INQUIRY INTO WATER AUGMENTATION

COMMITTEE MEETING FRIDAY 2ND JUNE 2017

Response to supplementary question regarding air space management arrangements

Most dams across NSW and the rest of Australia have been constructed as water supply storages, with very few dams designed or intended for flood mitigation so are not provided with flood gates for discharge control.

As outlined by MDBA (2013) many water supply dams are managed/operated to meet the following objections in priority order.

1. Protect the structural integrity and safety of the dam: then
2. Maximise water availability : and then
3. Limit flood damage to downstream communities and increase benefits to the environment and public amenities.

Permanent lowering of storage can be quite effective in providing flood mitigation, but it will compromise water security and the annual allocation of water, which is why the dams exist.

Pre-release is feasible, either on a seasonal basis , or an event by event basis, but is not as effective.

The MDBA airspace management or "pre-release" strategy for Hume and Dartmouth dams provides for some airspace, but only to the extent that water security is not negatively impacted.

All dams provide some form of flood mitigation as rainfall and inflows are stored within the freeboard of the dam before overflowing through the spillway.

Use of water supply dams as a tool for flood mitigation and control should be only one element in an overall flood plan for any area which may compromise:

1. Structural measures – such as levees, dykes, floodwalls, floodways and diversion works etc.
2. Non-structural measures – such as land use restrictions, forecasting, warning systems, evacuation plans, relocation of essential services etc.

We believe it is timely that all current air space provisions should be reviewed on a regular basis. As flood plans evolve, so will need for airspace change.

This is all about a trade-off between flood protection (i.e. airspace) and significant economic impacts due to loss of available storage in the dams.

Where dams were built specifically for water supply and irrigation, any requirement for flood mitigation needs to be carefully considered to uphold the integrity of the original legislation. The question comes up as to whether we are doing the best with the present resources we have.

In conclusion AWEC has great confidence to suggest that, when the Government invests in prime water storage infrastructure, the returns will be endless. Not 5 years, not 10 years not 20 years but endless.

Attachments:

1. Using Major Water Supply Dams for Flood Mitigation and the Potential Impacts Down Stream. B.M.McPherson, NSW Public Works et al.
2. Submission by MDBA to the Enquiry into Flood Mitigation Infrastructure in Victoria.
3. Water Resources Reform Australia **North American Report**
4. Scan of cover of California State Water Project Atlas available from CA. Dept of Water Resources
5. Submission of the MDBA to Inquiry into Flood Mitigation Infrastructure in Victoria
6. Plan of theColarado-Big Thompson Project in Colorado USA

CONTACT INFORMATION

Water Supply Authorities in California and the Colorado River catchment.

1. California Department of Water Resources: www.water.ca.gov.

2. US Bureau of Reclamation: www.usbr.gov
   click WATER AND POWER, click PROJECTS, select Central Valley Project.

   Other projects we have been to include a)Central Arizona Project
   b)Colorado-Big Thompson Project
   These projects can be selected under PROJECTS. See also enclosures

3. Los Angeles Department of Water and Power: www.LADWP.com

We have found these Authorities to be very helpful and able to provide a wealth of information on their projects.

Attached: Cover picture of al Atlas of all State Water facilities. It also includes a history of the project. Enquiry should enable one of these to be obtained.

USING MAJOR WATER SUPPLY DAMS FOR FLOOD MITIGATION AND THE POTENTIAL IMPACTS DOWNSTREAM

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Abstract

There is significant community interest in the potential for water supply dams to be adapted for flood mitigation, particularly for major dams located upstream of flood vulnerable populations. There may be a number of large dams which have the potential to provide significant flood mitigation benefits to Australian communities if they can be adapted for flood mitigation functionality. Other dams already provide significant flood mitigation benefits, however their limitations are not properly understood by the general public. Two major dams located near a large urban town centre prone to flooding are examined as a case study and some international cases are presented.

Flood mitigation often has a different funding source to water supply. The funding arrangements for flood mitigation dam works can be complex, considering the potential stakeholders and somewhat intangible benefits. If the community wants to use a water supply dam to provide flood mitigation then what options are available, how does this interact with other flood mitigation measures such as downstream levees and who provides the funding if structural modifications are required.

Introduction

As defined by BTRE (2002), the purpose of flood mitigation is to decrease or eliminate the impact of floods on society and the environment. It is generally not possible to eliminate the potential for flood damage to certain communities located in flood vulnerable locations, however it can be possible to significantly reduce the risk of damage with flood mitigation dams. Flood mitigation is not limited to dams and can include other structural measures as well as non-structural measures such as property modifications and response modifications. The focus of this paper is, however, on the use of major dams for flood mitigation in Australia.

A large dam is defined by ANCOLD (2012) as one which is:

a) more than 15 metres in height measured from the lowest point of the general foundations to the crest of the dam,

b) more than 10 metres in height measured from the lowest point of the general foundations to the crest of the dam, provided they comply with at least one of the following conditions:

   i. the crest is not less than 500 metres in length

   ii. the capacity of the reservoir formed by the dam is not less than 1 million cubic metres

iii. the maximum flood discharge dealt with by the dam is not less than 2000 cubic metres per second

iv. the dam is of unusual design

VICSES (2013) outlines that the degree of flood mitigation a dam can provide depends on a number of factors including:

- the operating rules of the storage
- the size of the flood event
- the catchment size
- the level of water in the dam at the beginning of the event
- the capacity of the reservoir to store floodwaters above its full supply level
- the area of uncontrolled catchment downstream of the dam
- the discharge capacity of the spillway

Most dams across Australia have been constructed as water supply storages, with very few dams intended for flood mitigation purposes. As outlined by MDBA (2013), many water supply dams are managed/operated to meet the following objectives, in priority order:

1. Protect the structural integrity and safety of the dam; then
2. Maximise water availability; and then
3. Limit flood damage to downstream communities and increase benefits to the environment and public amenity.

The costs associated with water supply dams are covered by the supply of water to communities, whilst dam works associated with the provision of flood mitigation involve very complex funding arrangement considerations. If the community wants to use a water supply dam to provide flood mitigation then who provides the funding for the modification works? While water supply may benefit the whole community in a region, the benefits of flood mitigation are usually confined to a small portion of the community.

The 2011 Brisbane floods, and particularly the role of Wivenhoe Dam (Figure 2) and Somerset Dams as partial flood mitigation storages, have been a major discussion point within the Brisbane community and throughout Australia in recent times. The devastating impacts of the 2011 Brisbane floods have sparked significant interest in the function of water supply dams for the provision of flood mitigation benefits to the community, particularly for those dams which are located near populations at risk of flooding.

This paper will explore the options available for adapting water supply dams into dual purpose storages with both water supply and flood mitigation functionality, along with the complex stakeholder funding arrangements for such projects. Some international cases will also be examined.

Additionally, the interaction between flood mitigation measures within a region's flood risk management system will be examined and the importance of detailed whole of system assessments, when changes to the system are proposed, will be outlined.

Methodology

All dams provide some form of flood mitigation as rainfall inflows are stored within the freeboard of the dam before overflowing through the spillway, however dams designed as water supply storages generally do not provide any significant level of control over flood releases.

There are very few large dams in Australia which have been constructed purely for flood mitigation aside from small detention basins which are typically used to mitigate floods in urban catchments.

In terms of flood mitigation functionality, dams typically fall within three categories:

1. Water supply and flood mitigation – designed for dual function (Refer to Case Study 1 below).
2. Water supply dam operated/modified to provide flood mitigation function (Refer to Case Study 2 below).
3. Water supply only - incidental flood mitigation function.

This paper focuses on category 1 and 2 dams as listed above, with particular attention to the adaptation of existing water supply dams into dual purpose water supply and flood mitigation storages.

There are numerous methods to adapt a water supply dam for flood mitigation, with the most common being:

- pre-releases well in advance of a flood event and/or alternative gate operational rules during flooding events (if applicable)
- permanent lowering of the full supply level (FSL)
- physical modification of the dam to provide additional temporary storage.

When assessing the possibility of adapting a water supply dam for flood mitigation a range of options must be considered. The advantages and disadvantages of each of the options must be evaluated and assessed on a value-benefit basis with focus on the effect on downstream communities. The following will examine in more detail the options available to dam owners.

Pre-releases – creating temporary airspace for flood mitigation

Pre-releases (releasing water prior to the 'wet season' or well before an expected flood event to create airspace within the dam to 'absorb' or capture the first of the floodwaters) is feasible for some dams but typically provides only minor incremental flood mitigation benefits when only a small loss of storage volume is acceptable to the dam owner. The time between the rainfall occurring in the upstream catchment of a dam and the dam filling and spilling provides only a limited time for releases to be made. This approach has other issues including the potential for the public to criticise the operation scheme employed by the dam owner, as was seen with Wivenhoe Dam during the 2011 Brisbane floods.

Dam owners can find themselves in a situation where if they release water too early and the expected flooding does not eventuate then they are accused of wasting water. Releasing water early can also exacerbate downstream flooding and reduce warning and evacuation times. Conversely if they do not release water soon enough or for long enough then they are accused of neglecting to provide adequate flood mitigation to the downstream community if a major flood does occur. Gated spillways can provide dam owners with limited flexibility to control discharges during a flood event, but in the aftermath of the 2011 Brisbane floods many dam owners may now prefer not to have gated spillway structures on their major dams to avoid the potential public criticism and legal risk which can result.

For pre-releases to be considered, it is crucial that the rainfall predicted actually occurs so that supply security is not lost. The Bureau of Meteorology can forecast rainfall events quite a number of days prior to the event with a certain level of confidence, however, the confidence levels increase as the event gets closer. Should the rainfall (location, duration, intensity) not occur as forecast and pre-releases have been made, then water that has been captured at some cost will have been lost. Also, if the rainfall event occurs downstream of the dam and pre-releases have been made, then this will have exacerbated the downstream flooding, causing the flood levels to be higher and reducing evacuation times.

Pre-releases from the dam may have the following issues:

- They could cause damaging flows downstream earlier than waiting for the dam to fill;
- Reduced warning times for evacuations or moving stock, goods or equipment;
- Earlier closing of the downstream bridges.
- Aggravated flooding due to the possible coincidence of the pre-releases arriving at the same time as flood waters from downstream sub-catchments
- The adverse impacts on water supply security should the rains (and more importantly, the inflows) not eventuate.

In summary, whilst pre-releases can create some airspace to capture and mitigate small events there is a risk that pre-releases could exacerbate flooding and reduce evacuation times, since flood events may not occur as predicted and timing is critical.

Alternate gate operating regime

If the dam is fitted with gates which are operated in sequence to enable the dam to pass flood waters while maintaining it's safety. Alternate gate operation methods may have some benefit for small floods, by slightly increasing the duration of flooding downstream, but will have little impact for larger flood events in terms of water levels in critical locations downstream. Hence, alternative gate operational rules do not often provide significant flood mitigation benefits.

Permanent lowering of FSL – creating permanent airspace for flood mitigation

Permanent lowering of the storage can be quite effective in providing flood mitigation benefit, depending upon how much the FSL is lowered; however the option is often not viable for most dam owners who cannot afford to compromise water security and the annual allocation of water which is depended upon for revenue.

The provision of permanent airspace in a dam has significant benefits over temporary flood mitigation airspace (i.e. pre-releasing). There is a guaranteed flood mitigation capacity (assuming the airspace has been re-created after the previous inflow event); the amount of flood mitigation which is available is not dependent upon accurate rainfall and flood forecasting; it slows the rise of the flood downstream, giving more time for emergency planning and evacuation; downstream flood peaks will be reduced for the same amount of airspace because the captured flood waters can be slowly released after the flood whereas with pre-releases the waters need to be released quickly before the flood; the available water supply is more certain in that if water is pre-released and the rainfall and inflows are less than forecast (generally this is the case) then water is unnecessarily lost. The benefits reduce as floods become larger.

In theory, the creation of permanent airspace is a more effective option than pre-releasing. However, there are costs and, depending upon how much airspace is created, and how demand for water increases over time with population growth, climate change impacts and the impact of water conservation and demand management initiatives, the need for alturnate water sources would be brought forward. This is a significant matter for long term water supply planning.

Physical modification of the dam

Physical modification of a dam, usually by raising the dam wall in combination with high level spillways to create additional temporary flood storage, can be a viable option for some dams and is generally the most effective means of providing substantial flood mitigation benefits; however, the capital costs associated with such works are typically high. NSW Public Works has undertaken various studies on dams that investigate the feasibility of modifying the dam for flood mitigation. Construction works for these projects can be very high, particularly considering that the works must be completed on an operational dam without interrupting the water supply function, in particular adverse construction impacts on the lake's water quality.

When assessing the potential for adapting a water supply dam into a dual function water supply and flood mitigation storage the following process is generally adopted:

1. Assess the feasibility of adapting the dam by identifying the potential methods of modifying the dam for flood mitigation and costing of the options.
2. Model (hydrologic and hydraulic) the dam, its downstream inundation and flooding consequences for a number of selected potential arrangements over a range of flood scenarios to assess and quantify flood damages, both direct and indirect,
3. Select the most cost effective and beneficial solution within stakeholder budget expectations.
4. Design and optimise dam modification works that will provide the greatest value-benefit to the downstream community.
5. Employ construction methodologies and staging that ensure water supply is uninterrupted, water quality is protected and the flood security of the dam is maintained throughout the construction. This can be very challenging and inevitably results in increased project costs.

The effectiveness of flood mitigation schemes is usually evaluated based on the reduction in peak dam outflows compared to the peak flood inflows for a range of flood events (refer to Figure 1). This is followed by an assessment of the impacts downstream of the dam for the selected configurations. Ultimately, it is the reduction in the downstream water levels achieved rather than the peak outflow which is the key outcome for evaluation of the flood mitigation benefits. It should be noted that whilst the level of downstream flooding is reduced, the time that the downstream area is inundated is extended. This 'trade-off' must be carefully assessed.

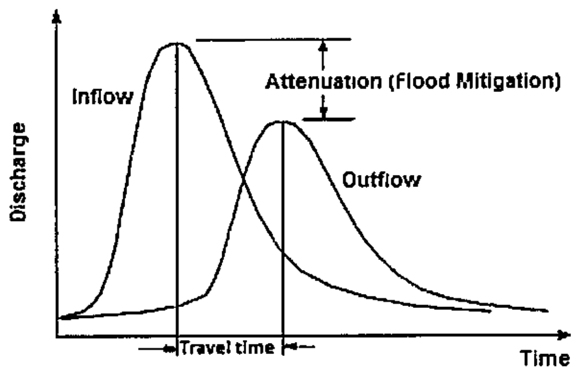

Figure 1: Flood hydrographs

A key decision for the dam owner is whether to design the flood mitigation works to cater most effectively for very large floods (up to the Probable Maximum Flood (PMF)); relatively small floods such as the 1-in-100-year Annual Exceedance Probability (AEP) event; or somewhere in between. The level of raising and the spillway arrangement must be optimised to achieve the targeted solution.

Due to water demand and potential water security risk the dam FSL cannot usually be lowered significantly during the construction period. Therefore, the design and construction staging must be able to accommodate the existing dam water supply function and operations throughout the entire construction period.

The following options are often assessed:

- Mass concrete raising/buttressing for arch or gravity dams
- Downstream rockfill and/or earthfill embankment or rockfill buttressing
- Upstream rockfill and/or earthfill embankment

Other raising options may also be considered. The provision of a hydro-electricity generation system could be viable for some dams and may be incorporated into the modifications works. The future revenue from hydro-electricity production could offset some of the costs incurred to modify the dam.

The above options will generally also involve modifications to the spillway arrangement. A high level spillway in combination with raising the dam wall is often required to provide large flood mitigation storage (air-space). The modifications to the spillway will have a significant impact on the appurtenant works at the dam including the outlet works and dam access. The raising options also present varying degrees of challenges to maintain water quality during construction. These considerations need to be accommodated in the final design and construction sequencing, resulting in increased capital cost.

The availability of construction materials on or near the site, along with the dam site geology are critical in determining which options are feasible and cost effective.

To achieve the optimum solution for flood mitigation a range of modified dam wall and spillway configurations must be modelled by routing a range of floods through the proposed configurations. Downstream damages assessments would be used to compare the benefits which could be achieved for each option and a cost-benefit study would be utilised to determine the preferred option.

Funding complexities

Physical modification of the dam is often the most feasible option available to the dam owner, if significant flood mitigation benefits downstream of the dam are to be achieved. However, given that the capital cost will be high and there are a number of different stakeholders that will benefit from the additional flood mitigation, the key question is: Who pays for the project?

If the project were to proceed then it is expected that significant flood mitigation benefits would need to be achieved for both small and large flood events. This is likely to provide significantly lower flood risk and lower insurance premiums for large downstream populations.

There would be many beneficiaries from the provision of flood mitigation but whose responsibility is it to fund the project and the related ongoing maintenance? Recovery of the capital costs through water charges or fixed levies results in all customers subsidising a benefit to a limited number of properties. The downstream communities benefit from lower risk of flood damage to their properties and lower insurance premiums. Federal, state and local government benefit from lower risk of damage to infrastructure and reduced liabilities. Insurance companies also benefit, with less risk and better market opportunities. Should all of these potential stakeholders be asked to contribute to the project funding and will legislative changes be required to facilitate the process?

Maintaining reduced flood risk

Another aspect which needs to be considered is how to ensure that flood risk reduction is maintained into the future if such a project was undertaken. Much of the risk downstream of the dams often develops due to the allowance of development and other activities in high flood risk areas. If the proposed works were implemented and the downstream risk is significantly reduced, large areas of land, which were previously below the flood planning level and therefore unusable, would become attractive to developers and other business interests. These groups would likely lobby to have land opened up for use and for the removal of existing land use restrictions. Although this would benefit many it may also lead to negation of some of the risk reduction that had been achieved. It would be the responsibility of state and local government agencies to ensure that the flood mitigation benefits which are achieved are maintained after construction and into the future, or the issue may return. Downstream flood evacuation routes still need to be upgraded as the works will not eliminate downstream flooding, only reduce the height and frequency, thus damages.

The interaction between flood mitigation measures within a flood risk management system

As outlined by Petry (2002), effective flood risk management requires a broad approach which should incorporate an integrated view of strategies, polices, plans, specific projects and other measures of social and institutional character. The selection and implementation of effective and optimised strategies is complex and there is a need for the integration of structural and non-structural measures to achieve successful flood risk reduction solutions.

If a dam is adapted for flood mitigation in a region subject to high flood risk, this measure is usually one of many strategies adoped for the community. The region's flood risk management strategy will likely include various other structural and nonstrctural flood mitigation measures also outlined by Petry (2002) and shown in Table 1 below:

Table 1: Overview of structural and non-structural flood mitigation measures

Structural measures	Extensive - reshaping of land surface - protection from erosion - delay of infiltration - urban works	Intensive - levees, dikes, floodwalls - dams and reservoirs - floodways and diversion works - polders and fills - drainage works
Non-structural measures	Regulation - land zoning - coding	Flood Defence - forecasting - warning - flood proofing - evacuation - relocation

All aspects of the flood risk management strategy which are affected by the dam, directly or indirectly, will need to be reassessed in light of the changes to water movement during flood events which will result from the dam's adapted function. The interaction between structural flood mitigation measures within a floodplain can be complex, requiring detailed hydrologic and hydraulic assessments to examine the impacts of changes in the system.

One example is levees located downstream of a dam which has been adapted for flood mitigation. Levees are commonly used to protect populations at risk from flood waters and are often located very close to the populations which they protect.

The flood mitigation benefits provided by dam modification works will result in reduced water levels at the location of downstream levees for a particular AEP event. Hence, a levee designed to provide a level of protection (e.g. the 1-in-100yr AEP flood) will then be able to cater for events which are rarer or more extreme than were originally intended. This is not a negative outcome for the community; however the significant investment in infrastructure which has transpired may not have occurred in the most appropriate manner.

Public lobbying for a particular flood mitigation solution can also influence decisions without an adequate assessment or understanding of the whole of floodplain implications. Decisions which result in significant changes to a region's flood risk management strategy need to be assessed in detail, considering the interaction between different structural measures within the system and the effect on response and planning approaches, to ensure that allocation of funding provides the greatest value-benefit to the community.

Case Studies

This section will review two major dams located near a large urban town centre prone to flooding as a case study. Some international examples of cities facing similar flood related issues to those in Australia are also examined.

Case Study: Wivenhoe Dam and Somerset Dam – 2011 Brisbane Floods

Somerset Dam on the Stanley River and Wivenhoe Dam on the Brisbane River were constructed to provide both urban water supply and flood mitigation. Somerset Dam is located upstream of Wivenhoe Dam. The two dams have a combine storage volume of 1.4 GL used for water supply and over 2.6 GL of temporary flood storage available to provide flood mitigation and to ensure that the dams have adequate flood capacity. The dams are operated to meet a range of flood mitigation objectives including impacts on the rural community, urban flooding and dam safety. Both dams have gated spillways which allow the dam operators to have some control over the discharge from the dam during a flood. The degree of control the dam operators have is dependant upon the and the size and type of the flood event.

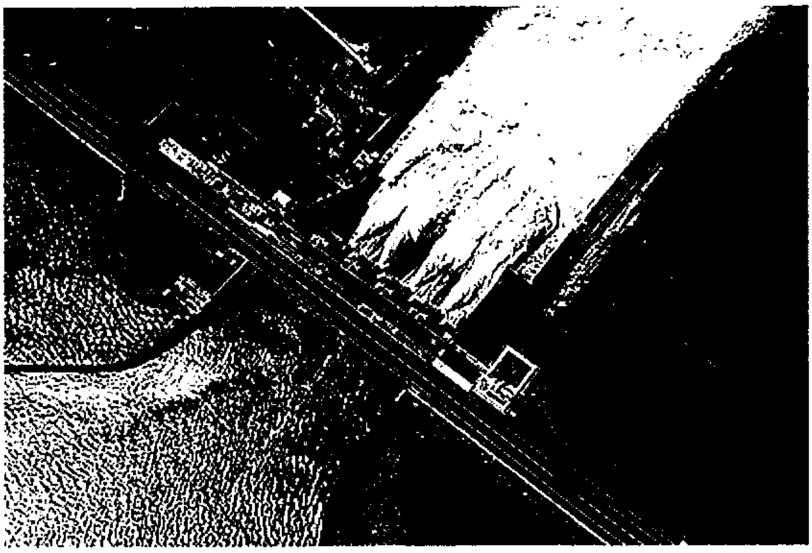

Figure 2: Wivenhoe Dam during 2011 floods (Photo: Dean Saffron)

Between 2003 and 2006 Wivenhoe Dam was upgraded to increase the flood handling capacity of the dam, in terms of overall stability, following a revision of the design rainfall events by the Bureau of Meteorology. NSW Public Works had significant involvement in the design of the upgrade works as part of the Wivenhoe Alliance. This upgrade involved the construction of a new auxiliary spillway through the right abutment of the dam, strengthening the existing spillway and raising the dam crest. A key component of the upgrade was to preserve the pre-existing flood mitigation capacity of the dam.

Since its construction in the 1980s, Wivenhoe Dam, in conjunction with Somerset Dam, has provided extensive flood mitigation benefits to the downstream community. During January 2011, Queensland experienced an extensive wet season with significant flood events occurring along many of the major river systems. The Brisbane River basin experienced large rainfall totals resulting in major flooding through the city of Brisbane. Both dams provided substantial flood mitigation benefits to the downstream community by both delaying the onset of flooding and reducing the peak outflow and duration of flooding downstream of the dam.

Figure 3: Flooding within Brisbane suburbs in 2011 (*Photo: REUTERS/Tim Wimborne*)

However, following the flood event, as examined by Raymond (2011), the public perception, driven by media coverage, was that the dam had failed to prevent flooding, without any understanding of the complex interaction between downstream tributaries and the limitations of the existing infrastructure. Managing flooding downstream of Wivenhoe Dam is difficult because the water released from the dam combines with other rivers downstream of the dam. Floodwaters from Lockyer Creek and the Bremer River enter the Brisbane River downstream of Wivenhoe Dam and therefore cannot be controlled by the dam. These downstream rivers alone can cause significant flooding in Ipswich and Brisbane.

The ongoing Wivenhoe and Somerset Dam Optimisation Study (WSDOS) is reviewing the flood mitigation operating rules to determine if there is scope for improved outcomes, but there remains the key issue of what can actually be achieved by the existing infrastructure. The focus is on achieving the best balance of the three key objectives; water security, flood mitigation and dam safety. In order to optimising the operations of Wivenhoe and Somerset dams it must be recognised that each potential flood will be different and that the operational strategies adopted must provide balanced outcomes across a large range of flood possibilities.

Some International Cases

According to Munich Re (2013), global economic losses from flooding exceeded $19 billion in 2012. Australia is one of many counties facing significant flooding risk from an international problem which will only be become more critical in the future as population of flood prone land increases and as a result of the effects of climate change as outlined in Hallegatte et.al (2013).

A recent example which highlights the potential risk and the need for flood mitigation measures in flood vulnerable cities is the "Great Flood" of Alberta, Canada, which occurred in June 2013. The flooding resulted in the loss of four lives, displaced thousands from their homes, disrupted hundreds of businesses and caused significant damage to private and public property, land and infrastructure.

As outlined by Alberta WaterSMART (2013), in response to the devastation, a variety of flood mitigation options are being investigated including utilisation of both on-stream and off-stream storages for flood control amongst other structural and non-structural measures. The dam related options identified are proposed for a number of existing structures and include permanent lowering of storage levels and increase in flood mitigation volumes through dam modifications as well as alternate operating conditions.

Heidari, (2009) has developed a structural master plan of flood mitigation measures for the Dez and Karun river floodplain in Iran. The study assessed construction costs verses expected value of damage reduction for a range of structural mitigation options. The mitigation options including detention dams, levees and dykes and flood diversions, were investigated and impacts were assessed for whole rivers reaches. The expected value of annual damage and damage-reduction were determined for the options and economic indexes for each plan were evaluated.

The most effective flood mitigation measures were found to be as follows, listed in order of effectiveness:

1. a detention dam on Shoor river (tributary in downstream of the Karun basin)

2. a diversion channel from Big Karun from upstream of Ahwaz city to estuary

3. levees in downstream of Ahwaz city

As outline above, the study found that a detention dam followed by a flood diversion channel were the most effective flood mitigation solutions in this case. Enforcing flood control operational procedures for upstream multipurpose reservoirs was also found to be effective.

Floods also pose a serious threat to people and monuments in Petra which is located in the southwest region of Jordan. Al-Weshah & El-Khoury (2000) have assessed mitigation strategies including afforestation, terracing, and the construction of check and storage dams, as well as various combinations of these measures, to determine the effectiveness of such options. A flood simulation model depicts reductions of up to 45% for the 1-in-100-year flood in flood-peak flows for storage dams alone.

These are just a few examples of dams used for flood mitigation and the critical role they can play in providing substantial flood mitigation benefits to communities in various locations around the world. Generally the use of dams for flood mitigation is part of a range of structural and non-structural measures implemented to achieve an effective flood control solutions for vulnerable communities.

Conclusion

The 2011 Brisbane floods sparked significant community interest in the functionality of dams, particularly around using water supply dams near major cities for flood mitigation in Australia. Wivenhoe and Somerset dams in Brisbane are good examples of dual purpose water supply and flood mitigation storages which have provided substantial flood mitigation benefits to their downstream communities. There may be the opportunity for some major water supply dams within Australia to be adapted for flood mitigation, with the potential for very significant benefits to downstream communities.

Modifying an existing water supply dam for flood mitigation can be complex and very expensive, and funding such projects is difficult and may require legislative changes. It is suggested that such projects could be undertaken via a public - private partnership with stakeholders that are likely to benefit from the works, including the Insurance Industry, being asked to contribute both financially and in kind support. Additionally, if flood mitigation works are undertaken then it is important that the risk reduction is maintained into the future through appropriate land use planning decisions by government agencies.

Lastly, decisions which result in significant changes to a region's flood risk management strategy need to be assessed in detail, considering the interaction between different structural measures within the system and the effect on response and planning approaches, to ensure that allocation of funding provides the greatest value-benefit to the community.

Acknowledgment

The authors gratefully acknowledge the support of NSW Public Works, Seqwater and State Water Corporation in the publication of this paper.

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Australian Government

MURRAY–DARLING BASIN AUTHORITY

Inquiry into flood mitigation infrastructure in Victoria
Submission no.52
Received 5 August 2011

5 August 2011

Executive Officer
Environment and Natural Resources Committee
Parliament House
Spring Street
EAST MELBOURNE VIC 3002

Dear Sir

Inquiry into flood mitigation infrastructure in Victoria

I refer to your letter dated 2 June 2011 inviting a submission to the Victorian Parliamentary Environment and Natural Resources Committee inquiry into flood mitigation in Victoria.

The Murray-Darling Basin Authority is pleased to provide the attached document, which addresses the terms of reference as appropriate.

Yours sincerely

for David Dreverman
Executive Director
River Murray

TRIM ref: D11/23462

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Australian Government

MURRAY–DARLING BASIN AUTHORITY

TRIM Ref: D11/23166

Inquiry into flood mitigation infrastructure in Victoria
Parliament of Victoria Environment and Natural Resources Committee

The terms of reference direct the Committee to investigate matters relating to flood mitigation infrastructure in Victoria, with particular reference to:

a. Best practice and emerging technology for flood mitigation and monitoring infrastructure including river gauges
b. Management of levees in Victoria, including ownership, responsibility and maintenance on both public and private land
c. Waterways management, including the nature and extent of vegetation clearing activities within waterways and their general maintenance
d. Identifying those entities and individuals having ownership of waterways and the responsibility for their clearing and their maintenance
e. The extent to which, if any, local knowledge of residents is employed in effecting waterways clearing and maintenance

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Submission by the Murray-Darling Basin Authority (MDBA)

Overview

MDBA manages the operation of the dams, storages and weirs of the River Murray System in accordance with the Water Act 2007 (Schedule 1, The Murray-Darling Basin Agreement). Although this infrastructure has not been designed to specifically mitigate floods, significant mitigation can occur as headwater storages fill and spill. The operation of individual structures must firstly safeguard the security of that structure and secondly fulfil its primary function of securing water supply. To the extent possible, and subject to meeting these primary objectives, operations aim to actively mitigate potentially damaging floods whilst attempting to optimise environmental outcomes. The primacy of water security has been determined jointly by partner governments under the Murray-Darling Basin Agreement.

The River Murray System is defined in section 86A(3) of the Water Act (2007) and includes the main course of the River Murray, all tributaries entering upstream of Doctors Point (near Albury), the effluents and anabranches upstream of the South Australian border (including the Edward-Wakool River system) and the Darling River downstream of Menindee Lakes. The system includes four major storages:

- Dartmouth Reservoir
- Hume Reservoir
- Lake Victoria, and

- Menindee Lakes.

Whilst flood operations at Dartmouth Reservoir and Hume Reservoir are actively directed by MDBA, flood operations at Menindee Lakes are directed by the NSW Office of Water and implemented by NSW State Water, taking advice from a committee, which includes MDBA operations staff. Lake Victoria, an off-river storage near the South Australian border, has only a very limited role during flood operations.

The two main upstream storages (Dartmouth and Hume Reservoirs) and Yarrawonga Weir have no specific design requirement for flood mitigation, however each provides some measure of mitigation due to their existence and mode of operation. Dartmouth Reservoir has a free overflow spillway with eight metres of freeboard at full supply level which provides significant flood mitigation by the nature of its configuration. When Dartmouth Dam spills all other releases from irrigation and power station outlets are ceased and the reservoir continues to spill without human intervention.

Hume Reservoir can provide considerable flood mitigation as the dam fills (normally in winter/spring). However once the storage reaches Full Supply Level, where the reservoir's waters are impounded by 29 spillway gates, there is very limited capacity to further mitigate inflows. To provide some additional flood mitigation, MDBA therefore operates a set of 'pre-release' rules which provides airspace to mitigate floods only to the extent possible without jeopardising water resource security (further described below).

It is important to note that the effects of any flood mitigation by headwater storages can diminish dramatically with increasing distance downstream of the dam. For example, the operation of Hume Reservoir during any particular flood event could have dramatic flood mitigation benefits for Albury/Wodonga a short distance downstream but will ultimately result in almost no perceptible change to any flooding that may occur in the mid and lower reaches of the River Murray. The reasons for this include the long travel times (measured in weeks and even months), the very large and complex flood plains and effluent systems (e.g. the Barmah-Millewa Forest and Wakool-Edward River system of the mid Murray) as well as the influence of each of the tributaries entering the River Murray system. Whilst a single 'rain event' might result in flooding in upper tributaries, flooding in the mid and lower reaches of the Murray and its tributaries is more commonly a result of the complex interaction of multiple rainfall events, in multiple tributaries over many weeks and months.

The ability for the Menindee Lakes to mitigate flooding is also influenced considerably by its available airspace at the commencement of an event. Floods arriving at Menindee Lakes on the Darling River generally rise very slowly, are of large volume and are naturally attenuated due to the long distances, low river slopes and expansive floodplains of the Darling and its tributaries. The slow pace of floods also provides river operators with longer lead times and an improved chance to create airspace and plan release strategies at Menindee Lakes. This can significantly lessen downstream flows and resultant flooding along the lower Darling River, and consequently along the River Murray downstream of Wentworth.

MDBA operates Yarrawonga Weir, 13 locks and weirs between Torrumbarry and Blanchetown, as well as the Barrages just upstream of the Murray Mouth in South Australia. As river flows rise, each of these structures is progressively opened to pass inflows unimpeded. In this way these structures are effectively removed from influencing upstream river heights at levels typically well below minor flood conditions. Once significant flooding in the Murray exists, these structures are opened such that they will neither have any significant mitigation benefits nor negative impacts on flood levels.

MDBA airspace management or 'pre-release' strategy

MDBA has been operating a set of pre-release procedures, to improve mitigation outcomes, for many years. The term 'pre-release' describes how releases are made prior to an expected spill at either Dartmouth or Hume Reservoirs – i.e. a 'pre-spill release'. The procedures aim to provide some airspace for flood mitigation but only to the extent that water resource security for the three States of NSW, Victoria and South Australia is not negatively impacted. The method is based on the lowest historical inflows that have followed recent observed inflows, i.e. "serially correlated minimum inflows".

The method effectively adapts to changing catchment, inflow and demand conditions. In dry times, when recent catchment inflows are low the method will most likely provide target flood mitigation airspaces of zero – that is to target a full reservoir to ensure that future downstream demands are met. In wetter times the method will yield airspace targets (up to a few hundred GL compared with storage capacities of 3,000 GL at Hume and about 4,000 GL at Dartmouth) which, based on historical inflow data and expected demands, can be adopted with very little risk to water resource security. The level of risk of not filling is in the order of a nominal 1%. Greater risks have been adopted in previous airspace strategies operated by the then River Murray Commission and Murray-Darling Basin Commission. However, after a near failure to maximise water supply, partner governments to the Murray-Darling Basin Agreement settled on the current risk profile in the early 1990s.

Whilst the pre-release procedures determine the quantum of airspace which may be used for flood mitigation, the operational approach employed by MDBA, once a flood arrives, can also have a significant impact on mitigation outcomes as discussed below.

MDBA flood operations

The fundamental aims which govern flood operations are:

- to pass the flood without endangering the safety of the dam
- to ensure as far as possible that the storage is near the prevailing airspace (pre-release) target after the flood so there is no loss of water resource
- to mitigate, or at least not worsen, the effects of downstream flooding, and
- to improve environmental outcomes if possible.

The approach taken by MDBA in its flood operations is based on a critical point that "no two floods are alike". Therefore, rather than having prescriptive approaches to release strategies generated solely from historical data, MDBA continually adapts to improving information, tools and changing physical and social circumstances.

The actual operation of structures in the River Murray system is carried out in conjunction with the various State Constructing Authorities (e.g. NSW State Water at Hume Reservoir), whose staff are located at the structure and physically operate the works under MDBA direction. During all operations involving a specific structure, and particularly during flood events, the MDBA works in close collaboration with the particular Constructing Authority staff. Each operational decision the MDBA makes is communicated directly with the Constructing Authority whose staff then carry out the physical changes required at the structure to implement the decision.

Communication

A critical component of flood operations is communication and MDBA liaises very closely during flood times with the Bureau of Meteorology (BoM), Constructing Authority staff at each structure. The latter inform and liaise with local community groups and SES as necessary. MDBA also coordinates meetings with agencies and landholder representatives prior to potential flood periods to aid in preparedness. MDBA has communication and decision making responsibilities documented in its Emergency Action Plan.

At all times, there is an MDBA duty operator available who is the principal point of contact for all MDBA assets, including during non-business hours for operational and emergency issues. In addition, the dams have local State Constructing Authority operators who are also available 24 hours a day.

Recent improvements to practice and technology

To optimise outcomes in any particular flood season, MDBA uses all available forecasting methodology and is actively involved in improving forecasting capacity, both internally, and in assisting BoM in its development of short and longer-term streamflow forecasting tools.

MDBA uses in-house spreadsheet based flow forecasting tools, draws upon rainfall and stream flow forecasting information from BoM, and is developing new real-time rainfall runoff models to further enhance capacity. Manual calculation methods are also retained for training and redundancy purposes. The advances in BoM rainfall forecasting over the last 10 years have been very significant and, in response to this capacity, MDBA has reviewed its past flood operations approach and is expected to adopt an improved methodology during spring 2011.

Proposed revision to flood operations strategy for spring 2011

As recently as 1996, and in the absence of reliable rainfall forecasting, flood operations were mostly undertaken in *response to* rainfall with limited consideration of forecasts. Historical operations were therefore geared to mitigate each minor flow or flood event as it arrived with the result being a loss of valuable airspace for potentially extended periods. As has been observed in the recent flooding in south-east Queensland the loss of airspace can be critical in circumstances where further rainfall and inflow events subsequently take place.

In its operations from spring 2011 onwards, MDBA is proposing to adopt the following approach in relation to the use of any airspace provided by the existing pre-release processes:

- Use airspace to mitigate floods carefully taking account of BoM short and long range forecasts
- Aim to protect airspace to mitigate against future moderate or larger floods
- Recover airspace as soon as reasonably practicable – aiming for approximately 1 week
- Ensure the storage is full at end of winter/spring inflow season – i.e. the day when system water demands exceed inflows.

This approach may mean that smaller flow events, which might historically have been captured or mitigated, could be passed downstream with only minor mitigation of the peak in order to preserve airspace for any potential subsequent larger event. This would improve the ability of MDBA to mitigate any subsequent larger flood events, particularly those in the moderate to major flood category. The concept of limiting the mitigation of a specific flood could even be applied during moderate or even major flood events should forecasts indicate the very real possibility of an *even larger* flood in the near future.

In this way the approach would adapt to current inflow conditions, the time of the year, expected demand conditions as well as short and longer term rainfall and stream flow outlooks. At all times the aim to mitigate the damaging effects of downstream flooding would remain. A complementary benefit of the approach is that smaller freshes and events could be passed in a more natural pattern with resulting benefits for the riverine environment.

Discussions with floodplain landholders downstream of Hume Reservoir have provided positive feedback to the proposal.

The future

A primary driver of the environmental degradation being observed across the Murray-Darling Basin is the capture and mitigation of flood events – particularly in the minor to moderate spectrum. Society's views of floods being as only damaging and dangerous is changing and with major policy shifts, including preparation of the Basin Plan, it can be expected that existing approaches to airspace management and flood operations will continue to evolve.

MDBA's proposed new operational approach is an example of how apparently competing objectives can be met in some circumstances.

Flood monitoring infrastructure

MDBA operates the River Murray System, including flood events in collaboration with various State Constructing Authorities. It uses rainfall and river height gauges and data supplied by the States and State water agencies, as well as the BoM. The methods for monitoring river conditions and gathering data are being progressively improved and automated as older manual technology is replaced by electronic (telemetry) gauges that supply data in near real time. Gauging sites are *constantly monitored and manual redundancies are retained for when faults or communication issues take place.*

MDBA is a contributing member of the Victorian Regional Water Monitoring Partnership and funds the operations and maintenance of approximately 80-90 gauging sites within Victoria. These sites are inspected regularly on a monthly basis and instruments and sensors are calibrated when required. Some of these sites are critical river operations and flood warning sites and MDBA is implementing redundancy in both onsite hardware and in telecommunication infrastructure at many of these critical river operations flood warning sites.

MDBA and flood levees

The MDBA is not involved in the management and maintenance of flood levees

The MDBA role in managing waterway vegetation and easements

The MDBA has only a limited role in the management and maintenance of waterways including vegetation and easements.

The Advisory Group for Hume to Yarrawonga Waterway Management is a cross jurisdictional group comprising representatives of government agencies and local stakeholders , that provides advice to MDBA on matters relating to waterway management in the reach of the River Murray from Hume Dam to Lake Mulwala. This group oversees and provides advice to MDBA on implementation of its Waterway Management Plan, which includes owning easements for passing regulated flows, as well as a program of riverbed and bank stabilising riverworks undertaken by the NSW Office of Water on behalf of MDBA.

The MDBA owns easements along the River Murray between Hume Reservoir and Yarrawonga Weir, as well as along the Mitta Mitta River between Dartmouth Dam and Lake Hume. The MDBA's easement rights allow only for the right to pass regulated flows up to 25,000 ML/day (measured at the Doctors Point gauge) along the River Murray, and up to 10,000 ML/day along the Mitta Mitta River. The MDBA does not have any other role in management of the lands over which the easements are held.

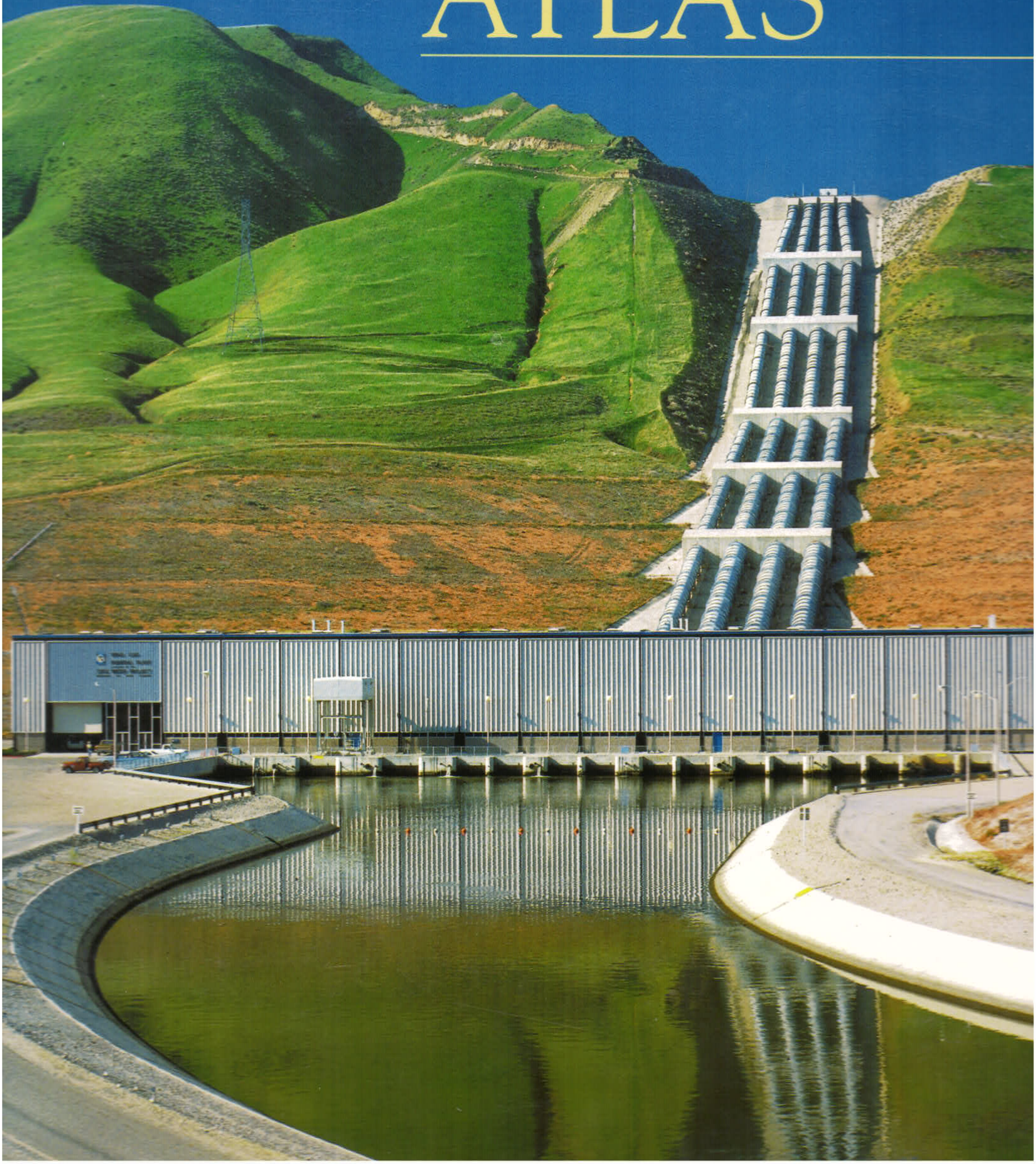
The MDBA's role in vegetation management is limited to assisting landholders with vegetation maintenance as part of our riverworks programs, in order to protect our investment in works. These works can include willow management, revegetation, grazing management and river bed and bank stabilisation works. Any vegetation management undertaken is with agreement of the landholder. These works are undertaken from Khancoban to Jingellic along the Swampy Plains and Murray Rivers, from Jingellic to Lake Hume, and from Lake Hume to Lake Mulwala along the River Murray, by the NSW Office of Water on behalf of MDBA. Works are also undertaken from Dartmouth Dam to Lake Hume along the Mitta Mitta River, and on the foreshores of Lake Hume by Goulburn-Murray Water in conjunction with the North East Catchment Management Authority on behalf of MDBA.

The MDBA does not have any legislative responsibilities or powers regarding vegetation management along waterways. Implementation of Native Vegetation legislation lies with the State Governments.

For a number of decades in the late 20th century, the River Murray Commission and later, the Murray-Darling Basin Commission, together with relevant state water agencies undertook programs of snag removal in the River Murray reach from Hume Reservoir to Lake Mulwala. The program primarily was aimed to increase the capacity of the channel to carry higher flows "within channel".

As one part of The Living Murray program, over the last decade there has been an active program to re-introduce timber "snags" into this reach to boost habitat for native fish, whose numbers had been observed to decline markedly with the progressive loss of habitat over earlier decades. Initial indications are that "re-snagging" is having a positive impact on fish populations and further re-snagging is likely in the future.

California State Water Project ATLAS



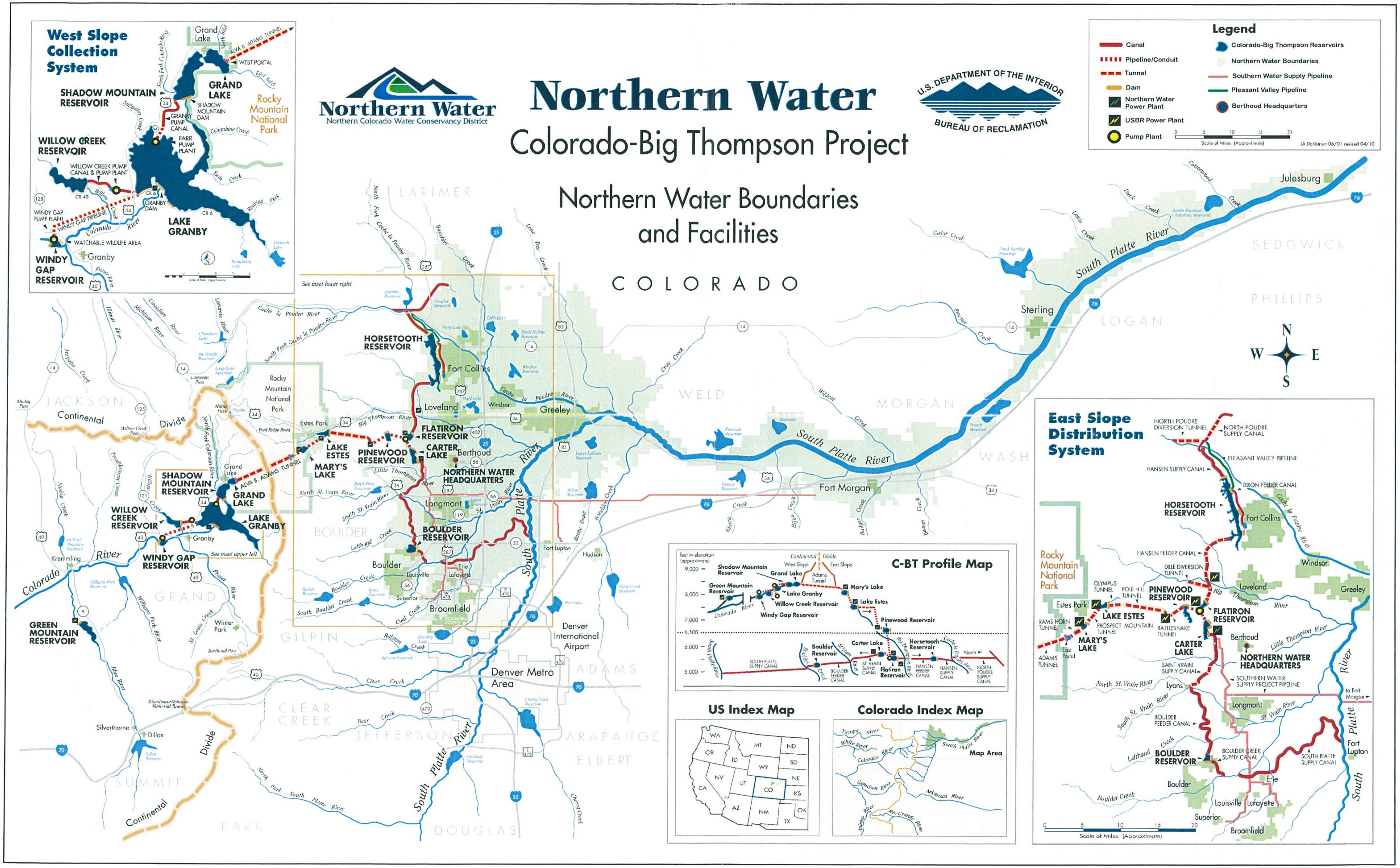
Northern Water
Northern Colorado Water Conservancy District
www.northernwater.org

Colorado-Big Thompson & Windy Gap Project Statistics

West Slope	Max. Capacity	Active Capacity*	Surface Acres	Max. Depth	Shoreline
Grand Lake	68,600 acre feet	n/a	515 acres	265 feet	4.5 miles
Shadow Mountain Reservoir	17,354 acre feet	1,839 acre feet	1,337 acres	37 feet	8.0 miles
Lake Granby	539,758 acre feet	465,568 acre feet	7,260 acres	221 feet	40 miles
Willow Creek Reservoir	10,553 acre feet	3,329 acre feet	303 acres	124 feet	7 miles
Windy Gap Reservoir	445 acre feet	n/a	106 acres	25 feet	1.5 miles
Green Mountain Reservoir	154,645 acre feet	146,779 acre feet	2,130 acres	254 feet	19 miles

East Slope	Max. Capacity	Active Capacity*	Surface Acres	Max. Depth	Shoreline
Lake Estes	3,068 acre feet	n/a	185 acres	45 feet	4.0 miles
Mary's Lake	927 acre feet	n/a	42 acres	33 feet	1.0 mile
Pinewood Reservoir	2,181 acre feet	n/a	97 acres	24 feet	3.0 miles
Flatiron Reservoir	760 acre feet	n/a	47 acres	18 feet	2.0 miles
Carter Lake	112,230 acre feet	108,924 acre feet	1,110 acres	180 feet	12 miles
Horsetooth Reservoir	156,735 acre feet	149,732 acre feet	1,900 acres	188 feet	25 miles
Boulder Reservoir	13,270 acre feet	11,970 acre feet	700 acres	28 feet	4.0 miles

*__Active capacity__ is the amount of water that can be stored and later released for beneficial purposes. In most reservoirs, some amount of the stored water cannot be evacuated due to the placement of the outlet works. The water that cannot be evacuated is sometimes called "dead storage."



Northern Water
Colorado-Big Thompson Project
Northern Water Boundaries and Facilities
COLORADO
Northern Water
Northern Colorado Water Conservancy District
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Legend
Canal
Pipeline/Conduit
Tunnel
Dam
Northern Water Power Plant
USBR Power Plant
Pump Plant
Colorado-Big Thompson Reservoirs
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Southern Water Supply Pipeline
Pleasant Valley Pipeline
Berthoud Headquarters
Scale of Miles (Approximate)
West Slope Collection System
SHADOW MOUNTAIN RESERVOIR
GRAND LAKE
WILLOW CREEK RESERVOIR
LAKE GRANBY
WINDY GAP RESERVOIR
Rocky Mountain National Park
ALVA B. ADAMS TUNNEL
WEST PORTAL
GRANBY PUMP CANAL
FARR PUMP PLANT
GRANBY DAM
WILLOW CREEK PUMP CANAL & PUMP PLANT
WINDY GAP PUMP PLANT
WINDY GAP PIPELINE
WATCHABLE WILDLIFE AREA
Granby
HORSETOOTH RESERVOIR
FLATIRON RESERVOIR
PINEWOOD RESERVOIR
CARTER LAKE
LAKE ESTES
MARY'S LAKE
NORTHERN WATER HEADQUARTERS
BOULDER RESERVOIR
GREEN MOUNTAIN RESERVOIR
Fort Collins
Loveland
Greeley
Windsor
Estes Park
Berthoud
Longmont
Boulder
Louisville
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East Slope Distribution System
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NORTH POUDRE SUPPLY CANAL
PLEASANT VALLEY PIPELINE
HANSEN SUPPLY CANAL
DIXON FEEDER CANAL
HANSEN FEEDER CANAL
DILLE DIVERSION TUNNEL
OLYMPUS TUNNEL
POLE HILL TUNNEL
RAMS HORN TUNNEL
PROSPECT MOUNTAIN TUNNEL
RATTLESNAKE TUNNEL
ADAMS TUNNEL
East Portal
SAINT VRAIN SUPPLY CANAL
SOUTHERN WATER SUPPLY PROJECT PIPELINE
BOULDER FEEDER CANAL
BOULDER CREEK SUPPLY CANAL
SOUTH PLATTE SUPPLY CANAL
Lyons
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Shadow Mountain Reservoir
Grand Lake
Green Mountain Reservoir
Lake Granby
Willow Creek Reservoir
Windy Gap Reservoir
Mary's Lake
Lake Estes
Pinewood Reservoir
Carter Lake
Horsetooth Reservoir
Boulder Reservoir
Flatiron Reservoir
US Index Map
Colorado Index Map
Map Area
JA Dahlstrom 06/01 revised 04/10