Medical implications of the use of vehicle mounted water cannon (Issue 2.0)

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Release conditions

Authorisation (Complete as applicable)			
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Executive summary

The Northern Ireland Office and the Home Office have requested an independent opinion on the medical implications of the use of water cannon in public-order incidents. The DSAC Sub-committee on the Medical Implications of Less Lethal weapons (DOMILL) has been requested to provide this opinion. On behalf of DOMILL, Dstl Biomedical Sciences has undertaken a review of published information from a wide range of sources on the reported incidence world-wide of injuries from jets of water from water cannon. This is believed to be the first such review despite extensive use of water cannon by police and other agencies in many other countries.

There were no fatalities reported in the literature that were directly attributable to the impact of the jet in public order situations. The overall reported frequency of serious injuries was very low.

The report also describes injury by water impact in general and offers an overview of the dynamics of water jets.

The policy and guidance to users of water cannon are reviewed and scenarios in which personnel may be more susceptible to jets of water from either direct impact or the subsequent displacement of the body are presented.

List of contents

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1 Introduction

1.1 Background

1.1.1 Recommendations from the "Patten Report" [1] into policing in Northern Ireland include two specific items relating to the public-order equipment to be used by the Police. These recommendations, 69 and 70, are:

"69: An immediate and substantial investment should be made in a research programme to find an acceptable, effective and less potentially lethal alternative to the Plastic Baton Round (PBR)"

"70: The police should be equipped with a broader range of public order equipment than the RUC currently possess, so that a commander has a number of options at his/her disposal which might reduce reliance on, or defer resort to, the PBR." [1]

1.1.2 In Summer 2000, the Secretary of State for Northern Ireland, in consultation with the Home Secretary, established a UK-wide Steering Group led by the Patten Action Team (PAT) to lead a research project. The project was to (i) establish whether a less potentially lethal alternative to the baton round is available and (ii) review the public-order equipment which is presently available, or could be developed, in order to expand the range of tactical options available to Operational Commanders.

1.1.3 The Steering Group has taken steps to ensure that its work is consistent with the approach being adopted by the Association of Chief Police Officers of England, Wales and Northern Ireland (ACPO). In addition, contact has been made with a range of bodies with relevant expertise, including, for example, the National Institute of Justice and Pennsylvania State University in the USA.

1.1.4 The terms of Recommendation 69 require the PAT/ACPO teams to address three specific areas – acceptability, effectiveness and proportionality. The criteria for acceptability must be agreed within a UK framework and benchmarked against legal requirements, set out particularly in the Human Rights Act, 1998. There are three closely linked areas under which acceptability should be considered, these are human rights and legal requirements, ethical and cultural grounds and medical issues. The latter are considered in this report.

1.1.5 The PAT/ACPO committee has initiated a research programme entitled "Alternative Policing Approaches Towards the Management of Conflict" [2]. One strand of this programme is an in-depth review and assessment of currently available less lethal technologies and those at a development stage. The Police Scientific Development Branch (PSDB) has conducted this work. Five technologies are currently classed as Category A (i.e. *"devices, which may be the subject of immediate, more in-depth research*"):

- impact devices;
- chemical devices capable of being delivered at variable ranges;

- electrical devices;
- distraction devices;
- water cannon.

1.1.6 With regard to water cannon, further details in the Patten report [1] relate explicitly to public order Policing and the use of water cannon, thus:

"9.16…Another alternative worth exploring is the water cannon, where new technology has transformed what used to be a rather ineffective weapon into something which now looks more promising for police purposes. We know the Northern Ireland police are looking into this (and had water cannon available at Drumcree in July 1999), and we welcome that."

This led to the annual loan of Mol MSB 18 water cannon from the Belgian Gendarmerie and the production of Issue 1.0 of this report and the subsequent production of an interim medical statement for the use of these vehicles during the Summer of 2002 and 2003.

The Northern Ireland Office has since been given approval for a business case for the urgent purchase of water cannon, and after a competitive tender process, has purchased six Somati RCV 9000 vehicles.

1.2 Aim of this review

1.2.1 This report reviews the available literature on the medical implications of the deployment of water cannon. Dstl Biomedical Sciences has prepared it for submission to the Defence Scientific Advisory Committee (DSAC) on Medical Implications of Less Lethal weapons (DOMILL). The primary role of DOMILL is to provide the Secretary of State for Northern Ireland (and Ministers in the Home Office and Ministry of Defence) with an independent opinion on the medical implications of the use of less-lethal weapons.

1.2.2 Dstl and DOMILL were tasked to provide a final medical statement on water cannon by October 2002. At a meeting of some members the PAT-ACPO Steering Group on 20 December 2001, DOMILL was requested to provide an interim statement by February 2002; at a meeting of the Steering Group in January 2002 this was extended to March 2002. The interim statement was required to facilitate the consideration of a proposal for the future purchase of water cannon for use in Northern Ireland.

1.2.3 Given the short time-scales, the Steering Group was advised that the statement could only be considered expedient, covering a review of published and historical data, and limited calculations. The statement would not be able to address detailed technical assessment of water cannon output, or experimental trials using specific equipment. Version 1.0 of this report was the result of the literature review and was used by DOMILL to formulate their expedient statement issued in April 2002 [3] and to develop a technical plan for the detailed evaluation of water cannon vehicles (both the Mol MSB 18 and any successor to be used by the Police Service of Northern Ireland) [4].

1.2.4 The report is generic in nature; further work involving the specific devices to be deployed will be necessary and a medical evaluation programme is outlined herein. Specific judgement may then be made on the injury causing potential of a particular

system after consideration of the findings of this report (although this report is only relevant to the guidance contained herein) and testing of the vehicle of interest.

1.2.5 Issue 2.0 of this report is an update of the original report to reflect further information gained from the literature search and experience of operational and training use of the Mol water cannon in service in Northern Ireland. This report has also been updated to reflect the decision by the NIO and PSNI to purchase six water cannon [5]; which were confirmed as Somati RCV 9000 vehicles after a competitive tender process. The intention of this report is to provide a medical perspective to the use of water cannon. This can then be used in conjunction with operator's policy and guidance and physical testing of appropriate vehicles to formulate an appropriate medical statement. It is suggested, as in the case with the Somati RCV 9000, that the performance of a new vehicle is compared to the performance of an existing model with operational history.

1.2.6 This report reviews, in general, those aspects in the operation of water cannon that may affect the potential for causing injury through direct impact of the body, protected by normal clothing (primary injury). It does not consider the possibility of injury through, for example, impact with the water cannon vehicle or injury due to hypothermia.

1.3 Report Structure

1.3.1 **Section 2** of the report summarises the approach taken in the review and the databases and other sources searched for information directly or indirectly relevant to assessing the injurious effects of high-speed water. An overview of the outcome of the review is presented in **Section 3**; the more detailed review is in **Appendix A**. **Section 10** lists over 400 references considered in the review.

1.3.2 **Section 4** presents the information available on the Mol water cannon and the desired output of the water cannon specified in the NIO Business Case. A technical overview of water jet dynamics is also given.

1.3.3 **Section 5** reviews the performance of the Special Water Dispenser, a device developed by MOD in the late 1970's and early 1980's. The scope and outcome of the trials to underpin independent medical statements on the injury potential of its output are summarised. **Section 6** summarises the guidance to users of water cannon in NI and elsewhere; the verbatim draft ACPO guidance are in **Appendix B**. Dstl comments (from a medical perspective) on this Guidance are in **Appendix C**.

1.3.4 **Section 7** offers conclusions on the incidence of injuries from the operational use of water cannon extracted from the review of the literature, and scenarios in which personnel may be particularly susceptible to jets of water from either direct impact, or the subsequent displacement of the body. **Section 8** outlines the experimental and modelling programme employed to compare the performance of the Mol water cannon currently used in NI, and the water cannon procured on the basis of the NI Business Case – the Somati RCV 9000.

1.4 Classification and release

1.4.1 The classification of this report is set to reflect the inclusion of commercial and other protected information, some of which may have been provided on the understanding that it shall not be disseminated outside the UK Government or its advisers. Elements of work covered in this report - such as the development of the Special Water Dispenser and tests carried out to validate its performance - is protected information. This report must therefore not be downgraded, released or distributed further without consultation with Dstl.

2 Technical Approach

2.1 Scope of Study

2.1.1 The short time-scale for the initial study (under 3 months) precluded a detailed practical assessment and relied principally upon a review of the literature, supplemented with basic calculations on water jet characteristics. This theme has been continued in Issue 2.0 of this report to ensure consistency and to enable test reports on individual vehicles to be produced and direct comparison between the performance systems to be carried out (in conjunction with this report), to provide an overarching assessment case.

2.1.2 This work has been performed to examine the effects of a jet of water from a water cannon impacting humans during public-order policing only. This study only considers the use of vehicle mounted systems with a sighting system, operated by trained personnel, adhering to approved guidance for use of water cannon. This study has not considered the following, unless they are explicitly mentioned in the text:

- Injury from impact with the water cannon vehicle (not considered, as the scenario is applicable to all vehicle movements during public disorder).
- Injury to a person falling from the vehicle (either due to the ground impact or vehicle design).
- The longer term effect of hypothermia after become wet (it is assumed that medical attention will deal with this issue).
- The use of any additives to the water (such as irritants, surfactants or viscosifiers/thickening agents) that may be used to modify jet structure.
- The use of contaminated water.
- The psychological aspects of the use of water cannon.
- The use of water cannon in icy conditions.
- The use of water cannon in conditions where accuracy would be affected by high winds.
- The use of water cannon in conditions that have poor visibility (for example poor light, fog, rain/snow or smoke).
- The possibility of injury due to protestors' weapons carried during public disorder being dislodged or mis-aimed due to water cannon (e.g. the dropping of a petrol bomb in a crowd).

2.1.3 The following issues have not been considered in detail in this report, and require a more experimental assessment:

- The possibility of injury to an individual from impact with street furniture or other debris, energised by the water jet.
- Characterisation of the biologically effective loading of the water on the human body (i.e. the actual forces on the body wall arising from longitudinal perturbations in jet structure and dispersion of the jet down range).

- The injury from displacement of the individual, with subsequent contact with the ground or other hard surface.

2.1.4 This work has also examined some of the existing documentation used in the UK deployment of water cannon and makes recommendations for elaboration of this guidance.

2.2 Methodologies

2.2.1 Subject to the limitations outlined above, the approach adopted for this study (Issue 1.0) was as follows.

1. Review the technical information supplied on commercially available water cannon considered by PSDB, to gain an appreciation of their operation and potential problems.
2. Preliminary investigation of biomedical aspects, relating to technology use and deployment.
3. Review of existing data relating to water delivery devices from MoD archives, and review of published and "grey" literature (including biomedical and biomechanical information on water cannon and the possible effects on humans). Specifically:
   - Review of work carried out on the Special Water Dispenser (SWD), including reports and files from the (then) Chemical Defence Establishment relating to the medical implications of the SWD.
   - Information from peer-reviewed open literature, scientific and technical journals on the effects of high-pressure water devices on humans, either as a result of testing less lethal weapons or as a result of accident.
   - Information from resources which are not publicly available <redacted>.
   - Contact with water cannon manufacturers and suppliers to acquire medical information and equipment specifications, if available.
   - Newspaper and journal articles.
   - Internal police information relating to the use of water cannon.
   - Patent database search.
   - Review of websites reporting the use of water cannon and medical effects of their use.
   - International legislation or regulations on high-pressure water devices (non-weapon related).
   - Health recommendations made by groups using high pressure water devices, such as the fire service, cutters and welders, water cleaning systems, oil rigs and shock damping in mines.
   - Effects of medical therapies using water pressure.
4. The potential injuries from the use of water cannon (and related systems) have been the principal focus of the search and have included:
   - Primary injuries from being hit with a water jet.
   - Injuries from impact with an object propelled by the water jet (from a water cannon).

- Tertiary injuries resulting from being thrown against a static object, as a result of being hit by a water cannon jet, or hyperextension/hyperflexion injuries due to impact.
- How water interacts with the surface of the body.
- Models of water impacting upon the human body.
- Effects on eyes, ear, nose and body cavities.
- Injuries sustained from accidents in which people have hit water at high speed, e.g. jet ski, speed boat or water skiing.
- The effects of the flow of the water jet on the body.

5. Acquiring tolerance data to human body impacts from various sources.
6. Assessment of the applicability of earlier work carried out on the performance and the injury potential of the SWD and the suitability of the SWD work to the study of water cannon.
7. Examination of the methods of determining the injury causing potential of water cannon.

2.2.2 The limitations of any models used in this study have been explicitly stated.

2.2.3 Issue 2.0 of this report incorporates a review of the literature published since Issue 1.0 and has been updated in the light of new information or experience gained during testing.

2.3 Terminology

2.3.1 Physical units

2.3.1.1 SI units have been used throughout this report, however where units have been converted, the original value and unit is also quoted in the text.

2.3.1.2 Water pressure measurements are read in bar, where 1 bar = 10^5 Pa = 10^5 N/m^2, and 1 atmosphere = 1.0125 bar. Note also 1 bar = 14.7 psi.

2.3.13 Comments relating to pressure have been taken from the reports in the context in which they have been used. If not explicitly stated whether the pressure is static or dynamic, it has been left to the reader to decide the applicability. The usage in many cases may be assumed from the context in which the work was carried out. For example, if the pressure refers to a free stream in atmospheric air, the pressure should be assumed as being dynamic. If the pressure refers to pump pressure or output pressure, then this may be the static or dynamic pressure.

2.3.2 Injury causes

2.3.2.1 In this report, injuries may be referred to as primary, secondary or tertiary injuries:

- Primary injuries are defined as those caused directly by the energy of a water jet impacting the human body (including hyperextension/hyperflexion injuries).
- Secondary injuries are defined as those caused by the impact on the human body of street furniture or other debris, energised by the water jet.
- Tertiary injuries are defined as those caused by impact of the body with other items, as a result of the initial event, such as being thrown against a wall or falling.

3 Review of Published Material

3.1 Methodology

3.1.1 For a detailed search of the world's literature, professional information scientists from Dstl Knowledge Services employed a number of databases. All codes were selected for their comprehensive array of relevant aspects to this study, with records drawn from world-wide primary and secondary sources.

3.1.2 Little information could be found recording the medical implications of use of water cannon directly, therefore the literature search also examined injuries from systems that could be regarded as having similar methods of operation that may cause injury. These included:

- Injuries attibutable to fire fighting water jets;
- Surgery using high power water jets as a scalpal;
- High pressure injection complications;
- Paint gun injuries;
- Childrens' water toys;
- Injuries from dropping water on fires using aircraft.

3.1.3 To supplement the literature search described above, a review of data/articles posted on the world-wide web and in newspapers/periodicals was undertaken, with the aim of ascertaining the type, incidence, severity and cause of injuries attributed to the deployment of water cannon. Additionally, a number of non-peer reviewed reports were obtained.

3.1.4 Dstl Knowledge Services, employing standard databases, reviewed newspaper and media articles. Internet sites were also reviewed and the authors have examined over 100 websites and referenced them below, where appropriate.

3.1.5 In total, over 580 references were collected from the peer-reviewed literature, periodicals and newspapers, patents and Internet pages. These were acquired, translated, where appropriate, and read; relevant aspects are reported herein.

3.1.6 A substantive review is detailed in Appendix A of this report; pertinent details are reported below.

3.2 Reports on Water Cannon Usage

3.2.1 Only one peer-reviewed report detailing injuries attributable to water cannon has been obtained [26], following the extensive literature search described above. The review found over 200 website and newspaper articles pertaining to the use of water cannon.

3.2.2 Where injuries have been reported in articles referring to the deployment of water cannon, it has not been possible to attribute the injury recorded directly to the water jet from the cannon. On many occasions, the security forces have also used other equipment such as batons, baton rounds, irritants, vehicle charge or live ammunition.

3.2.3 Two technical reports [9, 10] detailing experimental deployment of water cannon against humans have been reviewed; these have provided indications of the force (given distance, nozzle pressures and flow rate) needed to initiate the knock-down or restraint against the jet of a subject.

3.2.4 Similarly, <redacted>, has measured the force:distance properties of the <redacted> [11]. This compared the output of the system against gunshot and baseball injury criteria - there was poor correlation with injury.

3.2.5 A report from British Society for Social Responsibility in Science [17] on the use of water cannon states is that *'water cannon very rarely cause death or serious injuries. (Though there is some danger from flying debris and glass if the jet hits buildings or loose material; and injuries can be caused particularly to women or children who have fallen down, as they can be rolled along the ground by the force of the jet.)'* **.**

3.3 Reported Injuries and Injury Potential

3.3.1 As alluded to in Section 3.2, where injuries have been reported related to the deployment of water cannon, few can be attributed directly to the water jet itself. Reports have been reviewed citing eye irritation, head, neck and back injuries, although the exact detail of the injury and severity has not been recorded, and in all cases tear gas and live ammunition were also used.

3.3.2 One case of a fatality from the use of a water cannon has been reported on a website [147] but the exact circumstances of this incident have not been available. In this case, a prison warden allegedly tortured and killed an inmate with a water cannon blast whilst the inmate was tightly restrained in leather handcuffs (which in turn have been criticised as a possible violation of the UN convention against torture).

3.3.3 There is one report that German police used water cannon to clear railway tracks during a protest *'which lead to several injuries'* [211]; some of which were caused to people hidden by a petrol-dowsed barricade [332]. The water cannon crew decided to soak and disperse the barricade to prevent ignition of the barricade, by increasing the water pressure gradually. Bruises and rib fractures were caused to the protestors hidden inside the barricade.

3.3.4 Given the paucity of data relating to injury caused by the water jet from a water cannon, the literature search was expanded to encompass all potentially injurious water impacts.

3.3.5 A review of patents on water cannon and water moving equipment and technical standards on fire-fighting equipment, produced no information on performance or injury risk. The hydrodynamic character of water jets used in the food and medical areas was found not to be comparable with water cannon output and provided no relevant information to this study.

3.3.6 The search has identified several areas of the human body potentially at risk from water impact, principally head/neck, eyes and ears.

3.4 Police use

3.4.1 Water cannon manufacturers, Police Service of Northern Ireland, Belgian Federal Police and German Border Guard have been contacted with regard to reported injuries from the use of water cannon during their operations.

3.4.2 The <redacted> have reported two injuries with water cannon [437], both of which occurred during training. The first occurred about ten years ago, when a volunteer jumped in front of the water cannon and was hit in the face. The volunteer suffered an eye injury, and was treated at the local hospital – apparently, there was no permanent damage (no records available). The second incident occurred when a police officer ran in front of the cannon and was hit with the water jet at full power (at about 20 bar), at a distance of 4 or 5 m in front of the water cannon. He fell down on the pavement and sustained a shoulder injury. The <redacted> first started using water cannon shortly after the Second World War and state that literally thousands of people have been hit with water jets [438]. They report that their vehicles are deployed on average three times per week to public events, but could not confirm how often they are used.

3.4.3 PSNI have reported no injuries from the use of water cannon during their policing operations.

3.4.4 Injuries reported by the <redacted> are as described in 3.3.2 above and a protestor was evidently run over by a water cannon [333]. Water cannon have been used in <redacted> since 1968 – no detailed information relating to the amount of use of these vehicles have been kept [334], however it is estimated that they are deployed and used about 30 times per year [335].

3.4.5 The <redacted> and <redacted> companies have not reported any injuries from the use of their Water <redacted> [11-16].

4 Water Cannon Output and Jet Dynamics

4.1 Examination of water cannon outputs

4.1.1 Two commercially available water cannon were initially relevant to this study, namely the MOL CY NV MSB 18, owned by the Belgian Police [357] and used by the RUC (now PSNI), and the Ziegler WaWe 9 [357, 358]. These vehicles were considered the most likely to be deployed in Northern Ireland, so these were initially considered. The latter met the specification laid out for the purchase of a water cannon by PSNI (see Business Case [359])[1]. The output of these devices was considered against the technical information available to examine the forces produced by these jets.

4.1.2 Technical information for the vehicles has been provided by PSDB [357] and manufacturers [358]; the data supplied is not exhaustive and further information was been requested [433-435] and incorporated into the review.

4.1.3 The Ziegler WaWe 9 is reported to having the following capabilities:

- Two monitor[2] assemblies and maximum flow rate of 1,200 litres/min per monitor (= 20 litres per second);
- Operating pressure of 15 bar (assumed dynamic water pressure, rather than static pump pressure);
- Maximum throw: 67 m.

4.1.4 The Mol CY NV MSB 18 is reported as being capable of delivering the following:

- Flow rate 900 litres per minute (= 15 litres per second);
- Operating pressure adjustable between 5 and 25 bar;
- Maximum throw: 60 m (both cannons working simultaneously.

4.1.5 The water monitors and jet from Zeigler and Mol water cannon are shown in Figure 1 and 2 respectively.

[1]The decision on which vehicle to finally purchase was decided after a competitive tender process. Somati were the successful competition winners.
[2]Monitor – the water nozzle and pipe assembly

Figure 1 - Zeigler water monitors

Figure 2 - Water jet from a Mol water cannon

4.1.6 The Mol vehicles have been loaned from the Belgian Gendarmerie and used in Northern Ireland during the Summers of 2002 and 2003, since the issue of the interim medical statement [3]. These vehicles were tested in October 2002, against the technical plan [4], to provide baseline results to contribute to the background evidence for the issue of the final medical statement for any new vehicles.

4.1.7 After the decision to purchase new water cannon was made by the NIO [5], it became apparent that the vehicle purchased would not be the Mol (because it was no longer manufactured) or the Ziegler WaWe 9 (because it could not meet some of the functional aspects of the PSNI specification). A different vehicle would therefore be purchased – the Somati RCV 9000. This is a new vehicle and no data was available at the time of writing of this document concerning the operational experience.

4.1.8 The Somati RCV 9000 was reported as being capable of:

- Flow rate approximately 20 litres per second through each monitor.
- Maximum operating pump pressure of 15 bar, which can be reduced by the cannon controller or the cannoneers.
- Tank capacity 9000 litres.

4.2 Water Jet Dynamics

4.2.1 Fluid flow is characterised by a dimensionless parameter called Reynolds Number ($Re=Vd\rho/\mu=Vd/\nu$, V = velocity of water, d = diameter of pipe, ρ= density, μ = viscosity, and $\nu=\mu/\rho$= kinematic viscosity). At low values of Reynolds Number the flow will be laminar and at high values turbulent. This transition takes place when $Re \approx 2000$ for a Newtonian fluid [304]. For water, $\mu = 1 \times 10^{-6}$ m^2s^{-1}, thus the transition from laminar flow starts to occur when $V.d \approx 0.002$ (in practice, for a nozzle diameter of 16 mm, this occurs at $V \approx 0.125$ ms^{-1}).

4.2.2 At a certain distance downstream, the water jet starts to show instabilities; these grow until breaks in the jet finally appear. This break up point has various definitions, but is normally defined by the point where the jet is continuous 50% of the time. If this is plotted experimentally with time for a particular fluid and nozzle combination, a curve similar to that shown in Figure 3 can be plotted, showing a laminar, transition and turbulent region.

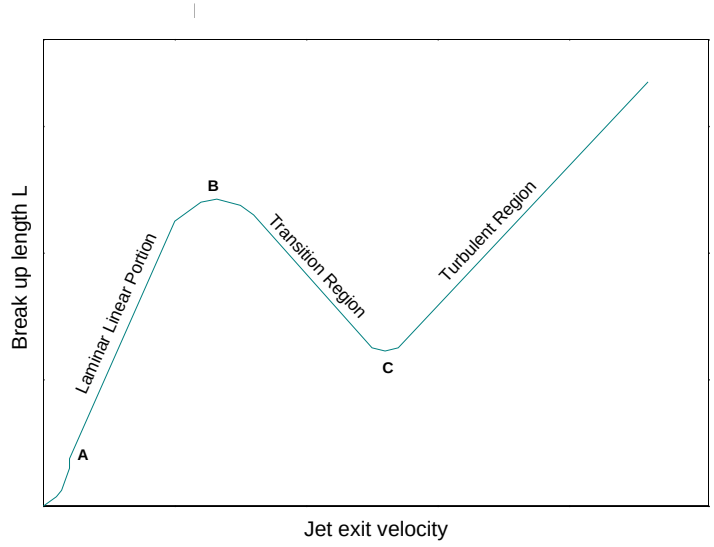

Figure 3 - Effect of velocity on break-up length

4.2.3 The laminar portion of this graph is best understood where the jet length increases with increasing efflux velocity. Here the most important factor is surface tension, where lowering the surface tension increases the break-up length [336].

4.2.4 Beyond a certain efflux velocity B, the unbroken length decreases with increasing jet velocity; this is when the flow starts to become sinuous and resistance of the air to the passage of the humps becomes more important than the surface tension [336]. At even higher velocities, the stream becomes purely turbulent where haphazard secondary motion produces eddies that are carried along with the flow. At Reynolds Numbers above 25,000, water jets begin to shed droplets because the surface tension is no longer able to restrain the eddy forces.

4.2.5 At even higher speeds, the inertia is too great to allow oscillations and the air and water interpenetrate along mutual boundary layers, resulting in a high velocity coherent core,

surrounded by an annular cloud of water moving in an entrained air stream [336, 337].

4.2.6 Rajaratnam et al [337] have examined the velocity profiles of very high pressure water jets in air. Their work was carried out with jets at speeds of 85-160 ms^{-1} and nozzle diameters of 2, 2.5 and 3 mm (Reynolds Numbers in the range 255600 to 320000). Their work found that the maximum velocity remained constant up to 100d (where d is the diameter of the jet), and then decayed continuously to 25% of the exit velocity at 2500d. They found that the water jet forms a central coherent core that had a linear growth rate of 0.007 on the radius with axial distance and a growth rate of 0.07 for the whole jet (i.e. the annular section of water and entrained air).

4.2.7 Further work by Rajaratnam and Albers [338] has shown that water concentration reduces rapidly with axial distance (axial water concentration 20% at x/d = 20, axial water concentration 2% at x/d = 200). This means dynamic pressure will also reduce.

4.2.8 The reduction in water concentration and increase in jet diameter means that air is entrained into the stream. The momentum flux of the jet will stay constant if the creation and shedding of water droplets is ignored. The result is that the velocity of the water/air jet will also reduce accounting for the reduction in dynamic pressure.

4.2.9 Work has also been carried out by Yanaida [339], Yanaida and Obashi [340, 341]; they have produced formulae for the velocity and pressure profile of turbulent water jets. This requires experimental validation of coefficients to describe the jet, however this approach yields useful graphs of the reduction in pressure of a jet with distance. Typically, the pressure on the jet centreline will half within 280 x the nozzle diameter with a flow with a Reynolds Number greater than 170000. Their work also characterised the flow of this type of jet into several sections, as defined in Figure 4. It is also possible to improve the range of the water jet with additives that change the physical properties of the water [342], however this is outside the scope of this current assessment.

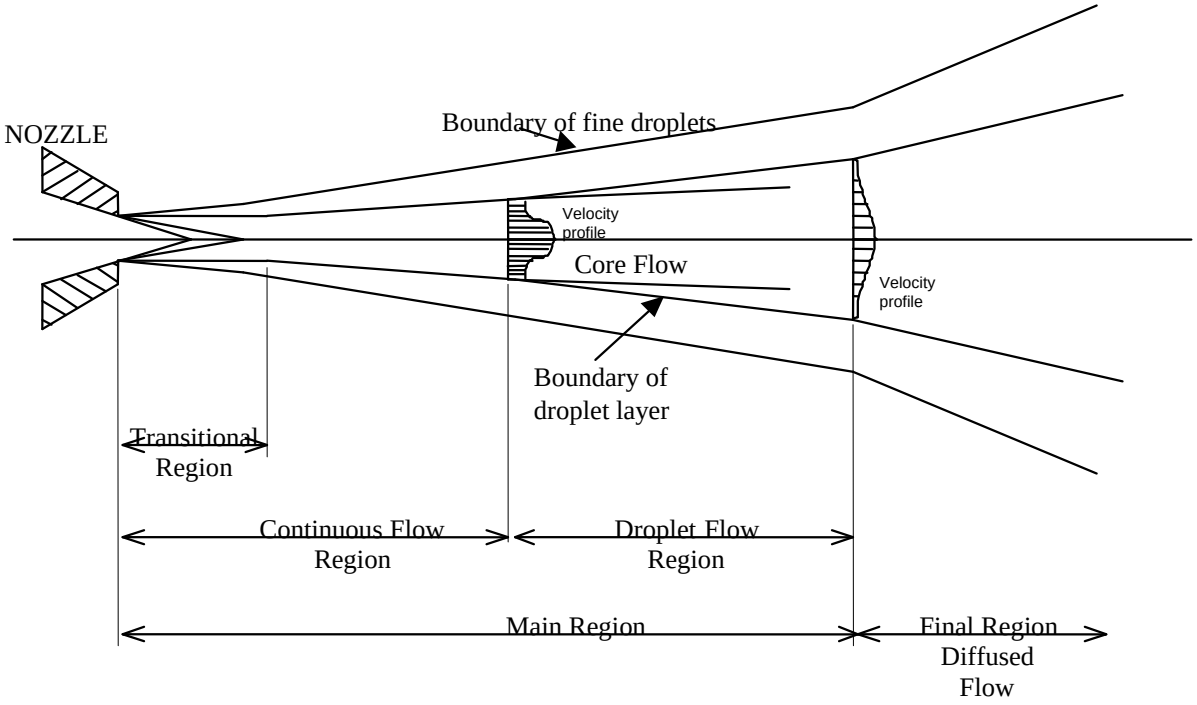

Figure 4 - Schematic diagram of turbulent jet in free air

5 Historical equipment

5.1 Special Water Dispenser (SWD)

5.1.1 The Special Water Dispenser (SWD) was an armoured vehicle designed to assist in the dispersal of aggressive crowds and the method employed was to effect knock-down of ring-leaders for subsequent arrest [343-346]. This vehicle was never deployed against crowds however there was a significant amount of work carried out in the late 1970's to assess the injury potential from this device, culminating in the issue of statements by the <redacted> (equivalent to DSAC today). The SWD is shown in Figure 5.

Figure 5 - Special Water Dispenser (SWD)

5.1.2 The SWD fired a bolus of water using a piston and in this respect differs significantly from modern water cannon, where the loads from the jet may be less impulsive during the growth of the stream, or the sweeping of the jet.

5.1.3 Tests were carried out against animals, to assess the injury causing potential. These tests included water shots against anaesthetised sheep [346] and pig eyes [34, 35]. Tests also included water shots against temporal bones [48] and examinations to determine whether head and neck injury could be caused by the equipment. The whole of this programme of work was never formally compiled in technical reports, but is contained within MoD files of the period [346, 348]. The principal findings were:

- Knock-down without serious injury was achievable by the SWD with a momentum delivery of 125 $kgms^{-1}$ (or an average energy delivery of 120J) in 0.2 seconds (i.e. a force of 625N) [336].
- Some minor lung contusion was possible (not requiring hospital treatment).
- To determine the potential of head and neck injury would have required the use of

large anaesthetised primates and it was therefore considered not possible to conduct.

- Mathematical models were not sufficiently advanced or validated to give a realistic prediction of injury.

- Characterisation of the water jet was problematic and insufficient to describe the force on the head/neck.

5.1.4 To assess head injury, it was necessary to investigate the response of a dummy head/neck to the force of the SWD output in pulse mode and apply standard automotive injury criteria at that time. These injury criteria were:

- The Gadd Severity Index;

- Comparison of the head acceleration pulse with the Wayne State Tolerance Curve;

- Calculation of the maximum angular rotation, velocity and acceleration.

5.1.5 The head impact injury assessment was carried out in two stages using an Ogle dummy head [346]. In the first, the head/neck assembly was attached to a free standing 5 foot high structure, simulating a man, and in the second set, the head/neck was rigidly mounted. The work found that none of the parameters measured gave values high enough to cause concern, however it was emphasised in the notes that these were only carried out with a limited number of tests.

5.1.6 The SWD underwent a significant amount of proving to assess its performance, repeatability, operational issues and the likelihood for causing injury. Early work was carried out using a prototype static cannon system. This provided initial details for the characterisation of the water pulse and the potential for injury. The system was then integrated into a vehicle and some confirmatory tests carried out on performance. These confirmatory tests found that the vehicle-mounted system was more aggressive than the prototype, and for the same mass charge, flow rate and nozzle exit velocity gave substantially different readings to the prototype static rig [349, 350].

5.1.7 It was later found that the integration of the system into the armoured vehicle required the change of plumbing and one valve in particular. The replacement valve and the original had ostensibly the same performance, but provided substantially different output by making the piston (ejecting the water charge) accelerate through the stroke. This had the effect of making the vehicle-mounted system more dangerous than the static system.

5.1.8 This has implications for the current evaluation of water cannon. A water cannon cannot be regarded as a generic item and each design must be considered individually. Additionally, the use of rotating parts in the pump system for the water cannon has raised the belief that the water flow cannot be assumed to be an ‘averaged’ constant flow – there may be higher energy pockets within the stream that should not be ignored.

5.2 SWD injury criterion

5.2.1 Sheep were also used to assess the potential of injury due to water impact. This lead to the observation that the momentum was the significant factor in the causation of injury [351] and that a momentum of greater than 125 $kgms^{-1}$ may cause injury. The reason why momentum, rather than energy, was a better characterisation of injury was never fully explained. It was believed that the dynamics of the water droplets in the spray was a significant factor, and since the momentum calculation was based upon average velocity, the dynamics of the jet meant that it had packets of higher energy material in an otherwise non-injurious pulse of water. This was never fully investigated, however it re-affirms the belief that water jet impact with the human body can not be regarded as a generic problem.

5.2.2 The momentum change of approximately 125 $kgms^{-1}$ was delivered by the SWD in approximately 0.2 seconds, producing an average force of 625N which may be equated to the 700N hose reaction produced by a 25.4 mm (1") diameter fire hose operating at 6.89 bar (100 psi). This is about the limit of hose reaction that can be held by one man [336].

5.2.3 Tests on a similar device were also carried out in the <redacted> at higher energies (in excess of 220J) [352]. These tests caused isolated cases of liver lesions, arrhythmia, fractured ribs and haemothorax, however the force profiles against the animals were not constant during the impact (they contained some high-energy phases).

5.3 Medical Statements relating to the SWD

5.3.1 In March 1976, the Independent Members of the "Medical Committee on the Hazards of Primary Injury from the Special Water Dispenser", issued a statement on the risks of primary injury from the SWD (D/DS10/44/21). The statement noted that "the SWD fires a 'slug' of water (about 5.5kg) with enough force to knock down malefactors. It is intended for use only against hard-core rioters. It will be used only by personnel trained in its use. Aimed fire will therefore be possible against selected targets and the slugs will always be directed at the trunk".

5.3.2 The Committee considered that, "used under these circumstances, the risk of injury to the trunk is negligible. However, it appears that there is about a 3% chance of head strikes, of which half may involve the eye or ear. There is a possibility of ocular or aural injury from these, but even so, in the majority of cases, there would be no permanent damage. The risk of fatal primary injury from the SWD is very low. In general, the hazards from the SWD appear to be similar to those inherent in the use of water cannon and baton round".

5.3.3 A further statement was proposed on "The Possibility of Secondary Injury from the SWD" <redacted>

5.3.4 The proposed statement read "The Trauma sub-group of the Medical Committee has considered the possibility of hazard from knock-down by the SWD at the request of the Secretary of State, Northern Ireland. In reaching their conclusions, they have taken into

account known values of energy transmitted by the SWD on impact. Results were also available of recent high speed cine studies of its effects on 70 kg dummies, rather than on the much lighter 12 kg ones used in the demonstration for the Secretary of State. *<redacted>*

5.3.5 "The energy imparted by the SWD is comparable to that delivered by a blow from a fist. It is probable that a man struck in the chest would lose his balance initially, but would be able to break his fall. If the impact accidentally involved the head, it is unlikely that the concussion would be caused. A fall onto a concrete surface would not be expected to cause skull fracture or other serious injury, since normal reflexes would be preserved. The risk of a spontaneous fall in a person without intact reflexes, for example a drunken man, would be greater".

5.3.6 "It appears, therefore, that the risk of secondary injury due to knockdown resulting from an impact by the SWD is small, and is comparable to that from a disposable baton round. However, the complexity of the many biophysical factors involved makes it impossible either to exclude such injury with certainty or to design further useful experiments which would allow this to be done".

5.4 Relevance to Current Study

5.4.1 The SWD data has been presented in some detail because wide-ranging tests were undertaken. It is not possible to determine currently whether these data and the SWD momentum based criterion have applicability to the output of water cannon. It is unwise to blindly apply the calculated values of current and future water cannon output to the SWD criterion, due to the significant differences in design.

5.4.2 The experience gained from the SWD is useful because of the background work on the operational considerations and the work on unbalancing people, but the comparison between the injury criteria and the use of water cannon to appropriate guidance is limited.

6 Assessment of guidance for use of water cannon and training

6.1 Police Guidance for water cannon use

6.1.1 The mode of operation and deployment of the water cannon may be the most important factors to consider in assessing the likelihood of injury that may be caused. Issue 1.0 of this report reviewed and commented on the initial instructions for the Police use of water cannon [352]. However, this has been reviewed again, since it was initially published and incorporated many of the comments that were previously raised. This document has now been submitted for ACPO approval (13 October 2003 and 1 December 2003) as guidance with applicability across all UK Police Forces [439-441].

6.1.2 Guidelines for the Police use of water cannon have been provided, which gives the tactical command structure for the deployment of water cannon [Ref. 440 and reproduced in Appendix B]. This Guidance has been approved by ACPO and will be incorporated into the appropriate tactic manuals [441]. It is seen as essential that this incorporation includes all the safety aspects mentioned in the Approved Guidelines.

6.1.3 The Chief Constable delegates authority for the deployment of water cannon to Regional Assistant Chief Constables; specific tactical objectives are drawn up by the Silver Commander and agreed with the Gold Commander to be implemented by the Bronze Commander. The instructions state that *'Water cannon will only be deployed following the appropriate threat and risk assessments, however in certain situations where there is limited time for detailed planning, commanders may have to undertake real time dynamic threat and risk assessments*' (see paragraph B.3.7).

6.1.4 It is also worth noting that despite the planning, the guidelines state (paragraph B.11.2) that *'In undertaking this role the operators must take account of the considerations set out in paragraphs 3.1 to 3.8 of this guidance'* (paragraphs 3.1. to 3.8 refer to the potential injuries, and threat and risk assessments). The law with which they must comply is also laid out in the guidelines, but also highlights, from a training perspective, the need for a training course to incorporate a briefing on the injury risks, and also from a maintenance perspective for the vehicle to perform as expected by the operator and for the operator to understand the difference between individual vehicles of the same design. It is also important that the operator is aware of any modification to systems since the last use.

6.1.5 The review of the RUC (PSNI) instructions for the Police use of Water Cannon [352] raised many concerns that were relayed to PSNI. The ownership of this document has now moved to ACPO and draft guidance was issued during this review. These have been compared with the existing review (see Appendix C) and most comments have now been incorporated. There are still operational issues with the current vehicle designs (such as ensuring the calibation of sensors and ensuring familiarity with particular vehicles) and the training of staff, that need to be resolved. Specifically, the current PSNI staff have been trained by the Belgian Police, but future training will be given internally. The nature of the syllabus for this course needs to be reviewed and levels for assessment of competence need to be set. This training should explicitly include instruction on the

medical implications and an understanding of the injuries that may be caused by water cannon.

6.2 Other water cannon guidance

6.2.1 Guidance has been produced for the training of water cannon crews [333] and also in seminar documents [355] which recommend the maximum jet pipe output pressures as:

- 15 bar for a subject greater than 10 m away;
- 20 bar for a subject greater than 15 m away.

The values are derived from the work of <redacted> [356], in a paper reportedly written to defend the actions of the <redacted> following an injury [332] during a protest [211] (reported in Section 3.2). These are for a particular cannon design, similar to the Ziegler WaWe 9, and are based upon the forces produced on pressure plates at a defined range. Limited information is available on the origin and specification of these settings. They are not appropriate for all types of water cannon because the pressure is measured at different stages in the system, and are of very limited use unless it is possible to provide accurate range measurement. It is more realistic to use a graduated response until the specific objective is achieved, rather than use pressure:range guidance that may be either excessive or cannot be proven.

7 Conclusions

7.1 This has been a review undertaken by Dstl to enable DOMILL to produce a statement for the Secretary of State for Northern Ireland and Home Department Ministers on injuries from water cannon. Experimental tests have been undertaken by Dstl on the Mol CY NV MSB 18 and the Somati RCV9000; these will be reported elsewhere, and this report should only be used in conjunction with those trials reports in the production of a final medical statement for the use of water cannon in Northern Ireland. In writing this report, Dstl has relied on the limited information provided by the manufacturers and users to undertake simple calculations to assess the output of the devices. On this basis and the review of a diverse body of literature - little of which had direct, substantiated relevance to the medical consequences of the operational use of water cannon or its use in training – the following conclusions are offered.

7.2 There was no evidence in the peer-reviewed journals, press, police or fringe literature reviewed that any person has been killed by the direct impact of a jet from a water cannon in operational use (although there was one unconfirmed case where the victim was reported as being subjected to wholly inappropriate use of water jets). This should not be interpreted to imply that water cannon are incapable of inflicting fatal injury, under operational conditions. This statement encompasses primary, secondary and tertiary injury.

7.3 There was an extremely low incidence of injuries attributed to, or actually caused by water cannon in the world-wide literature, that could be classed as life threatening.

7.4 The Belgian and German police authorities, and the PSNI have not reported instances of serious or life-threatening injuries that could be attributed to the use of the Mol CY NV MSB 18 or Ziegler water cannon.

7.5 In public-order incidents in which water cannon are deployed, it may be difficult to differentiate injuries arising directly from its use, or from other sources of trauma such as batons, kinetic energy projectiles or irritants. This clouded the review of all sources of published information on the use of water cannon, and will have implications for assigning injuries arising from future deployments, in the audit of their use.

7.6 The behaviour of free water jets is complex. Although the bulk properties of a jet of water could be calculated (mass flow rate; average jet velocity), it is extremely unlikely that the effective loading on the body could be calculated from first principles. The distribution of energy in the jet can be altered by ostensibly minor changes in pump/nozzle characteristics, with little overt effect on bulk output. This has three consequences:

- the effective loads on the body must be determined experimentally;
- all evaluations must be undertaken on operational equipment, not prototypes or rigs;
- more than one example of each specific water cannon should be evaluated.

7.7 The ACPO training doctrine should include reference that there is a enhanced risk of injury under the following circumstances:

- jets directed at the ground in front of personnel where there may be debris or gravel on the ground, or street furniture that may be projected at the person;
- jets striking the head, even peripherally;
- jets interacting, even peripherally, with personnel using optical equipment or with the equipment (cameras etc) directly;
- personnel adjacent to obstacles such as walls, barricades and vehicles, or lying on the ground;
- personnel on top of structures (walls, vehicles) who may be toppled by the jet;
- to people adjacent to weak structures (such as weak walls or windows) that may collapse under the water jet pressure;
- to people who may be pushed into a dangerous position (such as the path of a moving vehicle);
- to people who are struck by two jets simultaneously;
- children, the elderly and small adults struck by the jet.

Dstl recognises that use in these scenarios is an issue of proportionality within existing guidance and standards, but users must remain aware of the enhanced injury potential.

8 Recommendations

8.1 A medical statement should only be produced after assessment of the performance of the water jet output of a water cannon, in particular with reference to:

a. Measurement of the bulk fluid output and comparison against an existing vehicle design with a known history of use.

b. Definition of the biologically effective loading within the jets using instrumentation that will measure force/time profiles.

c. Measurement of the contact velocity/acceleration of the head with a rigid object such as a wall or the ground; this could be achieved using Hybrid III anthropomorphic dummies.

d. Measurement of the initial linear and rotational acceleration of the head/neck assembly following direct or sweeping interaction of the jet with the head, and with the torso. This could be undertaken using the Hybrid III.

e. The distribution of representative debris accelerated by the cannon directed to the ground, and the potential for specific injuries such as ocular trauma.

f. The risk of primary injury to the torso and head assessed models such as:

- the chest deflection gauge in the Hybrid III, which could be used to calculate the Viscous Criterion[3];
- an instrumentation system that would determine the forces to the tympanic membrane and the eye.

8.2 In the light of the experience with the SWD, it is recommended that DOMILL does not issue a final statement until tests have been completed on the operational equipment delivered for use.

8.3 A medical statement should be written in the context of defined guidance.

8.4 A medical statement should be subject to periodic review to assess its validity in the light of new evidence on the effects of water cannon.

[3] The Viscous Criterion is an index used in the automotive injury to predict the severity of torso injury. It is the instantaneous product of body wall deflection and the body wall velocity.

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11 Glossary

ACPO	Association of Chief Police Officers
DOMILL	DSAC sub-committee on Medical Implications of Less Lethal Weapons
DSAC	Defence Scientific Advisory Council
DTIC	Defense Technical Information Centre
HIC	Head Injury Criterion
MSC	Mean Strain Criterion
PAT	Patten Action Team
PBR	Plastic Baton Round
PSDB	Police Scientific Development Branch
PSNI	Police Service of Northern Ireland
RUC	Royal Ulster Constabulary (now PSNI)
SWD	Special Water Dispenser

Appendix A Review of Published Material

A.1 Reports on Water Cannon Usage

A.1.1 This search has included a review of websites and newspaper reports on water cannon, reported uses and attributed injuries. The review found over 140 websites and 90 newspaper references pertaining to water cannon. None of those reporting the use of water cannon detailed any injuries that could be directly attributed to water cannon, although some contained comments such as *'There were dozens of injuries as black-clad demonstrators threw rock at the police, who replied with water cannon, and tear gas'* [6]. It is not known whether these injuries were due to the water cannon itself or other factors (such as the use of batons). Two websites in particular referred to injury that may be caused by water cannon and included the following statements, referring to possible problems or experience of water cannon use:

- 'gauging appropriate levels of force, and the possibility of causing serious or fatal injuries to a subject' [7]
- water cannon can cause '..head/eye injuries and particularly if directed at supine body' [8]
- reported case of a person freezing to death after being sprayed by a water cannon [8].

These are obviously important considerations, but are not substantiated.

A.1.2 Newspaper and internet citations have generally fallen into the following categories: political and personal comments on water cannon [104-121], the export and sale of water cannon [7, 122-138], manufacturers' data [139-146] and occasions when water cannon have been used [147-329]. Where injuries have been reported in articles referring to the deployment of water cannon, it has not been possible to attribute the injury recorded directly to the water jet from the cannon. On many occasions, the security forces have also used other equipment, such as batons, baton rounds, CS, vehicle charges and live ammunition. Only those reports that have raised points directly relevant to water cannon are discussed in the following sections.

A.1.3 One report [147] has related directly to the fatality of a person from a water cannon. The article in question was discussing the abuse of Japanese prisoners by wardens. The particular incident in question was also related to the use of leather handcuffs, which were also '*criticized as a possible violation of the U.N. convention against torture – are wrapped tightly around an inmate's waist, with one hand strapped to the front and the other to the back.'* The report states:

'A warden at Nagoya Prision was arrested last month for allegedly torturing and killing an inmate two years ago with a water cannon blast while the inmate was tightly restrained in leather handcuffs.'

No further information could be obtained about this incident, but this demonstrates that fatal injuries are possible under certain circumstances, but operation under these circumstances would be outside the guidelines for the use of water cannon within the UK.

A.1.4 Two technical reports of tests on human subjects using water cannon systems to assess the suitability of these devices for crowd control were reviewed, - <redacted> [9] and <redacted> [10]. In both, prototype water cannon were evaluated; the reports gave details of the maximum sustainable force and effects on the human body. <redacted> water cannon tests [9] found that a force of 310-445 N (70-100 lb) was sufficient to initiate a knockdown and possibly sweep away a 104 kg (230 lb) man. The author of this report was also concerned about the water jet hitting the subject's head when approaching the nozzle and formed the opinion that it was possible for the water jet to cause injury at close range. No detail was given reporting the type or severity of injury that may be expected. This work also found that the distance which the subject could approach the water cannon was affected by the mass of the subject, with lighter people finding it more difficult to approach the water cannon than heavier people.

A.1.5 This work also found that the accuracy of the water cannon was affected by wind [9], which may be a significant factor to consider when assessing the aim point of a water cannon in poor weather.

A.1.6 <redacted> [10] refers to a <redacted> water cannon tested against human subjects, which could operate in either steady or pulsed stream modes. With a steady stream, the jet was capable of holding a 200 lb man at 22.9 m (75 feet), at a nozzle pressure of 11.1 bar (160 psi), nozzle diameter of 15.9 mm (5/8 inches) and flow rate of 12.1 litres per second (158 gallons per minute). This holding distance could be increased to 24.4 m (80 feet) if the nozzle pressure was increased to 13.2 bar (190 psi) and flow rate to 12.8 lps (168 gpm). At these distances the subject '*had difficulty advancing or maintaining balance, was being bruised, and was pre-occupied with protecting his head and eyes.*'

A.1.7 Reports were also found of the use of water cannon as riot control equipment used in Northern Ireland [17]. This describes the water cannon as having certain tactical aspects, one of which is that '*water cannon very rarely cause death or serious injuries. (Though there is some danger from flying debris and glass if the jet hits buildings or loose material; and injuries can be caused particularly to women or children who have fallen down, as they can be rolled along the ground by the force of the jet.)*' [17].

A.1.8 A number of reports have stated that users have favoured the deployment of water cannon when the only other option was live ammunition. Conversely, on occasions where gunfire was used, it was felt that water cannon would have been more suitable [113, 125-129 & 302].

A.2 Related Water Impact/Water Jet Data Sources

A.2.1 The literature relating to the mechanical recovery of meat, cutting and processing of foods has been examined to determine whether any comparable effects could be identified and pulled through to this study. The review has revealed that substantial cutting forces can be produced using water [57, 58], however the pressures employed in the preparation of food are substantially higher than those witnessed in water cannon (410 bar minimum), and the nozzle diameter is very small (less than 1 mm diameter).

A.2.2 Surgical uses of water jets vary from liver resection [62-67], fatty-tissue dissection [68], corneal surgery [69-71], brain dissection [72] and surgery of other organs [73-75]. All use fine water jets (0.1-0.2 mm) at high pressure (up to 1000 bar), and low flow rate. There is little comparison with water cannon use. Water jets are also used in wound debridement, typically at pressures up to 14 bar and deliver up to 2.4l per minute [76, 77]. Again, these are not comparable with water cannon.

A.2.3 Water jets are used during dental work to clean teeth and as a form of irrigation [59-61], however these are designed such that they do not produce injury. They were used at water pressures up to 14 bar, but have low flow rates, because they use small diameter nozzles (typically 0.125mm – 0.8 mm).

A.2.4 A review of the technical standards relating to fire-fighting equipment found little relevant information. The technical standard for fire fighting hose fittings [78] did not give detailed information on the performance of the equipment or any information relating to the risks of injury.

A.2.5 A review of patents relating to water cannon and related water moving equipment also failed to produce any information relating to the performance of the equipment or any details of injury risks [79-103]. The only comments of this nature were included in Schaffler's patent [102], which stated that "no serious injuries" would be produced by water cannon, although this was not elaborated.

A.2.6 Joffe et al [56] have reported the incidence of injuries of play with fire hydrants, as an activity that has resulted in several injuries requiring treatment, most of which involve lacerations, abrasions, contusions, fractures and concussion. None of these were attributed to the fire hydrant jets, but were mainly due to broken glass in the street, falling or playing in the road in front of oncoming traffic. The falling, and in some cases being pushed in front of the traffic, was cited as being less of a problem at hydrants where sprinklers were fitted. These reduced the force of the outlet jet by producing a diffuse flow. Injuries attributable to water from, for example, water/theme parks [330] and children's toys [32, 33 & 331] have also been reviewed; these, in general, have provided no additional information, although some data has been incorporated into the section on ocular injury potential (see Section A4.3).

A.3 Reported Injuries

A.3.1 Several websites and newspaper reports refer to injuries that have been caused when water cannon have been introduced [6, 130, 157-268]. These reports have no specific details on the cause or type of injury incurred. In all cases there were additional activities that may have caused the injury, for example tear gas, baton charges, large scale rioting, live ammunition or vehicle charges.

A.3.2 Some reports have stated that the use of water cannon increased the number and severity of injuries, however, it is not reported whether this was due to the physical effects of the water cannon, or increased activity by security forces and increased levels of force. The use of irritants added to the water in some cases may have added to panic or caused problems in their own right, such as eye irritation [151, 228-230]. However, the indication in one report [229], is that the use of water cannon caused head, back, eye and neck injuries (although the exact detail of the injuries or the severity was not recorded).

A.3.3 One reference has reported that several people required treatment for eye injuries following a riot where water cannon were deployed [223]. One man also had a neck injury that required intensive care treatment. During this incident, however, tear gas and live ammunition were also used and none of the injuries were attributed directly to the water cannon.

A.3.4 There have been isolated reports referring to the misuse of water cannon [130, 131], where it is suspected that there was excessive use of force (during a reportedly peaceful protest). In these cases it may be possible to conclude that the use of water cannon was unnecessary, or that the pressure setting on the jet was too high.

A.3.5 A number of reports on the deployment of water cannon have indicated concerns on its usage:

- Problems *"gauging appropriate levels of force, and the possibility of causing serious or fatal injuries to a subject"* [7].
  - *"Injuries to the head/eye are possible from water cannon,particularly if directed at a supine body"* [8].
  - *"Jets can cause injuries on full force"* [113].
  - Use of a water cannon from a whaling ship against protestors on an inflatable boat produced the risk of washing the protestors into icy waters [294-296]

A.3.6 Other web-sites have recorded particular cases where the injuries can be directly attributed to the effects of water cannon (without additives):

- Freezing to death after use of water cannon in cold weather [8].
- Being knocked to the ground by the water cannon vehicle [224].
- Eye (and presumably other laceration) injuries from shattered glass (not spectacles) [225], resulting in the loss of an eye.
- A protestor '*was knocked down by a blast from a water cannon, fell on his head and fainted*' [267].

- Injuries due to tertiary impact (i.e. subject being thrown by the force of a water jet and hitting a wall) and broken spectacles [268].

A.3.7 There is one report that German police used water cannon to clear railway tracks during a protest '*which lead to several injuries*' [211]; some of which were caused to people hidden by a petrol-dowsed barricade [332]. The water cannon crew decided to soak and disperse the barricade to prevent ignition of the barricade, by increasing the water pressure gradually. Bruises and rib fractures were caused to the protestors hidden inside the barricade.

A.3.8 The Internet search also found two sites with particular relevance to the use of water cannon. The first of these was a report by a football supporter, who was targeted with a water cannon during a disturbance. He wrote that '*I naturally did the wrong thing entirely, which is to turn your back, and was sent spinning across the road*' [292]. This implies that movement in the stream of a water cannon may make it more potent and that certain orientations of the body are better able to withstand the force of the jet.

A.3.9 The second site reported the agenda of a mass action planning/briefing that included reference to training given on how to protect yourself from water cannon and what to expect when water cannon arrive [135]. This report indicates that anti-water cannon tactics are being developed; these may need to be considered when assessing the medical implications of water cannon, because it is conceivable that certain tactics may undermine a medical statement.

A.4 Specific Injury Potential

A.4.1 Whole body impact

A.4.1.1 Isolated cases of whole body impact have been recorded from the dropping of fire fighting 'water bombs' [18] and extreme water impact [19, 20].

A.4.1.2 The incidents involving the dropping of water bombs, resulted in injury to seven soldiers whilst fire-fighting, two of whom received fatal injuries [18]. The fire-fighting aircraft that caused the injuries dropped approximately 5500 litres of water over an area approximately 20 m x 85 m, from an altitude of 30 m above the top of the trees. A more precise estimation of the forces involved, or the nature of the impacts is not provided, however five of the injured soldiers were reported as having received isolated lacerations and contusions to the hands, face, chest or legs. These were minor and not difficult to treat. Two of the soldiers were thrown by the force of the water hitting them, and received head impacts with rocks as a result, which ended up being fatal (one immediately and one after ten days).

A.4.1.3 One of the soldiers also received lacerations and contusions to the right ear lobe and after clinical examination was found to have a traumatically ruptured right ear drum and acute inflammation of the right middle ear. Conductive hearing in his right ear was reduced by 50 dB immediately after the incident, but had improved by 25 dB after two weeks. He was returned to unit with advice and a prescribed programme of medical examinations. No follow up information is available on this case.

A.4.1.4 Extreme water impact reports have examined cases of people who have survived water impact from falls over 15.2 m (50 feet) [19] and the injuries that have been received by fatal water impacts from the Golden Gate Bridge (altitude approx 37.19 to 38.04 m) with water impact velocities of 32.92 to 33.53 ms^{-1} [20]. This work found that the orientation of impact was critical to the probability of survival (feet first providing the best chance). Frontal impact, typically involved chest fractures, lung and heart injury (aortic and ventricular rupture); these impacts all occur with a moving body that is stopped abruptly, so the inertia of the heart wants to continue in motion, whereas a water jet impact would be trying to accelerate the whole body. This work is therefore of limited use.

A.4.1.5 One of the victims of the fatal impacts [20] was a pregnant woman (in the second trimester) whose foetus and uterus were apparently undamaged by the impact. No detail is given on her injuries, other than they were fatal, or the orientation she was in; but this implies that the foetus is well protected to whole body water impact. No other information could be found to indicate that foetus may be more or less susceptible to injury from water impact, so it is not known whether this has any direct relevance to water cannon jet impact.

A.4.2 Head/Neck injury

A.4.2.1 Head and neck injury due to impact of a water jet may be identified as a potential problem (from primary, secondary or tertiary injury effects). Substantial work has been conducted in the transport research area to quantify the risk of head and neck injury, due to impact type acceleration, and in biomechanical strength assessment to determine head/neck injury tolerance. This may be used as a starting area for judging the tolerance to injury from a direct impact.

A.4.2.2 Firth in his paper on head and neck injury has made several observations on injury causation [21]. These conclude that the principal head injury mechanisms are:

- Penetration, with tissue laceration and/or bone fracture;
- Load or point deformation;
- Acceleration, producing head and neck flailing, in addition to impact insult.

A.4.2.3 These appear, at first glance, to be simple mechanisms to address, though head acceleration exerts its effects through at least three further sub-mechanisms:

- Blood vessel disruption;
- Brain tissue shear;
- Percussion and cavitation.

A.4.2.4 This in turn is complicated by several other factors, such as:

- The vector profile of the insult;
- The changing material properties of the brain, due to blood flow;
- The head and neck position during the impact;
- Muscular tone and condition of tissues;

- Individual variation in tolerance; anthropometric variation and any degradation in the condition of the biological structures (either through ageing, disease or pre-existing injury).

Each of these are significant during an impact and may be exacerbated or attenuated by several further factors, such as use of protective equipment (e.g. helmets) or body position.

A.4.2.5 The neck and, in particular, the spinal cord are well protected to impact injury, however the margin between safety and serious injury is narrow. The cervical vertebrae protect the spinal cord, however once disruption of these protecting structures has occurred, cord destruction is easily achieved (often by further impact or movement).

A.4.2.6 When the differences in, say, the magnitude, duration, onset rate or momentum change, of each impact is also considered, it is easy to appreciate how difficult it is to quantify the limits for tolerance for head impact injury. Nevertheless, work has been carried out to look at head injury mechanisms, and the tolerance of the neck to forces in various directions.

A.4.2.7 Current head impact standards do not attempt to identify a particular impact injury mechanism, or try to isolate and predict particular injury patterns. The principle reason for this is that until recently, the actual head impact injury mechanisms could not be identified with any great certainty. The principal impact injury criteria are therefore the head injury criteria (HIC) [359] and the Mean Strain Criteria (MSC) [361, 362]. The HIC is used principally to examine contact injuries and the MSC to examine non-contact injuries. Other injury criteria exist, but are not well accepted [382].

A.4.2.8 The HIC and MSC are based upon the measurements taken from purely translational accelerometers. They take no account of the effect or magnitude of rotational accelerations, except where rotational motion manifests as a linear acceleration. The concern that exists in the literature relating to impact, therefore must raise questions to their reliability, however, no approved surrogate head exists which may be used to model motion. This concern has also been raised by other researchers [363] who have proposed their own brain injury criteria, however they have found that insufficient data exists on brain injury during impact with rotational and translational acceleration. Their proposal was based on linear scaling on head injury between a linear acceleration of 250 g and a rotational limit of 10,000 rad/s^2.

A.4.2.9 As has been stated, the nature of brain injury is highly directional - any boxer knows that to knock someone out they should hit their opponent on the side of the head and not on the front. Also, accident statistics of head impacts show that the actual injury site is directional. On the whole, a frontal impact will cause coup or distributed injuries, a rear impact will cause principally contrecoup injuries and lateral impacts will create mainly contrecoup and distributed injuries. This is demonstrated in the data in Table A-1 [364].

Location of Impact	Number of Injuries	Percent location of injuries		
		Only or mainly coup	Only or mainly contrecoup	Equally Distributed
Frontal	280	48.6	5.5	45.8
Rear	36	0	97.2	2.8
Left Side	33	12.1	66.6	21.3
Right Side	31	12.9	67.7	19.4

Table A-1 - Location of head injury against impact site

Relative skull and brain motion has also been measured in cadaveric testing [365, 366] and it is believed that this skull/brain motion is the principal brain injury mechanism [367].

A.4.2.10 Further tests have examined the pressure distributions within the skull on cadaver heads. Due to the invasive nature of fitting pressure arrays, this is limited to measuring pressure on the external portions of the brain (either subdural or epidural). These have been carried out on a variety of subjects, including animals [368-370], standard [371-373] and re-pressurised cadaver [374] heads, and have also been correlated to injury mechanisms using finite element models [375, 376]. Yanagida, Fujiwara and Mizoi [377] have also looked at the difference in intracranial pressure caused by a fall or a blow to the head (i.e. head moving and stopped by the impact and head stationary and hit by an object). Their work reports that coup injuries are mainly caused by a blow and contre-coup injuries by a fall. The work examined this phenomena with a water filled model head and carried out simulated fall and blow experiments with matched amplitude forces, indicating that an impact to the head triggers a different response in the intracranial space, dependent on whether the force was caused by a blow or a fall. This may be explicable by the examination of the acceleration of the brain and cerebro-spinal fluid, but has relevance when considering the injuries expected against the injury criteria.

A.4.2.11 Diffuse brain injuries occur when the head is subjected to a violent rotational motion. The shearing of the brain produces strains in the brain which extend the neural connections in the head, producing prolonged injury, coma and death, depending on injury severity. The most significant of these injury mechanisms being referred to as Diffuse Axonal Injury (DAI), which causes widespread straining of the axons in the brain. Concern is being raised about this type of injury, its significance and the fact that current measurement and injury criteria are failing to predict its occurrence. Some research exists which indicates that DAI is a directional injury, with the most severe DAI occurring in lateral rotation, with the horizontal and frontal rotation producing less severe injury for comparable conditions [378].

A.4.2.12 Other attempts to use surrogate models of the skull to represent the brain to predict the shear and pressure patterns around the skull have also been carried out using silicone gel [379]. These employed simplistic materials and methods to model the skull, using optical rather than pressure sensing techniques, and were developed to give an estimate of brain shear. Another series of tests used a sectioned monkey head to apply pure linear, pure rotational and combined motion to the skull and used strain markers on the brain to demonstrate brain strain and motion [380]. This work also found that the rotational motion was most significant in producing diffuse brain injuries. These findings have

been supplemented by other studies [381], expanding the understanding of neural (axonal) injuries by measuring strains of between 5 and 10 percent occurring at strain rates in excess of $50s^{-1}$ and axonal membrane structural failure at 25-50 percent elongation at comparable strain rates.

A.4.2.13 Ewing [386] has received the tolerance of human neck injury and concluded that neck injury comes from energy transfer either directly or indirectly to the neck. Direct energy transfer comes from direct neck impact, and indirect energy transfer comes from head or torso motion relative to the neck. Standard automotive injury assessment reference values for neck loads exist which may be used [387].

A.4.2.14 The most important factor affecting the chance of neck injury was found to be the level of constraint of neck motion and the direction of the force vector which may result in spinal instability and hence spinal cord damage. Although this report was aimed primarily at vertical (axial) loading of the spine, some of these observations are also the case for frontal or lateral loading where initial configuration and constraint of motion may be significant.

A.4.2.15 The direction of the load applied to the neck and its importance in the nature of the injury that would be caused is also a topic that Burstein has commented upon [389]. He has also commented upon the importance of musculature in the cause of injury (and prevention), and has stated that he does not believe that a simple injury prediction method will work when considering neck injuries because of all the factors leading to neck injury and the variability in injury outcome based upon all these factors. He has therefore proposed that a statistical or probabilistic approach should be taken to predict the likelihood of neck injury. Some work has been carried out in this approach examining the possibility of neck injury from tensile loading [390]. This work has reviewed the available data (similar to the review of Sandover [383] and the work by Gadd, Culver and Nahum [384], and lists neck tensile data). Carter et al [390] have developed curves for the probability of neck injury based upon the axial loading suitable for a 20-39 year old population of two sizes of people (large individuals>73kg>small individuals). This criterion is purely applicable to axial loading.

A.4.2.16 Burstein [389] has also commented briefly upon the mechanism of an injury stating that displacement is the dominant factor in long duration impacts (greater than 100 milliseconds) such as American football injuries. This would probably be the case in an impact from a water jet.

A.4.2.17 The impact from a water cannon jet may be severe, so the possibility of impact injury must be considered. However, the duration of this impact may also have be long, especially compared with other injury mechanisms, such as whole body (automotive type) impacts or blunt trauma. This implies that displacement type injuries (primary), especially of the neck, and consequential impact injuries (tertiary injuries) must also be considered.

A.4.3 Ocular Injuries

A.4.3.1 A number of reports have referred to eye injury from water impact : fire hoses [22-25], water cannon [26], water sprinklers [27], paintball guns and other water impacts.

Another alleged case of ocular injury has been reported after the use of water cannon in a riot situation [28], however, the water cannon jet itself is not confirmed as being the cause.

A.4.3.2 Direct water jet impacts of the eye have been reported [22-27], resulting in injuries with impairment of vision. In some cases, this has resulted in long term problems, but others have recovered normally. The reported injuries in the medical literature have usually resulted from short range (1-5m, where reported); the impact with the water was at jet pressures/velocities comparable to water cannon nozzle output (jet outlet dynamic pressures 10-30 bar and velocities in excess of 30 ms^{-1}).

A.4.3.3 Typically, the injuries have been bilateral due to the diameter of the water jet, and have usually been confined to the lower portion of the eye (due to the reaction to look up and a lack of protection from the facial bones [25]). Often these impacts are more severe than from a large solid object impact (such as a cricket ball), because they occur with high kinetic energy and have longer impact duration. The bones of the cranial vault also fail to dissipate the impact energy in this situation, and the pressure from a water jet will act across a wide area, meaning that the globe cannot relieve the force by distorting.

A.4.3.4 Cases are often reported with increased intraocular pressure and dilated pupils, accompanied with iris sphincter rupture. Patients have been presented with multiple symptoms, including ecchymosis, subconjunctival and subretinal haemorrhage, retinal detachment, vitreous haemorrhage and detachment, inferior commotio retinae, posterior fundus and 1.5-3mm hyphaema (bleeding between iris and cornea). Traumatic mydriasis often persisted [22-27]. None of these cases have been presented with either globe rupture (without laceration) or blowout fracture of the orbit.

A.4.3.5 One case has been reported where a jet of water from hot asphalt hit the subject in the region of his left eye [24]. The eyeball was projected forward of the socket and repositioning within 2.5 hours restored sight. It is hypothesised that the water jet pushing the eyelid behind the eyeball caused this dislocation and contraction of the orbicular oculi muscle dislodged the eyeball. Alternatively, water pressure in the eye socket projected the eye forwards. Not much is known about the pressure at which this happened, or the size of the jet, so it cannot be confirmed whether this is a significant risk when subjected to the jet from a water cannon.

A.4.3.6 Since the eye is such a vulnerable organ and reports of injuries have been recorded from water jets at 10 bar within 5 m of the nozzles; careful consideration should be given to determine the minimum range/water jet pressure that should be tolerable. Water is used on the posterior capsule lens in cataract surgery, however the pressure is maintained below 4 bar [25], they have been shown to rupture at 8 bar [27]. This level would probably not be suitable to select as a pressure below which impact at the eye could be tolerated, because petechial and conjunctival haemorrhage have been witnessed at air blast pressures of 0.6 bar during emergency escape from aircraft [29]. Similar injuries are typically not recorded in blast events [30], however, where the pressure exceeds this level (sufficiently to cause tympanic membrane rupture). There may be three reasons for this, namely;

- The ejection event produces sufficient dust and debris to increase the injury severity;

- The air blast may not last long enough to cause displacement leading to injury and the tissues of the eye are sufficiently similar that stress waves do not cause injury;
- They are not recorded because far more significant injuries occur.

A.4.3.7 Tests have also been carried out on personal water jet toys, were there was a risk of ocular trauma [31]. These tests used two proprietary water guns that could reach working pressures of up to 45 psi (3.1 bar). Tests on cadaver porcine eyes, using fine water streams from the toys, with pressures of 12 psi at close range (0.8 bar), demonstrated there was potential for injury, with the production of large corneal abrasions and hydroinjection of orbital tissues.

A.4.3.8 Cases of non-permanent eye injuries (hyphema) received by two children (age 6 and 7) were also reported on the internet [32, 33] with a water toy. The ophthalmologist involved in this case stated that there was no scientifically derived data to give an indication of pressures on the eye that would cause injury, however a pressure reducing valve that limited the outlet pressure to 1.7 bar (25 psi) was installed and this was judged as safe.

A.4.3.9 Tests were also carried out on anaesthetised pigs to assess the potential injury to the eye. These tests were carried out using the Special Water Dispenser (see Section 5) at impact energies of 120J over approximately 0.1 second. This energy level was regarded as sufficient to knock down a subject, but not cause serious injury. These tests carried out direct impacts to the eye and caused no injury [34, 35].

A.4.3.10 The use of water-jets in cataract surgery has also been examined to determine at what level, serious injury may occur. Wilhelm *et al* [36] have examined the resistance of the lens capsule to the water jet. Their work found that rupture of the lens iteself was possible at pressures in excess of 8 bar, although the work does not state whether this is pressure of the jet setting or the actual pressure exerted by the jet on the lens. This equipment produced a very fine jet of 1.2mm diameter.

A.4.3.11 The presence of personal items, such as spectacles, protective visors, respirators or camera equipment, which may enter the eye (either intact or after breaking during an impact) must be considered. These may increase the severity of the impact trauma by globe rupture [37], penetrating injury or orbital fracture injuries such as those seen from sporting, recreational and conflict injuries. Therefore, where the potential exists for water jet impact on a subject with an object in front of their face, or with a risk of impact to the eye by an object, then the jet should not be targeted at the face or head zone.

A.4.3.12 Eye injuries have been reported with paintballs; these projectiles are reported as travelling at speeds up to 200 mph, and having sufficient energy to cause the loss of, or damage to, an eye [38, 39].

A.4.3.13 Injuries to the eyes have also been reported from high-pressure hydraulic line rupture in mining processes. These typically operate at pressures in the region of 300 bar. A review of the injuries caused by failure of these lines has shown that injuries similar to those reported above have been witnessed [40]. Once again, damage to the globe was prevalent with no reported cases of orbital rupture, which is a different pattern to those seen in blunt impact of the eye [41].

A.4.4 Auditory System Injury

A.4.4.1 Impact to the ear that closes or causes a pressure rise in the auditory canal may rupture the tympanic membrane [42-46], and may, in rare cases, cause ossicular dislocation. This will cause conductive hearing loss (i.e. hearing loss due to failure of the sound transmission from the outer ear to the cochlea) which should be restored. This will also cause sensorineural hearing loss in about 20-24% of cases [45, 46] (i.e. hearing loss from the sensory, rather than conductive element of the hearing process – cochlea through the eighth cranial nerve).

A.4.4.2 Tympanic membrane ruptures (without ossicular dislocation) heal spontaneously in 80-92% of cases without further treatment [43, 46], however the presence of contaminants (usually during membrane rupture in water) may complicate the issue with subsequent infection. The rupture caused by water impact also tended to be larger and more severe than those caused by trauma sealing the auditory canal (from a punch or slap) and were found to be potentially less likely to close spontaneously [45].

A.4.4.3 Jensen and Bonding [47] have examined the pressure required to induce rupture of the tympanic membrane by applying over-pressures to subjects *post-mortem*. They also reviewed the literature and found that typical static overpressures of 1.1 bar (1.1 atm) would rupture 50% of tympanic membranes. They found that a static pressure of 1.2 bar (1.2 atm) ruptured 50% of the membranes in their study. Their study was carried out as part of the normal autopsy of 90 subjects, which as a nature of the autopsy meant the age was biased towards the elderly (age range 0-93 yr, average 76 yr). They examined the tympanic membranes before and after the test and noted any particular features. The role of the Eustachian tube was duplicated with the insertion of a shunt into the mastoid. The tests were carried out statically (n=86) and quasi-statically (n=58), i.e. with an increased pressure rate, but not high speed, blast type pressures.

A.4.4.4 No statistical significance was found with the rupture pressure between the statically and dynamically applied pressures, with a mean rupture pressure of 1.2 bar and a range of 0.5 bar to 2.1 bar. Any predisposing disease, such as atrophic scars was shown to have reduced rupture pressures. These (n=23) burst at pressures between 0.3 bar and 0.8 bar (average 0.6 bar).

A.4.4.5 As part of the approval case for the SWD, tests were carried out to examine the risk of injury to the tympanic membrane from water blasts to the ear [48]. Temporal bones were used and subjected to blasts of water from the SWD. At dynamic pressures of 0.69 bar (10 psi) the ear drum would rupture if the tragus was removed, but would stay intact if not. At a dynamic pressure of 1.03 bar (15 psi) the ear drum would rupture even if the tragus was present. It was judged that the injuries that were caused at this pressure would heal spontaneously in 60-70% of the cases, and 90% of the remainder could be achieved with tympanoplasty.

A4.4.6 In these tests, the pressure in the middle ear was always higher than in the outer ear, and in only one occasion a very small pressure increase in the inner ear was noted (values not stated).

A.4.4.7 Another case of aural injury due to water impact has been reported earlier (see Section A4.2.2), from Reference 18.

A.4.5 Pneumocephalus

A.4.5.1 A case has been reported of pneumocephalus as a result of a water skiing accident [49]. A 26 year old male, in a good state of health, fell face first whilst water skiing at high speed. At the time he felt a large rush of water enter his nose. He suffered only a minor headache and continued to ski. Later that day, he began to suffer with a severe right-sided headache and reported to hospital. Initially the patient was discharged with no apparent injury. Later attendance at hospital revealed a high temperature, severe headache and photophobia. Several tests were carried out and computed tomography scans revealed a collection of air and a cerebral contusion in the right frontal area. Also evident were multiple opacified ethmoid air cells with mucous membrane thickening of the right ethmoidal sinus.

A.4.5.2 It was assumed that this person received a microscopic fracture of the cribrifrom plate as a result of the powerful water jet that entered the nose. The air trapped above the water jet was then forced across the cribrifrom plate.

A.4.5.3 If this type of injury is possible in water skiing accidents (although apparently very rare), then the velocities of water may be comparable to those from water cannon, and the volume of water presented to the face may be sufficient to repeat the effect in extreme cases.

A.4.6 Laceration/Injection injuries

A.4.6.1 High pressure liquid industrial equipment is used for a variety of processes, such as painting, cleaning, cutting, lubrication and fuel injection. These typically operate at nozzle pressures in excess of 50 bar, with nozzles and mass flow rates much less than water cannon. Several injuries have been reported of injection and laceration injuries from this type of equipment that have resulted in hospital treatment [391-412]. In most cases injuries have been caused by equipment with nozzle pressures in excess of 120 bar, and all of these have occurred at close range (less than 1m from nozzle exit). These have little relevance to water cannon type injuries. Summers and Viebrock [413] have reviewed some of the injuries caused by the impact of waterjets on human flesh. Most of the cases reported refer to high pressure cleaning, cutting, painting and greasing equipment working at very high pressures (greater than 110 bar). In their report, however, they comment that injuries (to flesh) occur at pressures above 4 MPa (40 bar), but this is not substantiated.

A.4.6.2 Most of these injuries have occurred to exposed skin (hands) and there has been research to show that the presence of interposing, loosely textured clothing may reduce the injury severity [414]. This may be an important factor that would actually reduce the potential for injury for subjects hit with a jet from a water cannon.

A.4.6.3 The most commonly reported injuries from recreational activity come from water skiing, personal water craft (jet skis) or water chutes. These typically occur to the genital tract or rectal areas, when a high-speed water jet causes injury, usually accompanied with heavy bleeding.

A.4.6.4 Vaginal injury has been reported with varying severity from water skiing [44, 415-418], personal water craft [419-423] and water chutes [424-425], however, only in isolated

cases has the speed of the person in motion been estimated (40-50 mph – 17.9-22.3 m/s), or the pressure output of the jet (1.4 bar [423]). These cases often cause internal bleeding and in isolated cases peritoneal perforation. These cases have caused termination of a pregnancy [415]. It has also been proposed that these cases have been made worse by the presence of tampons [418, 424, 425].

A.4.6.5 Rectal injuries are also reported, some of which caused dissection of the bowel wall and damage to the colon [426-431]; it was also reported that hydrostatic rupture of the colon wall occurs at pressures in excess of 120 mmHg (0.16 bar). The pressures exerted by the water jets were far in excess of this.

A.4.6.6 Injuries from low pressure water injections have also been reported in a child that fell onto a water spout [432]. Water was injected into the floor of the mouth and resulted in swelling of the face and neck due to dissection of the superficial soft-tissue layers of the neck. The initial puncture of the base of the mouth was caused by puncture with the water spout nozzle, but the water was at mains pressure (2.5-4 bar).

A.4.7 Torso/Abdominal Injuries

A.4.7.1 Reports have documented the occurrence of injuries from Personal Water Craft and Water Skiing. Most of these accidents involve contact with other vehicles, bridges or the vehicle itself during the impact, and therefore may be compared with automotive or similar crash events. Some state that the impact with water itself has caused injuries to the torso (resulting in L1 burst fracture [50] and rib fracture and bilateral hemothorax [51]). It must therefore be assumed that the since the speeds involved in personal water craft and water skiing are in the order of 50-60 mph, and the jet from a water cannon may exceed this, that the possibility of bone fracture may possibly exist from the direct impact of a high power water jet, if it was introduced directly and rapidly onto the torso.

A.4.7.2 Chest impact from a water jet has been reported by Eyres and Keel [52]. They record the case of a 48 year-old male construction worker who was inspecting a water mains when a seal ruptured. A jet of water struck him in the chest, propelling him 6m (20 feet) into the air according to witnesses. This (and the following ground impact) resulted in sternal fracture, two vertebral crush fractures and injury to the aorta. The pressures or flow rate during the incident are not recorded, however this does demonstrate the types of injury that are possible with high pressure water impact.

A.4.7.3 Another injury case report has been published where a healthy 35 year-old female suffered a dissection of the circumflex coronary artery that is believed to have occurred during water skiing [53]. The subject did not recall any significant impacts, but suffered from chest pain after the skiing and attended an emergency department. No injuries were noticed after two inspections, but the patient was diagnosed with musculo-skeletal pain. Following investigation, the patient collapsed, required resuscitation and mechanical ventilation, and was declared brain-dead eight days later. The injury was only detected during autopsy. This is believed to be a rare case of cardiac trauma following blunt trauma in this specific activity.

A.4.7.4 Hydroforce, Inc. have declared on their website that they have analysed the risk of rib injury from their Water Restraint System [54]. Copies of this analysis have been requested [55], but have not been supplied at the time of writing.

Appendix B ACPO Guidance on the Deployment and Use of Water Cannon (repeated text from ref 440-441)

B.1.1 The purpose of these guidelines is to facilitate an understanding, and to provide practical guidance concerning the deployment and use of vehicle mounted water cannon.

B.1.2 The guidelines have been audited to ensure the content is in compliance with the provisions of the Human Rights Act 1998 and the provisions of the United Nations Basic Principles on Use of Force and Firearms by Law Enforcement Officials and the UN Code of Conduct for Law Enforcement Officials. Account has also been taken of the Police Service of Northern Ireland Code of Ethics.

B.1.3 Managing conflict and responding to violence are core police functions. Police response is underpinned by Human Rights and in particular the obligation under Article 2 of the European Convention on Human Rights, to uphold the right to life.

B.1.4 Article 2 of the UN Basic Principles on the use of Force and Firearms states that:

'Governments and law enforcement agencies should develop a range of means as broad as possible and equip law enforcement officials with various types of weapons and ammunition that would allow for a differentiated use of force and firearms.'

B.1.5 Vehicle mounted Water Cannons can be used in a variety of modes and therefore provide the police service with an additional, flexible and graduated means of responding to situations where use of force is considered necessary to disperse individuals or persons causing violence. As well as the physical presence of the water cannon providing a deterrent The modes of operation are:

a. Spray or Diffused Mode.

b. Short bursts of water jets.

c. Continuous water jets.

B.1.6 The design and use of the vehicle mounted water cannon system are subject to strict criteria. Only water cannon that have undergone a full technical evaluation and consideration of the medical implications of its operation may be used within in the United Kingdom. The 'RCV9000 Vehicle Mounted Water Cannon' is currently approved for use within the UK.

B.1.7 The deployment and use of water cannon will be informed by reference to the ACPO Conflict Management Model. The availability or deployment of the Water Cannon should not however be considered as a replacement for other less lethal weapons but rather as a further tactical option. Whilst primarily designed as an option for dealing with unlawful protest and disorder water cannon may provide a tactical and less lethal response in other situations where a use of force is required.

B.1.8 The deployment and use of water cannon is required to be documented as soon as practicable thus providing an audit trail of decision making in respect of command and operational decisions.

B.1.9 Water cannon are one tactical option within a range of tactics and equipment that are available to the police service when responding to unlawful protest, disorder and threats of violence. They provide a graduated, flexible and proportionate police response and may reduce the need to resort to other less lethal weapons or other uses of force. Police, in carrying out their duty, shall as far as possible, apply non-violent means before resorting to the use of force. Force may be used only if other means remain ineffective or without any promise of achieving the intended result. In dealing with assemblies that are unlawful but non-violent the use of force should be avoided, or where that it is not practicable, such force shall be restricted to the minimum extent necessary.

(*Sourced from United Nations' Basic Principles on the Use of Force and Firearms by Law Enforcement Officials - Principle 4)*

B.1.10 A unique characteristic of water cannon is the ability to graduate the delivery of water from a diffused spray to a directed jet and at varying pressures. Thus water cannon provide a graduated and flexible application of force ranging from use of the water cannon in spray or diffused mode to deter or discourage unlawful protestors from remaining in an area, to forceful water jets that can physically push people to disperse them. This represents a use of force option that may be considered appropriate in a variety of situations falling short of serious disorder and riots where its use may prevent the escalation of violence.

B.1.11 Water cannon are intended to complement the existing range of tactical options and equipment. Size, weight and manoeuvrability may place constraints on their use. Therefore, whilst water cannon may be an appropriate option in many circumstances, the topography of the area and ground conditions may negate their use and other appropriate tactical options should be considered.

B.1.12 Nothing in these guidelines should be construed so as to constrain the police service in its fundamental responsibility to save life, protect property and maintain the peace. Police officers shall at all times fulfil the duty imposed upon them by law, by serving the community and by protecting all persons against illegal acts, consistent with the high degree of responsibility required by their profession.

B.2 Outline Description of the RCV9000 Vehicle Mounted Water Cannon

B.2.1 The RCV9000 water cannon vehicle consists of a six wheel drive chassis on which is mounted a superstructure consisting of a crew cabin; a pump compartment and a water tank. Water Cannon may only be operated by officers who are currently trained in their use.

B.2.2. Within the cab there is a comprehensive set of controls and recording equipment to capture data from sensors monitoring water pressure, date and time of use. Each vehicle has two water cannons mounted on the roof of the cab.

B.2.3 The vehicles are each equipped with a public address system, distinctive audible sirens and blue flashing lights. A high intensity light bar is fitted to the front of the cab above the windscreen.

B.2.4 Due to their size and weight water cannon should normally be deployed at least in pairs to provide mutual support and immediate recovery capability in the event of a mechanical failure.

B.3 Considerations for Deployment and Use of Water Cannon

B.3.1 As with the use of any vehicle in areas where there is large crowds of people there is a risk that the moving vehicle could result in a collision and injure individuals. The provision and of use the public address system, distinctive audible sirens and blue flashing lights system will provide a means to warn persons present of impending use.

B.3.2 The ability to discharge jets of water in differing modes and at varying pressures is a unique characteristic of water cannon representing a use of force option that may be considered appropriate in a wide range of situations.

B.3.3 Water cannon can provide an effective means by which persons using violence towards the police or others involved in the destruction of property, or who are engaged in unlawful assemblies, protests or demonstrations, can be kept at a distance, contained or dispersed. In dealing with assemblies that are unlawful but non-violent the use of force should be avoided, or where that it is not practicable, such force shall be restricted to the minimum extent necessary. (*Sourced from the UN Basic principles on the Use of Force and Firearms by Law Enforcement Officials – Principle 13*)

B.3.4 Water cannon are intended to be a less lethal use of force option. The method of delivery and use is intended to avoid causing serious or permanent injury. However as with any use of force there is the potential for unintended or unforeseen injuries being caused. In respect of water cannon the following potentials for injury have been identified.

a. Direct injury from water jet. In particular the application of two jets on individuals (E.G. both jets from one vehicle or one jet from two vehicles) will increase the risk to subjects.

b. Running, tripping or falling when trying to evade water cannon.

c. Being pushed onto hard or sharp objects and windows by the force of the jets (Tertiary Impact).

d. Being knocked off walls or other high positions.

e. Secondary missiles being propelled from the ground or dislodged from buildings of other structures.

B.3.5 Training will address these considerations and other potential risks from :-

- Jets directed at the ground in front of crouching/sitting persons where there may be debris on the ground;
- Jets striking the head, even peripherally;
- Jets striking, even peripherally, persons using optical equipment or with the equipment (cameras etc) directly;
- Persons adjacent to obstacles such as walls, barricades and vehicles, or lying on the ground where the pressure of water may cause them to fall against such objects;
- Persons on top of structures who may be toppled by the jet;
- Persons who may be thrown into the path of moving vehicles by the jet:
- Children, the elderly or small adults being struck by the jet.

B3.6 Water cannon should be supported by other public order tactical options and equipment and should not ordinarily be deployed as a standalone option.

B.3.7 Water Cannon will only be deployed following appropriate threat and risk assessments, however in certain situations where there is limited time for detailed planning, commanders may have to undertake real time dynamic threat and risk assessments**.** Specific tactical objectives will be drawn up by the Silver Commander and agreed with the Gold Commander to be implemented by the relevant Bronze Commander(s).

B.3.8 Given the flexibility in use of the water cannon it is impossible to provide a definitive list of situations or precise criteria for their deployment and use but the following principles should taken into consideration:

a. The physical presence of water cannon can act as a deterrent to those intent on disobeying lawful and reasonable police directions or using violence, however their presence may also inflame a situation and the decision to move water cannon forward and into view must rest with Bronze and Silver Commanders at the time.

b. The public address system, high intensity lights, flashing blue lights and distinctive sirens can all be used to provide warnings and alert a crowd of the presence of water cannon and police intentions.

c. Water cannon may be considered as an alternative tactical option to police officers physically engaging with unlawful protests and violent persons in situations that would otherwise require the intervention of officers at close quarters, thus placing police and others at potentially greater risk.

d. The modes of use (diffused or directed jets of varying duration) and level of water pressure used on any given occasions must be necessary and proportionate to situation being encountered.

e. Use of the water cannon is likely to result in more that one person being affected and the use of the water cannon may have a direct or indirect effect on the whole crowd hence the importance of providing warnings as outlined at paragraph 7 of these guidelines.

B.4 Useful Definitions

B.4.1 In the course of reading these guidelines the following definitions will be of assistance:

Deployment – Water cannon is deployed when it has been made available for operational purposes.

Authority to Deploy - the authorisation by an officer of Assistant Chief Constable/Commander rank to make water cannon and trained personnel available for operational purposes.

Use – Water cannon is deemed to have been used when it has been discharged at any person in pursuit of police operations.

Authority to Use – The authorisation given by the Silver Commander (Inspecting and Superintending ranks) to discharge water cannon, in accordance with the principles set out in these instructions. The authority to use water cannon is not an order to discharge it. It is a decision that is made, based upon all of the information available, that water cannon may be a necessary and proportionate response to public protest or disorder.

Assistant Chief Constable/ Commander - an officer of substantive ACC or Commander rank or an officer of Superintending rank who is specifically designated to perform the role of ACC/Commander in the absence of the relevant ACC/Commander**.**

B.5 The law relating to the use of force

The law relating to the use of force is set out in this section and must be complied with.

B.5.1 The deployment of water cannon does not, of itself, constitute a use of force. It is only when water cannon are used to discharge water against persons that the considerations contained in this section become relevant.

The law is contained within …

Section 3 Criminal Law Act 1967 and Section 3 Criminal Law Act (Northern Ireland) 1967

B.5.2 'A person may use such force as is reasonable in the circumstances in the prevention of crime, or in the effecting or assisting in the lawful arrest of offenders or suspected offenders or of persons unlawfully at large'

Section 117 Police and Criminal Evidence Act 1984 and Article 88 Police and Criminal Evidence (Northern Ireland) Order 1989

B.5.3 'Where any provision of this Act or Order

a. confers any power on a constable; and

b. does not provide that the power may only be exercised with the consent of some other person other than a police officer, the officer may use reasonable force, if necessary, in the exercise of the power.'

Common Law

B.5.4 The Common Law has always recognised the right of self-defence.

European Convention on Human Rights (ECHR)

B.5.5 When making a determination as to whether the level of force used was lawful in any particular instance the courts will take cognisance of the Articles under the ECHR.

B.5.6 Whilst water cannon are intended to be a less lethal use of force option it is recognised that the use of any force may have unintentional lethal consequences and, as such, Article 2 of the ECHR is of particular relevance.

B.5.7 Article 2 – Right to life

Everyone's right to life shall be protected by law. No one shall be deprived of his life intentionally save in the execution of a sentence of a court following his conviction of a crime for which this penalty is provided by law.

Deprivation of life shall not be regarded as inflicted in contravention of the Article when it results from the use of force which is no more than absolutely necessary:

I. in defence of any person from unlawful violence;

II. in order to effect a lawful arrest or to prevent the escape of a person lawfully detained;

III. in action lawfully taken for the purpose of quelling a riot or insurrection.

B.5.8 The European Court has held that 'in keeping with the importance of this provision [the right to life] in a democratic society the court must, in making its assessment, subject deprivation of life to the most careful scrutiny …taking into consideration not only the actions of the agents of the State who actually administer the force but also all the surrounding circumstances including such matters as the planning and control of the actions under examination'. (McCann v United Kingdom (1995) 21 EHRR 97 at paragraph 150).

B.5.9 The test of absolute necessity found in Article 2 of the ECHR relating to the obligation to protect life provides a stricter test of proportionality than is required in other areas of the Convention. It is also a stricter test than is provided by the concept of reasonable force within s 3 Criminal Law Act 1967, s 117 of Police and Criminal Evidence Act 1984, the equivalent Northern Ireland legislation and the Common Law. Even where the use of force may be seen as being reasonable it may not be absolutely necessary.

B.5.10 Water cannon can be used in a variety of modes and its use in any given circumstances must be based on the principals of proportionality.

B.5.11 The justification for the mode (spray or jet), the pressure and duration of use will always be dependant on each situation and based on the principles of legality, necessity and proportionality. For example directed jets may be a necessary and proportionate level of force against a violent and riotous crowd who have refused to disperse and their dispersal is necessary for the maintenance of the peace and the prevention of disorder. However if dispersing an unlawful but non-violent assembly, in the first instance a diffused spray may be appropriate followed by lower pressure jets proportionate to the amount of resistance offered by the crowd. A record is maintained on the pressure of the jets on each occasion they are used.

B.5.12 When that force is used it should be reported at the time, or as soon as practicable thereafter, by the Crew Commander to the Water Cannon Commander and to the Silver Commander. It is not intended that each short burst of water need to be reported, however a report(s) should be made when a particular phase of use has ended. It is impossible to set strict guidance in this respect and must be left with the discretion of the Crew Commander who has a duty to report the use of force.

B.6 Authorisation for the Deployment and Use of Water Cannon

Deployment of Water Cannon

B.6.1 Chief Constables\Commissioners may delegate the authority for the deployment of water cannon to an officer of Assistant Chief Constable\Commander rank. The authority to deploy water cannon should be limited by time and geographical boundaries. These may be for as long and cover as wide an area as necessary for the purpose of the operation(s) for which they are being deployed.

B.6.2 The deployment and use of water cannon in situations of unlawful public protest and disorder should only be considered where it is believed that their use (in conjunction with other methods of policing disorder) is appropriate in order to achieve lawful objectives.

B.6.3 A Tactical Adviser, who is specifically trained in the characteristics and use of water cannon, will be consulted prior to any deployment. The Tactical Adviser must be consulted on the deployment and use of water cannon in the planning phase and during the operation.

B.6.4 **Pre-Planned Deployments** - for pre-planned operations, the Gold Commander in consultation with the Silver Commander must make an assessment of the threat to public order and the need to deploy water cannon. Where the Gold Commander is not an Assistant Chief Constable/Commander, a written request for the deployment of water cannon, based upon this assessment, will be made to the relevant Assistant Chief Constable/Commander by the Gold Commander.

B.6.5 Water cannon vehicles will be deployed under the overall command of the Water Cannon Commander. The Water Cannon Commander will liase with the appropriate Bronze Commander to ensure co-ordination in achieving tactical objectives.

B.6.6 The relevant Gold and Silver Commanders will keep authority to deploy water cannon under constant review.

Use of Water Cannon

B.6.7 Once authority to deploy water cannon has been granted the authority to use water cannon is vested in the Silver Commander (Inspecting and Superintending ranks).

B.6.8 The Silver Commander will keep authority to use water cannon under constant review through liaison with the relevant Bronze Commander(s) and Water Cannon Commander.

B.6.9 Water Cannon can be used in the following ways:-

a. Stationary

b. As part of a forward moving police line.

When being used as part of a moving formation care must be taken to avoid striking any person with the vehicle.

B.7 Warnings

B.7.1 The use of the public address system, high intensity lights, flashing blue lights and distinctive sirens can all be used to provide warnings and alert a crowd of the presence of water cannon and police intentions. RCV9000 water cannon vehicles are equipped with a powerful public address system and distinctive audible sirens that can be used to give audible warnings. Blue flashing lights mounted on the front and on the roof will provide a visual warning of their presence.

B.7.2 Water Cannon Crew Commanders should ensure that sufficient warning is issued to the crowd before water cannon and/or any other use of force option is deployed. The warning(s) should make it clear to the crowd that unless they disperse, a specified use of force tactical option will be used. The officer delivering the warning will keep a record of the time of the warning(s) and the words used. The following words should be used:

"Attention, attention this is a police message. Unless you disperse immediately, water cannon (or other option(s)) will be used"

B.7.3 Warnings should be repeated, as frequently and as often as is necessary to ensure that all of those engaged in the unlawful activity and bystanders have heard the warning(s) and have had an opportunity to disperse. The police objective should be to ensure those who choose to remain are left in no doubt of the police intentions.

B.8 Command

B.8.1 In order to ensure appropriate operational command over the use of water cannon, the following procedures are to be implemented. These procedures are intended to enhance command and increase accountability whilst maintaining the ability to evidence the need to use water cannon.

B.8.2 Policy and command decisions in respect of the deployment and use of water cannon should be subject to continuous critical review during the lifetime of any incident or operation. The officer in overall command of the incident (Gold Commander) should ensure formal review and documentation of the requirement for water cannon as the disorder enters each new phase.

B.8.3 All command decisions in respect of the authority to deploy and use water cannon (or not, as the case may be) should be fully documented. The relevant Bronze Commander will be responsible for documenting the assessment of the situation and rationale pertaining to the decision to request the authorisation to use water cannon. In addition each Crew Commander will, in respect of the vehicle under their command, ensure that a record is maintained of the use of water cannon and that reports are completed as soon as practicable after each use.

B.8.4 In the event of spontaneous outbreaks of public disorder water cannon may, or may not be readily available. In any event the officer in charge of the scene of disorder should ensure the introduction of formalised command and control structures (Gold-Silver-Bronze) with the minimum delay and if water cannon are available they must be duly authorised for deployment and use. However, nothing in these instructions should be so construed so as to prevent an immediate and effective police response or the use of water cannon where their use is justified on the grounds of necessity and proportionality where decisive intervention is likely to bring about an early resolution of a potentially violent situation.

B.9 Role of Crew Commanders

B.9.1 Crew Commanders are responsible for the safety of the entire crew and that of the vehicle. A Crew Commander has overall command of their respective vehicle.

B.9.2 Crew Commanders will set a water pressure for any period of use that is a proportionate response to the unlawful protest or disorder being encountered. They will also determine the appropriate mode of use (diffused or directed jets). Whilst this will be the overall water pressure individual water cannon operators have the ability to reduce the pressure in their respective cannons by 5 or 10 bar or can close their cannon if appropriate.

B.9.3 Once a decision has been made to use water cannon the Crew Commanders will be responsible for directing and commanding their respective water cannon vehicle whenever their use has been authorised. The Crew Commander must also issue orders to cease the use of water cannon when the tactical objective has been achieved or when ordered to do so by the Water Cannon Commander.

B.9.4 A Crew Commander (nominated by the Water Cannon Commander) will cause a warning(s) to be given to the crowd using the on-board public address system when available. Details of date, time, method and wording of the warning(s) should be recorded by the person issuing the warning.

B.9.5 Crew Commanders will ensure records are kept in respect of the use of water cannon, including records of date, time place of authorisation and use.

B.9.6 Crew Commanders will be responsible for ensuring that water cannon crews wear protective clothing and equipment appropriate to the level of threat pertaining to the circumstances.

B.9.7 The Crew Commander is responsible for the filling of the water cannon with water. To this end he will ensure correct procedures are followed at all times.

B.10 Role of Water Cannon Commanders

B.10.1 When two or more water cannon vehicles are deployed the senior Crew Commander will act as the overall Water Cannon Commander unless an additional officer has been specifically appointed. When authority for the use of water cannon has been given, the Water Cannon Commander will brief and instruct the Crew Commanders and crews as to the tactical objective(s) determined by the Bronze Commander for the sector in which the vehicles are then operating (Territorial Bronze). A record of authorisations, times etc. must be made at the time or as soon as possible thereafter (by the Water Cannon Commander, Crew Commanders and the relevant Bronze Commander) for evidential purposes.

B.10.2 The Water Cannon Commander is the person in charge of the water cannon vehicles deployed and his or her status in terms of the command structure is that they are in charge of a resource in a similar fashion to that of a PSU / TSG Inspector. The Water Cannon Commander's role is therefore subordinate to the relevant Bronze Commander as shown in Appendix 'A'.

B.10.3 The Water Cannon Commander is responsible for the overall safety of the water cannons, any escort and support vehicles and their crews.

B.10.4 Water Cannon Commanders / Crew Commanders are trained to provide Tactical Advice to Gold, Silver and Bronze Commanders. If an additional Water Cannon Commander has been appointed he or she can operate from within the vehicle or in close proximity outside the vehicle, providing communications can be maintained by the use of radio / intercom.

B.11 Water Cannon Operators

B.11.1 Water Cannon Operators control the use of the jets and must be appropriately trained and qualified.

B.11.2 In undertaking this role the operators must take account of the considerations set out in paragraphs 3.1 to 3.8 of this guidance.

B.12 Water Cannon Drivers

B.12.1 Drivers must be trained in driving water cannon and hold appropriate driving licences and internal police service qualifications for this category of vehicle.

B.12.2 Drivers have a great responsibility for the safety of the crew and the public when moving to and from deployments and during operational use and must therefore drive in a safe, responsible manner appropriate to road conditions, crowd conditions and general traffic legislation.

B.13 Selection of Personnel

B.13.1 Water Cannon Commanders and crews are selected on the basis of the following criteria.

a. Length of service and relevant experience

b. Attitudes and approach to work

c. Motivation and interests

d. Temperament, maturity and personality

e. Relationships with colleagues and supervisors (teamwork)

f. Personal Skills and competencies

g. They are Public Order trained

h. Only those officers who are capable of displaying a mature and professional approach to public order policing should be selected.

B.14 Medical Considerations

B.14.1 Police officers will ensure that assistance and medical aid, where possible, are secured for any injured or affected person(s) that they are aware of at the earliest possible opportunity.

B.14.2 The relatives and close friends of the injured or affected person should be notified at the earliest possible opportunity

B.14.3 Where it is known that death or injury has been caused by the use of water canon, the police officer becoming aware will report the matter promptly to his or her supervisor.

(*Sourced from United Nations' Basic Principles on the Use of Force and Firearms by Law Enforcement Officials, Article 5 and Article 6*.)

B.15 Records

B.15.1 Water cannon vehicles are equipped with electronic means of recoding data including date and time of use, the pressure set at any specific time by the Crew Commander, the pressure and flow rates used by the individual cannon operators and the duration of each use and the temperature of water in the water tank. The Crew Commander, who is in charge of a specific vehicle and is responsible for all technical aspects, will ensure the recording equipment is tested prior to deployment. If it is not working and cannot be repaired in time before necessary deployment the Crew Commander will ensure these records are recorded manually. The water Cannon Commander will ensure that records are maintained for all vehicles under his or her command.

B.15.2 Water cannon vehicles are equipped with video cameras mounted beside each cannon, behind the front windscreen and on a telescopic mast mounted to the rear of the cab. An additional two cameras are mounted at the rear of the body as a safety aid for the driver before reversing.

B.15.3 Whilst the images from cameras will be recorded during operational deployment water cannon are not intended for primary use as an evidence-gathering platform. The cannon mounted cameras are primarily intended to be an aiming aid for the cannon operators before the cannons are used. When in use the spray from the water jets generally obscures the image that these cameras can capture.

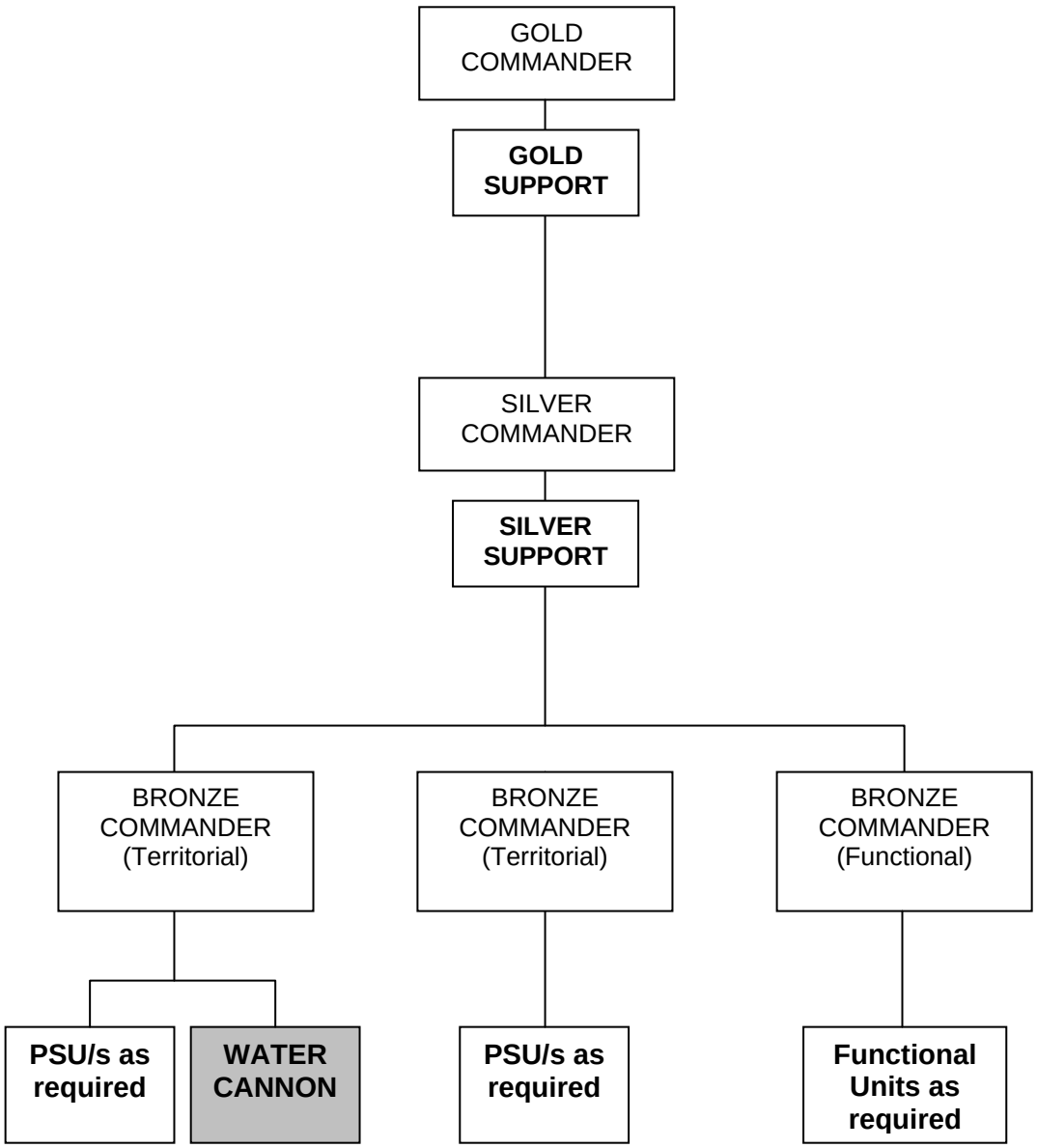
B.15.4 The combination of the various cameras means the crew has 360^0 vision around the vehicle, primarily for road safety purposes and the safety of the crew and others deployed in the vicinity. Images from this camera will also be recorded and when water cannons are in use the mast mounted camera should be forward facing to capture images from above the water jets, although these images may also be obscured by spray depending on prevailing conditions.

B.15.5 During the deployment the Crew Commander should at the time, or as soon as possible thereafter, make contemporaneous notes concerning deployment and use of water cannon. At the end of the deployment the overall Water Cannon Commander will submit a report to the officer in charge of the operation through normal channels which may be used as necessary for local debriefing purposes or to assist in any form of investigation.

B.15.6 The Crew Commander will ensure data and images recorded during operational deployment are downloaded from the data recorder, logged and stored in accordance with existing force instructions and practice in respect of the storage of electronic data for evidential purposes.

B.15.7 All equipment required for the recording of data and images must be tested frequently and any faults reported for prompt attention and repair. If during operational use the Crew Commander becomes aware of any defects in this equipment they must make a contemporaneous note of this and take all reasonable steps to record events by other means including contemporaneous notes.

APPENDIX 'A' COMMAND STRUCTURE



Appendix C Comments related to the medical implications of water cannon guidance

C.1 General

C.1.1 Dstl reviewed the initial Instructions for the Police use of water cannon [ref 352]. This highlighted issues relating to safety that required clarification. These concerns were then relayed to the PSNI branch responsible for the production of the guidance [433]. Responses to this are included in this Section [from reference 434]. Many of these concerns were also raised in Issue 1.0 of this report and have since been addressed in the latest draft of this document [441439](which is reproduced in Appendix B for convenience).

C.1.2 These concerns related to:

- The training and certification of officers
- The use of the water cannon against specific individuals
- The mode of the introduction of the water jet to individuals
- The particular water cannon equipment

These concerns are repeated in Table C1 below, along with how they are now addressed in the current guidelines [441]

Issue	**Comments on RUC (PSNI) Instructions [352]**	**Relevance to ACPO draft Guidelines (Appendix B) [441]**
How were officers selected?	Selected from Public Order Instructors or Tactical advisors [354]	Explicit in ACPO guidelines on requirements for officers (Para B.13.1)
What was the training syllabus and the experience of trainers?	Staff were trained by the Belgian Gendarmerie [354]	Trained by Belgian Gendarmerie, but a specific training course to be developed by PSNI before use
Level of approval and control over the production and control of the guidance	Local (PSNI) level of control	Now an ACPO document to be produced for national use and review, with force specific information added as required (e.g. for training, etc)
Reasons for deployment of the vehicle	Based upon a risk assessment [354]	Now explicit in the document to provide a graduated response after an appropriate threat and risk assessment (para B.3.7). Only authorised if their use '*is appropriate in order to achieve lawful objectives*' (Para B.6.2).

Guidance on the mode of the spray/jet	Personal judgement	Several references to a graduated response (Paras B.1.5, B.1.9, B1.10, B3.8), particularly a single reference to a '*flexible application of force ranging from use of the water cannon in spray or diffused mode to deter or discourage unlawful protestors from remaining in an area, to forceful water jets that can physically push people to disperse them'* (Para B.1.10)
Use of vehicle by untrained crews	Concern was raised that untrained crews may be able to use the vehicle under certain circumstance and they need to understand the medical implications	Now explicitly states in the ACPO document that '*Water Cannon may only be operated by officers who are currently trained in their use'* (Para B.2.1) and *'Water Cannon Operators must be appropriately trained and qualified'* (Para B.11.1). Selected staff must also be public order trained (Para B.13.1)
Use of a water cannon against a particular individual	Concern was raised over targeting a single person (either isolated or in a crowd)	If deemed necessary and '*is appropriate in order to achieve lawful objectives*' (Para B.6.2). It is also highlighted that the possibility of hitting one person in a crowd is unlikely and several people may be affected (Para B.3.6e). Additional risks have been highlighted for the effects of the jet putting someone into danger (such as pushing them in front of a moving vehicle – parap B.3.5) and the increased risk of injury from two jets (para B.3.4.a)
Mode of introduction of water jet	Guidance was required to explain the mode of introduction	Requirement that the force is proportionate (para B.3.6.d), and references to a graduated response (Paras B.1.5, B.1.9, B1.10, B3.8), but no reference to method of introducing the jet to the body. Explicit reference to the

		responsibility of Crew Commander to selection of pressure and selection of mode of water (diffuse spray or jet) – para B.9.2.
Concern on debris being swept into protestors	No reference to risk of debris	Explicit concern that debris may be projected at people (Para B.3.4.e and B.3.5)
Possibility of impact (tertiary injury)	No reference of risk of impact injury from being thrown	Now explicit (Para B.3.4.c)
Control system accuracy	No reference to accuracy of the control system	Explicit that people must be trained. (Para B.11.1)
Communication system	No mention of communication systems that need to be used	Some requirements placed on communications for cannon commanders (Para B.10.4). New vehicle design has good radio and communications between exterior and interior through vehicle mounted system.
Fail-safe system	No mention in system design of any fail safe mechanism	Current vehicle design has emergency shut-off for water jets and the power take off from the engine has a power cut-off. Water distribution system has an electronic control system (although there is no mention of calibration)
Movement in crowds	No mention for the safety of people when the vehicle is moving	Mention of care required when moving vehicle and need for sufficient warning (Para B.3.1)

Table C1: Comparison of RUC Instructions for the use of Water Cannon [352] and ACPO Water Cannon Guidelines [441]

Distribution list

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1. Originators Report Number incl Version No: Dstl/TR08591 Issue 2.0		
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3. Title of Report The medical implications of the use of vehicle mounted water cannon (Issue 2.0)		
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15. Abstract (A brief (approximately 150 words) factual summary of the report)

Dstl Biomedical Sciences has undertaken a review of published information from a wide range of sources on the reported incidence world-wide of injuries from jets of water from water cannon for the DSAC Sub-Committee on the Medical Implications of Less Lethal Weapons at the request of the Home Office and Northern Ireland Office. This is believed to be the first such review despite extensive use of water cannon by police and other agencies in many other countries.

There were no fatalities reported in the literature that were directly attributable to the impact of the jet in public order situations. The overall reported frequency of serious injuries was very low.

The report also describes injury by water impact in general and offers an overview of the dynamics of water jets.

The current instructions to users of water cannon are reviewed and scenarios in which personnel may be more susceptible to jets of water from either direct impact or the subsequent displacement of the body are presented.

16. Abstract Protective Marking including any Caveats
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17. Keywords/Descriptors (Authors may provide terms or short phrases which identify concisely the technical concepts, platforms, systems etc covered in the report.

Water jets, water cannon, NLW, less-lethal weapons

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