**CSIRO** PUBLISHING
*Australian Health Review*
https://doi.org/10.1071/AH18153

# How Local Health Districts can prepare for the effects of climate change: an adaptation model applied to metropolitan Sydney

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**Abstract.** Climate change adaptation can be defined as a form of risk management (i.e. assessing climate change-related risks and responding appropriately so that the risks can be pre-emptively minimised and managed as they arise). Adapting to climate change by hospital and community health services will entail responding to changing health needs of the local population, and to the likely effects of climate change on health service resources, workforce and infrastructure. In this paper we apply a model that health services can use to predict and respond to climate change risks and illustrate this with reference to Sydney's Local Health Districts (LHDs). We outline the climate change predictions for the Sydney metropolitan area, discuss the resulting vulnerabilities for LHDs and consider the potential of LHDs to respond. Three 'core business' categories are examined: (1) ambulance, emergency and acute health care; (2) routine health care; and (3) population and preventative health services. We consider the key climate change risks and vulnerabilities of the LHDs' workforce, facilities and finances, and some important transboundary issues. Many Australian health services have existing robust disaster plans and management networks. These could be expanded to incorporate local climate and health adaptation plans.

**What is known about the topic?** There is an inextricable relationship between climate change and human health, with important implications for the delivery of health services. Climate change will affect health service demand, and the resources, workforce and infrastructure of health services.
**What does this paper add?** This paper outlines how local health services can use existing data sources and models for assessing their climate change-related risks and vulnerabilities to predict, prepare for and respond to those risks. This is illustrated with reference to Sydney's LHDs.
**What are the implications for practitioners?** Adaptation to climate change by health services is an important component of risk management. Local health services need to prepare for the effects of climate change by assessing the risks and developing and implementing climate and health adaptation plans.

**Additional keywords:** health services, health systems, population health, risk management.

Received 24 July 2018, accepted 29 September 2018, published online 21 December 2018

## Introduction

There is an inextricable relationship between climate change and human health.[1,2] In many parts of the world, the changing climate is already having major health and social effects due to weather extremes, reduced food and water security and the spread of infectious disease.[3,4] As a result, leading international agencies and Australian health organisations have prioritised action on climate change, including the growing need and importance of adaptation by local health services.[5–8] In Australia, the Climate and Health Alliance (CAHA) has led the development of a framework for a national strategy on climate, health and well-being that outlined seven areas requiring government policy action, including emergency and disaster preparedness and building a climate-resilient health

sector.[8] The national framework has also been referenced in a recent Senate Select Committee report on the implications of climate change on Australia's national security.[9]

Thus, climate change adaptation can be defined as a form of risk management (i.e. assessing climate change-related risks and responding appropriately so that they can be managed as they arise).[10,11] The UKCIP (formerly known as the UK Climate Impacts Program) at the University of Oxford offers online risk-based adaptation resources to assist organisations with local climate change adaptation planning.[10] Steps include assessment of current and future climate vulnerabilities and development and evaluation of agency-appropriate adaptation measures.[10] The US Centres for Disease Control have developed a similar framework for Building Resilience against Climate Effects (BRACE) by public health agencies.[11] Adapting to climate change by hospital and community health services would entail identifying effects on a population's health and its use of health services, as well as preparing for the effects of climate change on health service resources, workforce and infrastructure. In this paper we illustrate how the existing models and available data can be used by local health services to predict the local risks and prepare for the effects. To do this, we outline the climate change predictions for the Sydney metropolitan area, present the health service problems and vulnerabilities for the Local Health Districts (LHDs) and consider the potential of LHDs to respond. As recommended by existing frameworks,[10,11] subsequent steps would entail the New South Wales (NSW) health service and its LHDs developing and implementing their own climate and health adaptation plans, possibly within the existing disaster management frameworks.

## Sydney's observed and projected climate change

Although average Sydney temperatures fluctuate from year to year, overall over the past two decades the winter warm spells have been generally lasting longer, occurring more often and becoming more intense.[12] Sydney summers are also getting hotter, with more frequent and intense extremes. For example, during the summer of 2016–17, Sydney had a record total numbers of days at 35°C or above, and January 2017 was the warmest month on record. Since the late 1950s, Sydney has also experienced progressively longer heatwaves (Fig. 1; see also Box 1). In the summer of 2016–17, Sydney had the second highest total number of '3-day heatwave' days, and its highest number of heatwave days in the extreme category. Even between heatwaves, the summer of 2016–17 was notable for its almost continuously above-average temperatures.[12]

Sydney's current climate is summarised in Box 2.

Future climate change projections for different Australian regions have been prepared by the CSIRO and Bureau of Meteorology.[13] The relevant projections for the East Coast Cluster – South (including the Sydney region) are compiled in Table 1.

In summary, Sydney's average temperatures will continue to increase in all seasons. There will be more very hot days, more frequent and longer warm spells and progressively harsher fire weather. The intensity of extreme rainfall will increase, and there will be some longer-term decreases in winter rain. Mean sea levels and the height of extreme sea levels will continue to rise. However, natural variabilities may mask or enhance longer-term anthropogenic changes over the next 20 years, particularly for rainfall.[13]

A projected increase in the average number of days above 35°C and 40°C is summarised in Table 2 (2030 and 2090 compared with the average for 1981–2010).[13] It is of note that the projected increase in the frequency and severity of extreme heat outlined in Table 2 appears conservative relative to the observed more recent heatwaves reported in Fig. 1. Indeed, other modelling from the NSW and Australian Capital Territory (ACT) Regional Climate Modelling (NARCliM) project, which provides data specific to the Sydney metropolitan area, suggests a greater increase in heat extremes.[14] The current annual number

**Box 1. Bureau of Meteorology heatwave definitions and categories**

From http://media.bom.gov.au/social/blog/891/how-will-i-know-if-a-heatwave-is-coming/ [verified 17 April 2018]

The Bureau defines a heatwave as three or more days in a row when both daytime and night-time temperatures are unusually high in relation to the local long-term climate and the recent past. These are categorised as follows:

- low-intensity heatwaves are the most common; most people are able to cope with this level of heat
- severe heatwaves are less frequent and are challenging for vulnerable people such as the elderly, particularly those with pre-existing medical conditions
- extreme heatwaves are the rarest kind. Extreme heatwaves affect the reliability of infrastructure, like power and transport, and are dangerous for anyone who does not take precautions to keep cool, even those who are healthy. People who work or exercise outdoors are particularly at risk.

**Box 2. Sydney's current climate**

Sydneys climate is humid subtropical and areas closer to the ocean have average temperatures ranging from approximately 15°C in winter to approximately 25°C in summer. However, like the rest of Australia, Sydneys weather can vary significantly and is highly influenced by the El Niño Southern Oscillation (ENSO). The negative phase of El Niño tends to bring below-average rainfall and warmer temperatures, whereas La Niña is associated with above-average rainfall and cooler temperatures.[15]

Sydneys average annual rainfall is 1200 mm, but this varies highly throughout the year. February is usually the wettest and winter is significantly drier. Sydney is also prone to severe storms, including approximately 20 thunderstorms per year. Storms often arise due to east coast lows (ECLs), which can occur at any time. ECLs tend to bring heavy rain, strong gusty winds and high seas, and cause significant damage to buildings and power lines, particularly from fallen trees, as well as localised flash flooding.[16]

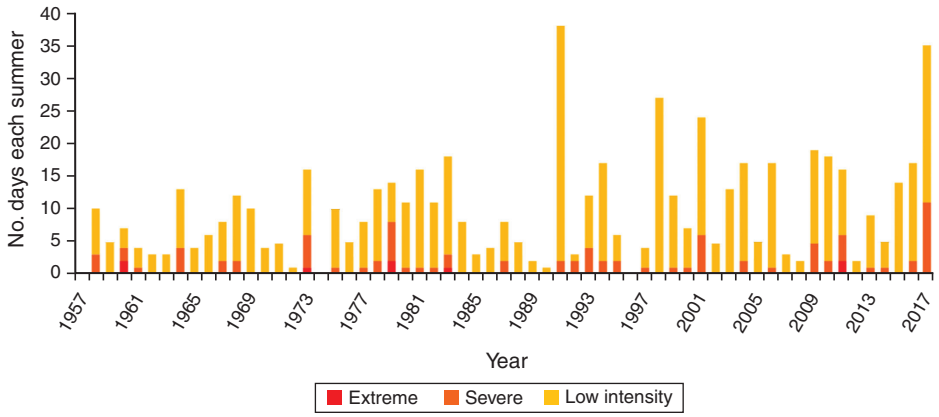


**Fig. 1.** Number of days in which Sydney has been in a 3-day heatwave during summer, within each heatwave severity category. Used with permission from the Bureau of Meteorology.[12]

of hot days (above 35°C) of less than 10 days per year near the coast and 10–20 days per year in the western suburbs is projected to increase by approximately 4 days by 2030 and by approximately 11 days by 2070. This is summarised in Fig. 2. Recent modelling by researchers at the Australian National University also suggests that Sydney may experience summer extremes as high as 50°C as early as 2040, even under scenarios where global average temperature increases are contained to 2°C.[17]

## Vulnerabilities for Sydney LHDs arising from climate change

The direct and indirect health effects of climate change have been well described, both globally and for Australia[1,8,18–20] (Appendix 1). The measurement and quantification of health effects will enable us to monitor the effectiveness of adaptation and mitigation strategies.[3,4,21,22] In Australia, the single most dangerous climate-related hazard is extreme heat, which has been responsible for 4555 fatalities nationwide (since 1900), more than from all other natural hazards combined.[23] Heat stress and heat exhaustion also affect morbidity (with children, elderly people, pregnant women and people with pre-existing conditions and disabilities most at risk) and severely affect work capacity.[24,25]

As demonstrated in Fig. 1, heatwaves are a significant concern for metropolitan Sydney, and thus its LHDs. For planning climate change adaptation, it can be useful to consider former climate- and/or weather extreme-related vulnerabilities, which, combined with climate change projections, can inform vulnerability predictions.[10] Some of the important former climate-related vulnerabilities for Sydney's LHDs are summarised in Box 3. These include increased heat-related ambulance call outs and hospital admissions from exacerbations of respiratory and cardiovascular conditions, mental diseases, diabetes, dehydration and heat stress. Health services have also been affected by other extreme weather events, particularly when these have caused spikes in demand while at the same time disrupting transport and power supplies.

Key vulnerabilities for the Sydney region identified by government service providers in 2015 are also included in Fig. 3.[26] We have added highlights to suggest which may be particularly relevant for LHDs.

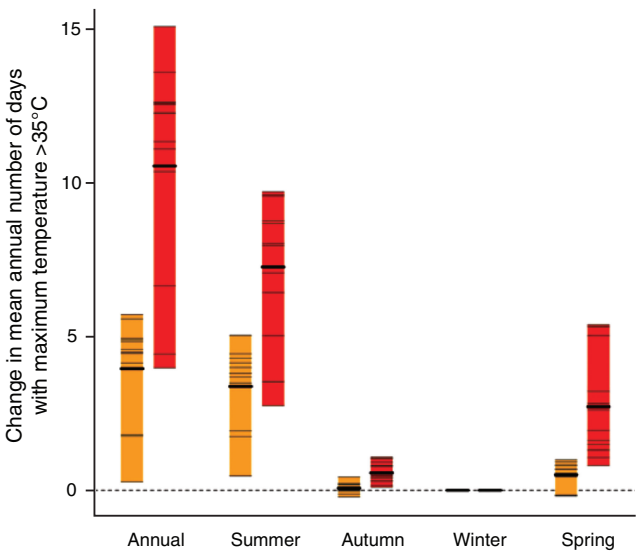


**Fig. 2.** Projected changes in the number of hot days (daily maximum temperature >35°C) for the Sydney metropolitan region, annually and by season, for 2030 (yellow) and 2070 (red). The length of the coloured bars shows the spread of model values for the region in each period; horizontal thin lines are values from individual models, whereas darker lines are the average of all models. Currently Sydney experiences <10 days per year with temperatures >35°C near coast and 10–20 days per year in western suburbs. Used with permission from the Office of Environment and Heritage.[14]

## Climate change adaptation options for Sydney LHDs

In NSW, LHDs and Speciality Networks (e.g. Sydney Children's Hospitals) report regularly on service agreements with the Ministry of Health and, via the Secretary of NSW Health, to the NSW Government. Ideally, climate risk assessment and adaptation by public health services would also be coordinated by the state (and national) governments to support and reinforce local implementation. Western Australia, for example, detailed

**Table 1. Projected climate change for the Sydney region**

Table compiled from data in Dowdy *et al.*[13] Representative concentration pathways (RCPs) represent future scenarios for greenhouse gas (GHG) emissions, with GHG concentrations and associated global warming modelled to Year 2100. For RCP4.5, global warming is projected as likely to be 1.1–2.6 °C by 2100. For RCP8.5, global warming is projected to be 2.6–4.8°C[27]

| Projections | Near future (2030) | Late century (2090) |
|---|---|---|
| | *Temperatures* | |
| Higher temperatures (see also Table 2) | Mean warming increase 0.4–1.3°C, with minor differences between RCPs (very high confidence) | Mean warming increase 1.3–2.5°C for RCP4.5 and 2.7–4.7°C for RCP8.5 (very high confidence) |
| Continued substantial warming[A] for mean, maximum and minimum temperatures | | |
| Mean temperatures have already risen 0.8°C | | |
| Hotter and more frequent hot days, longer hot spells | Substantial increase in the temperature reached on hottest days, the frequency of hot days and the duration of warm spells (very high confidence) | Substantial increase in the temperature reached on hottest days, the frequency of hot days, and duration of warm spells (very high confidence) |
| Less frost | | Substantial decrease in the frequency of frost-risk days (high confidence) |
| | *Rainfall* | |
| Increased intensity of heavy rainfall events | Increased intensity of heavy rains (high confidence), but magnitude of change uncertain | Increased intensity of heavy rains (high confidence), but magnitude of change uncertain. |
| Less rainfall in winter | Natural climate variability will remain main driver of main rainfall changes (high confidence) | Decrease in winter rainfall under RCP4.5 and RCP8.5 (medium confidence) |
| | *Fire risk* | |
| Harsher fire-weather climate | Increasing risk of bushfires (high confidence) but magnitude of change uncertain due to uncertain rainfall projections | Increasing risk of bushfires (high confidence) but magnitude of change uncertain due to uncertain rainfall projections |
| | *Sea levels* | |
| Higher[A] sea levels and more frequent sea level extremes | Sea level rise of 0.08–0.18 m, with minor differences between RCPs (high confidence) | Sea level rise 0.30–0.65 m for RCP4.5 and 0.44–0.88 for RCP8.5 likely (at least 66% probability) |
| Sea levels are rising 1.6 mm per year and will continue to rise during the next century | | |
| | *Ocean temperature and acidity* | |
| Warmer and more acidic oceans (acidification to date: 0.1 pH fall in ocean surface water) | Decrease in pH of 0.08 units (very high confidence) | Decrease in pH of 0.1 units for RCP4.5 and 0.14 units for RCP8.5 (high confidence) |
| Sea surface temperature has risen across the globe and warming will continue (very high confidence) | | |

[A]Above climate or levels of 1986–2005.

**Table 2. Current average number of days (1981–2010) in Sydney above 35°C and 40°C and below 2°C compared with projections for 2030 and 2090**

Table compiled from data in Dowdy *et al.*[13] Representative concentration pathways (RCPs) represent future scenarios for greenhouse gas (GHG) emissions, with GHG concentrations and associated global warming modelled to Year 2100. For RCP4.5, global warming is projected as likely to be 1.1–2.6 °C by 2100. For RCP8.5, global warming is projected to be 2.6–4.8°C[27]

| Threshold | No. days | | | |
|---|---|---|---|---|
| | Current | 2030 RCP4.5 | 2090 RCP4.5 | 2090 RCP8.5 |
| >35°C | 3.1 | 4.3 (4.0–5.0) | 6.0 (4.9–8.2) | 11 (8.2–15) |
| >40°C | 0.3 | 0.5 (0.5–0.8) | 0.9 (0.8–1.3) | 2.0 (1.3–3.3) |
| <2°C | 0 | 0 | 0 | 0 |

in 2008 a whole-of-government adaptation strategy for the health effects of extreme events and climate change.[19] The Queensland Government recently developed a human health and well-being climate change adaptation plan, and work is underway for a climate change adaptation plan for Victoria.[28–30] The NSW Government supports climate change risk assessment and adaptation planning by local councils.[31] However, although NSW Health offers advice to the public on extreme heat,[32] there is no current government-endorsed health sector vulnerability assessment process or adaptation advice for the LHDs. The Australian Federal government only briefly describes the health risks of climate change.[33]

Some LHDs in NSW have environmental sustainability plans[34] aimed at improving efficiency in the use of resources and reducing greenhouse gas emissions.[35] However, as yet no LHDs have developed plans for the assessment of and adaptation to climate change effects. LHDs will need to consider the exposure and risk of climate change to their own substantial workforce and facilities, as well as their capacity to respond to the changing needs of the populations they serve. Health sector adaptation to climate change requires clear governance arrangements, flexibility (of location, scale and type of

**Box 3. Examples of previous vulnerabilities with implications for Sydney Local Health Districts**

- Sydney's growing exposure to heatwaves; approximately 10–20 heatwave days per year over the past 20 years, and 35 days in 2017 (see Fig. 1 and Loosemore and Chand[36])
- Between 1991 and 2009, very hot days in Sydney were already associated with significantly increased hospital admissions (e.g. due to respiratory and cardiovascular conditions, mental diseases, diabetes, dehydration and heat-stress)[37]
- The 2011 Sydney heatwaves were associated with a 14% increase in all-cause ambulance call outs (with 116 specific to heat) and a 13% increase in all-cause mortality;[38] the 2009 heatwave in Melbourne of three consecutive days >43°C can also indicate the scale of potential effects of heatwaves in other cities (i.e. a 46% increase in demand for ambulance services, a 2.8-fold increase in cardiac arrests, a 12% increase in emergency department (ED) presentations, with a 37% increase for those aged >75 years[39]
- Sydney storms with heavy rains cause dangerous flash flooding and major disruptions to transport and power supplies (e.g. recent effects on Sydney's inner-west suburbs[40]); following Sydney hail storms, community health services have reported extended periods of exposure to leaking roofs and damp by low-income families unable to afford rapid repairs
- In September 2017, NSW Health issued warnings to asthma sufferers based on the severe epidemic of 'thunderstorm asthma' in Melbourne in 2017, which saw 4000 ED presentations, 30 intensive care admissions and nine deaths, as well as on previous outbreaks (although of lesser scale) in New South Wales (NSW) and Canberra[41]
- In August 2007, Sydney's main water catchment (Warragamba Dam) was affected by a major algal bloom due to a combination of low water levels and very heavy rainfall stirring up nutrients in the dam that was only one-third full following a period of severe drought[42]

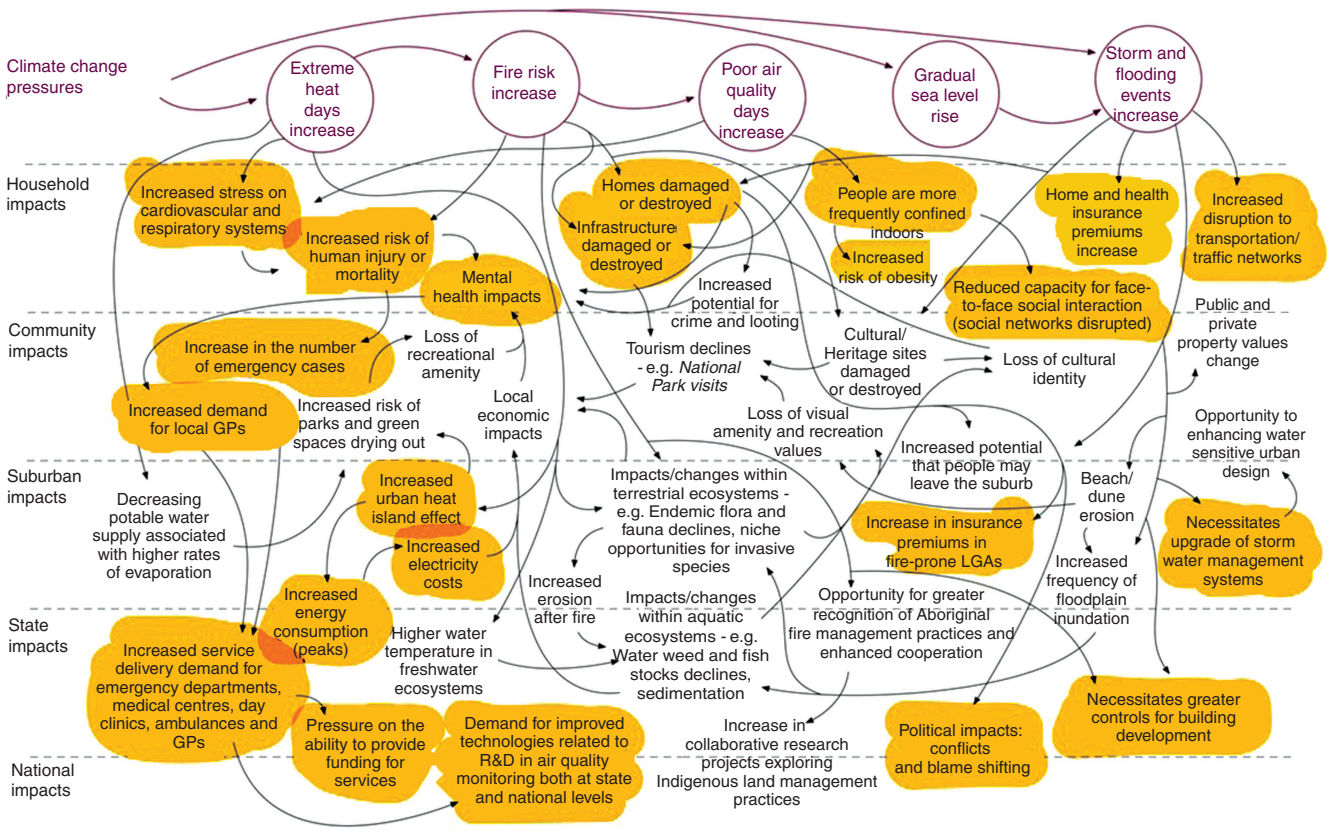


**Fig. 3.** Systems map of climate effects and their pathways from an integrated regional vulnerability assessment of Metropolitan Sydney. Reproduced, with some modifications, from Dunford *et al.*[26] (Our highlights indicate issues highly relevant to Local Health Districts.) GPs, general practitioners; LGAs, local government areas; R&D, research and development.

services across administrative boundaries), strategic allocation of resources (to adapt existing services, prioritise vulnerable groups, ensure equitable access) and robustness (resilient infrastructure, consistent services, sustainable workforce).[20] It also requires a systems approach.[43]

The United Nations identifies climate change as a core consideration in disaster risk management.[44] One existing and robust mechanism that could incorporate NSW LHDs' climate change adaptation planning is the NSW disaster management network, which consists of a central Health Emergency

**Table 3. Factors to be considered by Sydney metropolitan Local Health Districts (LHDs) in climate change adaptation**

CC, climate change; CKD, chronic kidney disease; GGHH, Global Green and Health Hospitals (see http://www.caha.org.au/globalgreen_healthyhospitals, accessed 5 November 2018); GPs, general practitioners; SLHD, Sydney LHD

| CC | LHD vulnerabilities and effects | Potential adaptations | Notes |
|---|---|---|---|
| | *Health Services* | | |
| Extreme events: hot days, heatwaves, bushfires, thunderstorms, flash flooding | **Ambulance, emergency, acute health care**<br>• Spikes in demand for ambulance services, emergency services, respiratory wards, cardiovascular wards<br>• Some staff may be unable to attend due to responsibility for home and family<br>• Concerns and questions from public and local media | Monitor severe weather predictions to inform emergency response planning within LHDs<br>Compile data on correlations between extreme events and spikes in demand to inform workforce and resource planning<br>Use opportunities created by extreme events for direct public education via local media stories on health and safety of extreme weather events, and broader health effects of CC | Investment in data collection will be cost-effective if it enables more efficient planning for emergency services<br>Although local data are important, this would be ideally led at state level<br>Media commentary may be politically sensitive for government employees, particularly if it implies criticism of current policies; some may speak or write publicly using non-government affiliations (i.e. professional bodies or universities) |
| Rising mean temperatures: more frequent, longer, warmer periods | **Routine health care**<br>• Increased referrals from GPs for diagnosis, treatment and follow-up of respiratory disease, cardiovascular disease<br>• Increased outbreaks of gastrointestinal or food poisoning, other infectious diseases<br>• Potential increase in demand for diagnosis, treatment and follow-up of CKD (especially if LHD has specialist referral centre)<br>• Extra demands or pressure on community mental health services | Representations to NSW Health on incorporating health services into government adaptation program for councils<br>Incorporate assessment and adaptation into next workforce plan (current 2016–20)<br>Support health staff to collaborative on research with local universities on CC adaptation | Adaption support for LHDs will require state-level partnership between NSW Health and Department of Environment and Energy<br>Advocacy for state-wide support best done in collaboration across all LHDs |
| | **Population and preventative health**<br>• Concerns and questions from staff, public and local media | Enhance distribution of health information on extreme weather events; link to and expand on existing NSW Health website, add local LHD webpage and hotline<br>Provide training for all LHD staff on health adaptation and mitigation | Information distributed via clinical and community health services, early childhood centres and health promotion programs |
| | *Workforce well-being* | | |
| Extreme events: hot days, heatwaves, bushfires, thunderstorms, flash flooding | Unsafe working conditions during extreme heat (e.g. if insufficient cooling or failed power supply)<br>Flooding and mould-related risk for staff respiratory health in flood-prone facilities<br>Psychological stress for emergency staff dealing with effects of extreme events | Review (and upgrade if required) cooling capacity risk in all facilities<br>Heat management plans for all staff, particularly if working outdoors or poorly conditioned facilities<br>Incorporate CC adaptation into future workforce planning and occupational health and safety assessments<br>Prepare, inform and debrief staff on extreme events | Priority must be to provide safe working environment, but staff education, health programs should incorporate adaptation<br>Staff will be affected as members of the public, depending on individual vulnerability and underlying medical conditions (e.g. pregnant women and age >65 years) |

| | | | |
|---|---|---|---|
| | | *Facilities* | |
| Heatwaves, thunderstorms, flash flooding | Flash flooding in many locations with effects on community and hospital facilities<br>Emergency services are often located on the ground floor or in basements and are subject to flooding<br>Potential interruptions to essential supplies (e.g. power, water, goods)<br>Acute and cumulative effects on costs of repair and maintenance of aging buildings and grounds | Incorporate explicit CC assessment and adaptation into strategic plans<br>Conduct CC adaption assessment of all major planned capital works<br>Review flood maps and highlight primary risk workplaces: prioritise for works or relocation<br>Join GGHH for adaptation planning advice | Draft strategic plan does not mention, let alone explicitly assess, effects of CC, so may require internal advocacy<br>At least two other LHDs in NSW have already joined GGHH |
| | | *Finances* | |
| All events | Exacerbation of financial pressures on health services with finite government resources<br>Significant opportunity costs from dealing with unbudgeted extreme events | Incorporate explicit CC assessment and adaptation into accounting and financial planning, internally and as part of performance agreements with NSW Health<br>Review insurance policies; ensure they cover extreme events and CC | Monitoring and data (above) will assist with business case to NSW Treasury (via NSW Health) for future CC budgeting |
| | | *Transboundary issues* | |
| Extreme events | Regional and city transport disruptions alongside spikes in demand for emergency and other staff<br>Pressure on existing staff, longer shifts<br>State power supply disruptions to emergency services | Link workforce planning to predictions of severe weather events outlined above<br>Implement advance notice system for essential services staff to optimise travel arrangements<br>Audit capacity of backup generators and power supplies<br>Ensure routine maintenance and review flooding risk (e.g. basements)<br>Explore alternative 'off-grid' solutions (e.g. solar power with battery storage) | Longer-term plans may require SLHD to provide back-up accommodation for emergency staff<br>Renewables and 'off-grid' power supply options likely to be cost-effective over the longer term |

Management Unit (HEMU) and LHD-based disaster management units, headed by a senior manager appointed as the Health Services Functional Area Coordinator (HSFAC). The NSW Health Services Functional Area Supporting Plan details the role of LHDs in disaster planning and response.[45] The plan adopts an 'all hazards, all incidents' approach, and a framework for planning and response that covers four core components: prevention, preparedness, response and recovery. This network and the work that it undertakes offer a robust mechanism that should incorporate climate change adaptation preparedness. The network has already begun such work (R. Hegner, pers. comm.), and this now needs to be continued and enhanced through the development and implementation of climate and health adaptation plans.

For the purpose of discussion and to inform health service planning, we have applied the climate change vulnerabilities identified in the sections above to compile some of the factors that may be considered by Sydney metropolitan LHDs in climate change adaptation (Table 3). We have cross-referenced the predicted effects of climate change in the Sydney metropolitan area (first column) with considerations of the resulting vulnerabilities (second column) and potential LHD adaptations (third column), a model adapted from the UK Climate Impacts Program.[10] The considerations are examined across the three 'core business' categories of: (1) ambulance, emergency and acute health care; (2) routine health care; and (3) population and preventative health services. In Table 3 we also consider the key climate change risks and vulnerabilities of the LHDs' workforce, facilities and finances, as well some of the important transboundary issues.

## Conclusions

Australian health services need to increase their preparedness to respond to the unavoidable effects of climate change, including spikes in local health service demands, as well as the direct effects on a service's capacity to respond. In this paper we illustrate how local health services can use available data and existing models of climate change impact assessment and adaptation, as applied to the example of Sydney's LHDs. The steps in climate change adaptation planning include drawing on available climate change projections and past exposures to identify local health service risks and vulnerabilities and using systems thinking to consider current preparedness and to forecast whether and what health service adaptations will be required. Health services are mandated to prepare for and respond to health emergencies and disasters on an ongoing basis. The adverse effects of climate change should be a key factor in such planning and response. Ideally, health service adaptation should also draw on existing planning for climate change adaptation by other government departments, incorporate other existing health service quality improvement structures and processes and be integrated across local, state and national levels. We believe that timely and effective climate change adaptation planning and implementation are essential and urgent, and can offer health services longer-term financial savings, as well as a safer environment, better health care and better health.

## Competing interests

The authors declare no conflicts of interest.

## Acknowledgements

This research did not receive any specific funding.

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## Appendix 1. Health effects of climate change

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