding its way into catchment chambers.

The Montserrat Water Authority, being aware of the susceptibility of the system to contamination, places great emphasis on disinfection and monitoring of chlorine residual and bacterial levels.

Disinfection is undertaken by the use of home made floating chlorinators in the major reservoirs, or in the case of Killiecrankie spring, in a chamber downstream of the spring

The chlorinators contain large tablets of hypochlorite which gradually releases chlorine into the water but close to the surface. The number of tablets used and the need to recharge the chlorinators is based on experience This is a "hit and miss" method of disinfection as the dosing is not related to flow and complete mixing cannot be assured as the reservoirs are

known to overflow, and during those periods the upper level of water which has received chlorination is being lost via the overflow.

In addition, disinfection is also practiced at the spring. This consists of sprinkling hypochlorite around the spring catchment, around the spring and in the catchment chambers. The benefit of this practice would be very short term since the available chlorine would be released relatively quickly, within hours rather than days, and each spring is normally visited only periodically, around once a week

The monitoring of sources for bacterial contamination shows periodically high counts. The reasons for the periodic high counts appear to be variable. In one instance the droppings from birds perched in the trees in the vicinity of the spring was considered the problem, which was resolved by cutting back the trees and vegetation.

After flash flooding, consumers are advised to boil drinking water. The main reason for this appears that the Environmental Health Department is concerned that water in the distribution system records little or zero chlorine residual at times.

3.3.5 Operational Aspects

From the time of Hurricane Hugo, the Authority's operations have been affected as a result of damage. While substantial recovery has since taken place, the recent events of the volcano have brought about significant dislocation, and they are currently operating out of residential accommodation in the Woodlands area The extent of operational detail from this base is not clear at this stage, but certainly in the existing conditions, the viability of the Authority as a self financing entity must be in question. As a result there will be significant dependency on emergency aid support at a time of keen competition for every dollar At the same time, the Authority has to be considering changes in the function of the systems to satisfy the shifting of demand for water.

Full time engineering support to the Authority is not currently available and is a major concern, not only with respect to day to day operations, but in terms of defining needs to satisfy the shifting demand, all at a time when demand for some staff's time on other operations in the emergency reduces critical availability, when additional resources are actually needed