PREPARING FOR DAM-FAILURE FLOODING: THE DEVELOPMENT

OF SPECIAL EMERGENCY PLANS IN NEW SOUTH WALES

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INTRODUCTION

There are in New South Wales several dams, large and small, which have been identified as "deficient" and at some risk of failure - most of them because of spillway capacities not large enough to cope with probable maximum flood (PMF) conditions. In some cases, works programmes designed to correct the deficiencies have not yet been worked out while in others the remedial measures which are being taken are likely to take several years to complete. Either way, the consequence is that communities downstream of some dams will have to live for a time with the real, though remote, threat of the extreme flooding which inevitably would occur after dam failure. In some of these communities, public awareness of the potential problems is well developed. Not surprisingly, a level of public disquiet exists as to both the security of individual dam structures and the consequences which would follow should any of the dams be breached.

Emergency action planning has an obvious application in situations such as these. The core concern, should circumstances exist in which dam failure is possible, must be the saving of human life downstream of the dam. Given the extreme severity of the flooding which would result from dam failure and the relatively short warning times which would be available, the only practical way of achieving this must be to move people quickly out of the path of the likely or impending flood. The central planning task, therefore, is to devise methods by which evacuation operations can be quickly and effectively carried out.

The combat agency for flood response in New South Wales, and therefore the organisation responsible for planning preparedness for and response to flooding, is the State Emergency Service. As far as dam-failure planning is concerned the SES is co-ordinating the development of a series of plans to guide evacuation operations should they become necessary downstream of specified dams. This paper seeks to define the planning problem, describe what has so far been achieved by way of the production of dam-failure plans and outline a forward

programme of planning work for the next two years.

DEFINING THE PLANNING PROBLEM

Dam-failure planning is not yet well developed in Australia, and only a few plans designed to guide responses to dam failures have so far been produced. Nevertheless, enough has been done that at least the **nature** of the planning problem is becoming reasonably clear - which is to say that the strategic questions have been posed and several of the answers have been developed. The questions are many, and not all of them can be dealt with adequately here. The following headings, though, indicate some of the more important of them.

Which Dams?

In New South Wales, the starting point for dam-failure planning is the Dams Safety Committee's list of dams with "serious deficiencies" relating to inadequacy of spillway or instability of embankment. Presently the list includes fifteen dams, all of which have been or are intended to be the subject of studies designed to produce recommendations to guide remedial works and/or the installation of warning systems. In all but one of these cases, the problem is one of a spillway which is not capable of safely passing the probable maximum flood which has been assessed for the dam site. The exception is a dam which has severe cracks in its wall.

Each one of these "seriously deficient" dams has people living below it whose lives would be at risk should failure occur. For some, the number of people at risk is no more than a few dozen, but in the worst cases the number likely to be affected is in the order of some tens of thousands.

These fifteen are not the only defined high-hazard dams in New South Wales. In fact there are more than thirty others (together with about sixty with a "significant hazard" rating), and it is not impossible that some of these, too, could be of marginal security given a flood event of near-PMF severity.

In principle, a case can be made that all high-hazard dams should have plans drawn up to guide evacuation operations, regardless of current assessments of the integrity of dam structure or the capacity of spillways. In practice it will be necessary to deal first with the worst cases (in New South Wales, the fifteen with "serious deficiencies") and to treat the development of plans for other dams as long-term goals rather than as urgent priorities. In the meantime the potential for the failure of dams which are not classified as "seriously deficient" could be addressed not by the production of separate plans but by incorporation within

planning for "normal" river flooding. In New South Wales, plans are to be produced over the next two years for all SES Divisions and covering all the state's river systems.

It needs to be recognised, too, that while remedial works will in some instances reduce the urgency with which plans need to be produced it is not impossible that **additions** to the list of "seriously deficient" dams will occur as a result of revisions to PMF figures, changes to flood modelling procedures or the discovery of problems relating to the physical stability of particular dams. Indeed it is revisions of previous PMF figures, largely derived from improved understandings of extreme weather events, which have led to the conclusion that some dams are more at risk than had earlier been believed. Presently, the Commonwealth Bureau of Meteorology regards the PMFs for dams in northern New South Wales (those for which any overtopping failure would be a result of heavy rain from ex-tropical cyclones) as being final, but the PMFs for dams in the state's south and in the transition belt between the northern and southern zones remain preliminary and subject to modification. Clearly, the present categorisation of dams in New South Wales needs to be seen as part of an evolution rather than as final or unalterable. In the meantime, the SES will focus its planning on the fifteen "seriously deficient" dams, but will add or delete cases from the list in accordance with advice from the Dams Safety Committee or other appropriate authorities.

Which Failure Scenarios?

The term "dam failure" suggests a single event - a quickly-rising superflood of fast-flowing water presumably varying in scale (depending on the volume of water released) and in human impact (depending on the size of the downstream population) but otherwise of similar character wherever it may occur. In fact, of course, dam-failure floods can be quite different depending on both environmental conditions and mode of failure, and these differences are likely to be of great significance in terms of defining appropriate emergency responses. In effect, different failure modes and different environments present quite different planning problems.

Ideally, of course, the plans which are drawn up must create a capacity for effective response regardless of environment or the precise nature of the flood which occurs. Given the existence of a plan or "family" of plans for each below-dam area for which evacuation operations may be needed, the environmental issue is necessarily built in to the planning problem on a case-by-case basis. Variation by failure mode presents more serious complications, however.

Broadly speaking there are two major types of failure scenario - flood

("overtopping") and "sunny-day" cases. The separation is not absolute, but the distinction is useful nevertheless. Overtopping failure relates to a dam's inability to cope with an extreme rain event. Presumably, very heavy rainfall which causes a build-up of water capable of overwhelming a dam is not likely to be confined solely to the catchment above the dam and entirely held back until the moment of failure. Rather, a dam-failure flood is likely to be accompanied, before and after failure actually occurs, by flooding downstream and in adjacent, possibly tributary, catchments. In such a situation it would be expected that the emergency services would already be active by the time the failure took place and that some people would already have been evacuated from low-lying areas. Equally, though, evacuation routes may have already been lost. The cutting of such routes is predictable in the case of rain-related dam failure and must be considered as part of the planning process.

Sunny-day failures, which may occur in many guises, have rather different features from an emergency management point of view. Worldwide, many dams have collapsed through internal erosion (piping), but failure may also result from "impact" events such as massive landslides, earthquakes or even terrorist activity. With the possible exception of piping or landslide-related problems (the latter of which presumably would take place as a consequence of rain-induced rotational slumping along well-lubricated shear planes in mountainous country), all these kinds of failure would be likely to occur with very little if any warning. Evacuation routes would not be cut prior to failure, but neither would the emergency services have been activated or be carrying out evacuation operations prior to or in expectation of failure actually occurring. The time framework within which response occurred would be quite different from that which would characterise a failure due to overtopping, and as a result so would some of the response elements themselves be different.

Enough has been said to suggest that from a disaster management standpoint there can be substantial differences between different dam-break floods and that these differences are likely to be highly significant in terms of response characteristics. How, then, should planners proceed? The answer must be that they should identify the most credible failure modes but that in planning for them must develop arrangements which are sufficiently flexible to encompass the possibility of less likely kinds of failure.

Most recorded cases of embankment failure have resulted from internal erosion (Smith,1989), frequently as a new dam has filled for the first time. In present-day Australia, though, piping-related failure is unlikely because of the quality of dam construction and of surveillance. Earthquakes, too, are probably not a major threat to dam security in Australia, partly because of their relatively low magnitude

here and the fact that they are generally too short to "excite" massive structures like dams. Landslides and mountain failures are also improbable given Australia's topography and geology, and to date it has been difficult to identify a credible terrorist threat which would leave structures such as dams vulnerable to attack - though this could conceivably change given changes in the international political climate.

Except for dams which are poorly constructed or which have been allowed to fall into poor states of repair - and in both cases there are likely to be engineering fixes to their problems - these failure modes would seem not to be as credible in the Australian context as the flood overtopping mode. Over the small span of time since European settlement began in Australia there have been a number of rain events which have led to flood magnitudes higher than 0.5 PMF in particular locations - and some of our dams would not be able to cope with flooding of such severity should it occur over the catchments they command. Again, of course, construction fixes are available. But with several dams having deficient spillways and with the upgrading works in some cases costing very large sums to undertake, it cannot be anticipated that engineering solutions will necessarily be quickly adopted or the construction works completed in short order.

If dams in New South Wales are to fail, then, flood overtopping is the most probable cause. This, therefore, is the threat on which planning should primarily focus unless particular cases dictate otherwise - but the arrangements which are outlined in the plans must be flexible enough to facilitate response to dam-failure floods of other origins or types (Haines, 1991). We will return to this issue in a later section.

What Information Needs?

Emergency planning is obviously most effective given a sound advance appreciation of the nature of the event which is envisaged. In the case of a flood resulting from dam failure, there are perhaps two principal features above all others which must be understood if the plan for it is to have utility. These relate to **warning time** and the likely bounds of the **area which will be inundated**. Neither can be known with precision, partly because dam failure has not yet occurred at the site of any existing dam and empirical data are therefore lacking, but partly too because no two floods emanating from the same location would ever be identical.

Warning time is a critical variable in planning the emergency response to flooding and ensuring that the impacts of floods are effectively mitigated. This is particularly so in the case of dam-failure floods, which almost by definition arise

more quickly and affect more people than do "natural" floods and which create more difficult problems in terms of the need to mount larger scale evacuation operations under more severe time constraints. Moreover, in some instances the amount of time which would elapse between dam failure and the cutting of escape routes would be very small - too small, in fact, too allow all the potential victims to be evacuated in time. It is therefore vital that warning be seen in terms of time **before** the dam wall begins to break as well as after.

This need clearly thrusts the question of the potential for dam failure into the field of meteorological forecasting. In very general terms, there are three different kinds of weather event which could have relevance in this context as far as New South Wales dams are concerned. In descending order of lead time likely to be available to the emergency services, these are:

(1) Ex-tropical cyclones, which could migrate sufficiently far south of the Tropic of Capricorn to affect dams in the northern half of the state. Such cyclones can be "seen" and tracked by meteorologists for some days before they reach the state, but in terms of "emergency time" - the amount of time over which they can be defined as credible threats to the security of particular dams - much less would be available to initiate evacuation operations.

(2) Southern storms, which could affect dams in the southern half of the state. For these, warning times are likely to be somewhat less than those which would apply in the case of downgraded tropical cyclones.

(3) Severe thunderstorms, for which the warning time is likely to be very short indeed - probably only of the order of an hour - even though the conditions under which such thunderstorms might develop could be recognised much earlier.

There remains much to be done before we can get a firm grip on the question "How much warning of a potential case of dam failure is feasible?". The answer, for a particular case, comes from an understanding of the nature of an approaching weather system, the predictability of its path, the time of concentration once the rain hits the ground (a catchment size consideration), the size of the storage and its state at the start of rain. Other things being equal, small dams in small catchments would be overtopped and could fail quickly, while large dams commanding large catchments would take much longer to collapse and would therefore provide more warning time. The State Emergency Service will soon be seeking advice from the Bureau of Meteorology on its capacity to provide advance warning of oncoming weather events with a potential to bring about the failure of a dam.

Advance warning, then, would be valuable in terms of buying time - both for activating emergency services and for beginning evacuation operations (possibly at the risk of having to call them off when an extreme weather event veers away or fails to realise its potential to cause dam failure). Clearly such early warning would facilitate response, especially for areas close to dams or when very large populations required evacuation.

Information on the extent and boundaries of areas likely to be inundated by dam-break flooding is also vital to effective planning. One of the characteristics of the flood-modelling studies done in New South Wales to this point is that few of them attempt to track the effects of superfloods for more than a few kilometres downstream from the dams. Yet inundation from dam-break flooding can occur literally hundreds of kilometres from the source, and enormous areas can be directly affected. Dam owners are, understandably, reluctant to model dam-failure flooding over great distances when increasingly tenuous assumptions about such things as the flood contributions of downstream tributaries must be made. Unfortunately, however, the consequent lack of information on the likely extent of the inundation area makes planning very difficult and forces planners into crude assumptions about the incremental effects of dam-failure floods above known floods of record. The precise areas which were inundated in these worst-ever floods are not, of course, always accurately known themselves. This is especially the case with floods which occurred many years ago.

THE PLANNING PROGRAMME

Completed Plans

During the late 1980s two plans were completed in New South Wales to cater for potential dam-failure flood events. These were for the areas downstream of Dungowan Dam, a storage owned by the Tamworth City Council and located on a tributary of the Namoi River, and below Chichester Dam, which is owned by the Hunter Water Board and sited on a tributary of the Hunter River above the town of Dungog. Both plans list the roles and responsibilities of the organisations which would be involved in response operations if dam failure became a possibility, and both describe plan activation procedures, warning and alert system arrangements, the mechanics of the evacuation requirements, resource needs and other matters of relevance. Chichester, however, is no longer characterised as "seriously deficient", remedial construction works having been carried out on it to enlarge its spillway capacity, and the remedial works designed for Dungowan are expected to be completed by the end of 1991.

Current Planning

Planning is in progress to deal with the potential for dam-break floods associated with seven others of the state's "seriously deficient" storage structures. These are the Warragamba, Nepean, Burrinjuck, Glennies Creek, Pindari, Chaffey and Captain's Flat dams.

The preparation of these plans is being co-ordinated from the state headquarters of the State Emergency Service. To avoid the plans being written in isolation from those who would be involved in flood preparedness and flood combat operations, however, the planning process involves close liaison with SES, police and other personnel in the appropriate regions of the state.

The structure of these various plans is in the broad sense similar from case to case. Each plan identifies the responsibilities of the various "actors" (individuals or organisations) who would be involved should plan activation become necessary, as well as describing warning and alarm procedures, flood response operations (including details on communications, information services, road control and evacuation tasks) and immediate recovery matters. In some cases, too, the planning process has been deliberately designed to produce a **number** of plans rather than a single document. This is so in those instances in which dam failure would produce a truly colossal impact, in terms of the scale of the response which would be required, and would do so across a number of jurisdictions. Thus the planning to cope with a Glennies Creek failure is likely to result in the production of seven separate documents - two to guide operations at Police District level (where the senior police officer, the District Emergency Operations Controller, would be in overall control) and one each to guide operations within each of the five Local Government Areas in which inundation would be experienced as a result of dam failure. For much smaller events, such as would occur should the Captain's Flat dam fail, a single plan is expected to be capable of covering the range of necessary arrangements.

Another difference between the various planning processes now in train relates to the way in which dam-break floods are being considered in relation to "natural" flooding. In some cases, the two types are being dealt with simultaneously within the same plans; this is the case with the planning for both the Warragamba and Captain's Flat dams. Elsewhere, natural and dam-failure floods in most instances are being treated as separate events with separate plans being produced for each type. Once the various plans are completed, the "positioning" of the two types with respect to plan content will be reconsidered as part of the process of plan review. At this point, integration will no doubt occur in at least some instances.

The production of the plans for the seven cases identified above is now well under way. Some documents are now in virtually complete draft form and are intended to be released by the end of 1991 as finished plans. All of the others are expected to be completed and released during 1992.

Upcoming Planning

Planning has yet to be initiated for the purpose of guiding preparation for the potential failure of any of the other eight "seriously deficient" dams in the state. These are in most cases small dams under local council or state government ownership. Generally speaking, any flood resulting from the failure of these structures would affect a few dozen people rather than the many thousands who would be at risk should dams like Warragamba, Glennies Creek or Burrinjuck fail. Likewise the flooding, while serious, would in most cases not affect vast areas or be felt great distances downstream. The dams are the Oberon, Spring Creek, Lyell, Coeypolly, Sooley, Chifley, Redbank Creek and Burrendong structures. Of these, only Burrendong can be considered large and likely to cause widespread inundation affecting a substantial population over a great downstream distance should failure occur.

In several of these cases the studies of the dams have yet to be completed. Until these studies are finished, and information on the likely extent of dam-failure inundation is available, detailed planning will be difficult and reference to potential dam-break flooding problems will of necessity be confined to general plans for "natural" floods. Once the studies are completed, though, the SES will be able to discuss with the Dams Safety Committee and the dam owners, on a case-by-case basis, the need and basis for emergency action planning specifically related to the dam-failure issue. Several of these studies are expected to be concluded late in 1991 or early in 1992, and detailed planning will be able to commence virtually immediately upon study completion. Most of these dams, being relatively small and in lightly populated areas, do not appear to present great difficulties as far as evacuation management is concerned.

The programme envisages the completion of plans during 1992 or 1993 for areas downstream of most of these dams. As this programme draws nearer to its conclusion, a new one will be devised to review and test the several individual plans which will have been produced and to identify further cases, if necessary, where planning would be appropriate. Meanwhile, the completion of individual plans or "families" of plans will be accompanied by public education programmes designed to ensure that people living in areas at risk of dam-break inundation are aware of the contents of the appropriate plan and of the evacuation arrangements

that would apply in their vicinity. The SES will seek to develop these programmes, in conjunction with the respective dam owners, to coincide with the release of the individual plans.

WARRAGAMBA DAM AND THE NEPEAN-HAWKESBURY RIVER

The Nepean-Hawkesbury river system drains a large area of the Great Dividing Range to the west and south-west of Sydney. The system floods frequently, and the evacuation of several scores of people during a single event is not uncommon. There is potential, however, for a very much larger number of people - more than 40,000 in genuinely massive floods - to need evacuation from the valley's several towns, dormitory suburbs and farming areas. This potential could be achieved either by very substantial natural flooding on a scale approaching the severity of the flood of record, which occurred in 1867, or by a failure of Warragamba Dam (the largest water storage in New South Wales).

The Planning Process

For the last few years, the State Emergency Service has been involved in developing emergency preparedness measures for the areas downstream of this dam. The planning work is now almost complete and a "family" of draft plans - nine in all - is due for release before the end of the year. The number of planning documents which has been produced reflects the complexity of the problem and the number of jurisdictions which would be operationally involved should very serious flooding occur within the valley.

In this instance, dam-failure planning has been integrated with flood planning in general. The plans cover, in fact, floods of all levels of severity. At a relatively early stage in the planning process the decision was made that the SES, an organisation with only a small number of locally-resident volunteers relative to the scale of the response tasks which the problem would create, did not have the capability to manage the larger-scale flooding events - including any flood involving a failure of the dam. The plans thus divide flood operations into two categories - first phase (covering floods reaching levels below the Current Planning Level, now thought to be represented roughly by the 1:70 year event) and second phase (covering floods reaching or surpassing this level). The first-phase operations, it is envisaged, would be controlled by the SES in its normal role as the combat agency for floods. For events predicted to exceed this level, when the evacuation problem will quickly become massive in scale, control will pass to the State Emergency Operations Controller who will direct the response on a valley-wide basis through the senior police officers at Emergency Management Zone and local levels. At the cut-off level (the Current Planning Level) the flood would have

a direct impact, through inundation, on approximately 2,200 dwellings and 7,000 people. By this point, it is clear, the management arrangements for control of the operational response would need to be quite different from those invoked for lesser floods including floods like the event of August 1990 which had an AEP value of 1:20-30 but which necessitated the evacuation of only a few hundred people.

During the planning process, the SES has benefited significantly from the contribution of the Sydney Water Board - the owner of Warragamba Dam - in defining the planning problem. The Board has provided a number of inundation maps identifying the likely extents of the areas which would be affected by floods of various levels of severity and covering the entire valley from the dam itself to a point well below the upper limit of tidal influence. In addition, the Board has developed a model hydrograph which estimates the rise of flooding during the development of a PMF event. This hydrograph highlights the extreme speed with which a PMF would be likely to develop within the valley. It has been used to estimate timings for the "achievement" of critical flood heights at which decisions to evacuate would have to be made.

In a sense, the plans tie second-phase response operations in to the "rhythm" of an extreme flood event. Given a forecast of a flood reaching or surpassing the Current Planning Level, Water Board and/or Bureau of Meteorology expertise thoroughly familiar with the river's behaviour and the development of existing weather systems would be seconded by the State Emergency Operations Controller. The task would be to designate a starting point (called in the plans "the onset of rain") from which the application of worst-case timings outlined in the plans would provide decision makers with an indication of how quickly they may have to begin the actions required to ensure a complete evacuation of the population of the areas for which they were responsible. The timetable is indicative rather than prescriptive, but most importantly it allows a massive response to be mounted **before** dam failure becomes imminent. This is crucial if the under-response which traditionally accompanies massive, fast-developing floods is to be avoided and if the enormous evacuation task is to be completed before the flood waters arrive and cut off the escape routes.

The various plans outline the nature of the evacuation tasks on a sector-by-sector basis. For each defined sector the evacuation routes and reception centres are nominated, the estimated time which would be required to complete the evacuation is given along with the size of the population which would need to be evacuated and the number of doorknockers which would be required. So too are the river height and time (related back to "onset of rain") by which the evacuation decision would have to be made in the worst case. Resource needs for

deployment along the various evacuation routes are also defined. The arithmetic of the planning indicates with stark clarity the scale of the problem of response which massive flooding - with or without dam failure - would create. It also indicates how response can be made flexible to meet the rhythm of particular flood events. While the planning has been developed with overtopping failure rather than sunny-day breaches in mind, the arithmetic base defined above is readily capable of recalibration - for example by indicating how much more rapidly resources would have to be deployed if a sunny-day failure occurred without warning and evacuation operations had to be initiated **after** rather than before the actual moment of failure. The task would be monumentally difficult, but the methodology underlying the planning is intended to maximise the efficacy of the response regardless of the precise mode of flooding which has to be dealt with.

The Plans

The plans themselves are intended to guide the response activities of a number of key actors with specific tasks to fulfil. The "umbrella plan", the Nepean/Hawkesbury Flood Emergency State Plan (a sub-plan of the New South Wales State Disaster Plan) gives a general outline of response operations, identifying the communities which would require either partial or complete evacuation for floods liable to reach or exceed the Current Planning Level, and designates the responsibilities of the State Emergency Operations Controller, the Sydney West and North West Zone Emergency Operations Controllers, the SES Sydney Western Division Controller, and the several Local Emergency Operations Controllers and SES Local Controllers. The tasks which would fall to the various emergency services (including the Police, the Bush Fire Service, the Disaster Welfare Service, Engineering Services, the Bureau of Meteorology and the Water Board) are also outlined. Activation arrangements and the mechanisms by which control responsibilities would be handed over in the transition from first-phase to second-phase operations are described, as are warning procedures and the basics of the intended response operations including the location of operations centres, communications needs, information-provision arrangements, transport arrangements and the like. Initial recovery measures are also identified.

Other, lower-level (Emergency Management Zone, SES Division and Local) plans have been designated as sub-plans to this main "state-level" plan. Each of these plans outlines, in more detail than the main plan but still following the same preparedness-response-recovery structure, the intended actions should flooding occur in its designated territory. Two of the plans relate to Emergency Management Zones (Sydney West and Sydney North West), one to an SES Division (Sydney Western), three to local government areas (Baulkham Hills, Blacktown and Hawkesbury) and two to parts of local government areas (eastern

Penrith and Emu Plains).

The planning process has identified a number of problems which will have to be overcome if the evacuation operations are to be successfully carried out. One of these relates to securing evacuation routes which are known to be affected at particular locations by local flooding even in flood events much less severe than those envisaged in the plans. Treating each designated route as an axis (with potential sub-routes identified for short tangents where necessary) low points have been identified. Discussions have begun to identify the emergency engineering works which would be feasible at these points: in some instances it is likely that additional culverts would be deployed, with gravel fill being utilised to raise road levels and with temporary levees being created on the upstream side of the road. Elsewhere, additional lanes might be required. It must be remembered, of course, that such measures would be needed only to "buy" a small amount of time for evacuation operations. They would not be intended as permanent solutions to the problems of evacuating people to higher ground. One Council, however, has agreed to prepare a submission for funding for further studies to investigate the problem of **permanently** upgrading key routes to flood-free status. Support for this initiative is likely to be sought via the State Emergency Management Committee.

Future Developments

While the Nepean/Hawkesbury plans are intended for release before the end of 1991, the work required to prepare the emergency services and the population of the area for massive flood events will continue well into the future. A public education campaign will have to be developed during late 1991 and early 1992 in conjunction with the Sydney Water Board as the owner of Warragamba Dam; this campaign will probably be delivered along with the Board's own programme related to the Warragamba Dam Environmental Impact Study. Beyond that, the plans will be periodically exercised and the bases on which they have been prepared will be regularly reviewed with revision and updating in mind. One initiative here will involve the application of census and other community-analytic information to the identification of the most vulnerable elements within the population of the valley. At present, 1986 census data are being assembled to identify the areas in which elderly people and car-less households are most heavily concentrated: this will allow the fine-tuning of the transport needs of the various communities so that bus routes and stopping points can be planned and appropriate numbers of buses and other carriers provided.

By late next year the output of the 1991 census should be available, which will allow an updating of this information. At the same time it may be possible to go

further with the use of demographic data in identifying ways of tuning the plans more effectively to community needs - something which to date has been lacking in Australian emergency preparedness planning (see Keys, 1991).

CONCLUSION

For dam-failure planning to be effective, there are several prerequisites which must be met. Amongst them are an appropriate legislative base, a workable set of command and control arrangements for response purposes, and a well developed understanding of the hazard which must be faced. In New South Wales the legislative base has been established and the command and control arrangements are being worked out on a case-by-case basis but to recognised and accepted principles. Some work remains to be done, though, to ensure that the best possible information about warning times and extent of innundation is available to the planners.

Even then, of course, there will be limitations on the effectiveness of plans which are designed to assist the response to dam-failure flooding. Some of these will relate to the quality of preparedness of the emergency services and the public. Others relate to the nature of plans themselves. Evacuation plans are not, after all, the ultimate solutions to enormous problems like dam-failure floods. No plan can anticipate all aspects of an event and make provision for every response detail; indeed to attempt to do so invariably leads to over-planning and inflexibility which can be nearly as bad as failing to plan at all. Plans need to be seen as instruments designed to facilitate and guide emergency response in very difficult circumstances once something has gone or is about to go seriously wrong. In catastrophic situations, when conditions may become highly chaotic and disorganised, some limitations on what plans can achieve must be recognised. Equally, though, the opportunity to anticipate and plan for catastrophe should facilitate and improve the response to it.

Over the next two years, a wide range of flood planning tasks will be completed in New South Wales. Most of these will be related solely to "natural" flooding, the plans for which will cover all eighteen SES Divisions in the state and all local government areas which can be considered to have a flood hazard. But some of these plans will also deal with the potential for dam-failure floods, and in addition there will be a number of special plans dealing solely with the issue of dam-failure flooding. The Warragamba-Nepean/Hawkesbury planning described above will undoubtedly take on the role of exemplar for dam-break flood planning work, which will nevertheless be firmly grounded in the local circumstances in which each such flood would potentially occur. For some time yet the SES will be seeking from dam owners, and other authorities, improved information related to

warning time and the likely extent of inundation. Such information will have as its reward a more effective preparedness on behalf of both the emergency services and the public which they serve.

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