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Bringing twentieth-century water projects into the twenty-first century: The case for revisiting dam operations in Alberta

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Like many semi-arid regions, southern Alberta, Canada, has many large dams and reservoirs, most of which were constructed decades ago. These dams provide important socioeconomic benefits, but can also degrade downstream aquatic and riparian ecosystems. Many of the larger water supply reservoirs are owned and operated by a provincial agency, Alberta Environment and Parks (AEP), in accordance with water allocation licenses that include operating requirements. In the heavily allocated South Saskatchewan River Basin, the province's water management plan recommends that AEP pursue 'optimization' of reservoir operations, recognizing that even modest changes may be beneficial. While AEP has made positive changes in dam operations, both formally and informally, it has generally not revisited dam operating plans. This paper recommends that AEP engage in comprehensive reviews of the long-term operating plans for its water projects; these reviews should incorporate the latest science and modelling, provide for public participation, and address the potential impacts of climate change. Resulting operational changes could increase public benefits without major costs to existing project purposes. Given the common challenges and opportunities associated with older dams, lessons from this case study should be broadly applicable.

Comme la plupart des régions semi-arides, l'Alberta du Sud possède de nombreux barrages et réservoirs aquifères de taille importante, dont la majorité a été construite il y a plusieurs décennies. Ces barrages offrent des avantages socioéconomiques considérables, mais ont également des répercussions néfastes sur les écosystèmes aquatiques et riverains situés en aval. Parmi les plus grands réservoirs aquifères, beaucoup sont détenus et exploités par l'agence provinciale Alberta Environment and Parks (AEP), conformément aux licences relatives à la distribution des ressources en eau, dans lesquelles sont spécifiées les conditions d'exploitation. Dans le bassin de la rivière Saskatchewan Sud, qui est abondamment desservi, le plan de gestion de l'eau de la province recommande que l'AEP « optimise » les opérations du réservoir, reconnaissant la nécessité de certains changements, aussi modestes soient-ils. Malgré les changements positifs apportés par l'AEP au niveau du fonctionnement, de façon formelle et informelle, l'organisme n'a généralement pas revisité les plans d'exploitation. Ce document préconise que l'AEP procède à une révision complète des plans d'exploitation à long terme pour ses projets hydrauliques. Une telle révision devra intégrer les derniers progrès de modélisation et de la science, assurer la participation du public et prévoir des solutions pour contrer les effets potentiels du changement climatique. Les changements de fonctionnement qui découleront de cette révision devraient considérablement avantager la population, sans entraîner de coûts trop importants pour les bénéficiaires du projet existant. Compte tenu des défis et possibilités généralement associés aux barrages moins récents, certaines leçons tirées de cette étude de cas devraient être largement applicables, notamment dans l'ouest des États-Unis et au Canada.

Introduction

Dams and reservoirs in Alberta's South Saskatchewan River Basin

Southern Alberta has a semi-arid climate since the Rocky Mountains intercept much of the precipitation moving inland from the Pacific Ocean. Snowmelt from those mountains is the main source of the Bow and Oldman Rivers, which converge to become the South Saskatchewan River, above the provincial border with Saskatchewan. The smaller Red Deer River joins the South Saskatchewan a few kilometers below that provincial border. Farther downstream, the South Saskatchewan joins the North Saskatchewan to form the Saskatchewan River, which flows from its namesake province into Manitoba on its way to Hudson Bay. The Bow, Oldman and Red Deer basins, along with the South Saskatchewan Basin below the Bow–Oldman confluence, collectively make up Alberta's portion of the South Saskatchewan River Basin (SSRB; Figure 1).

Slightly more than two thirds of the average annual flow of the Bow and Oldman rivers has already been allocated for offstream uses (Pentney and Ohrn 2008). Even more heavily allocated are the Oldman River's 'southern tributaries', the Waterton, Belly and St. Mary rivers, with 75 to 118% of average flows allocated. The Red Deer, in contrast, is less than 20% allocated. The largest use is agricultural irrigation, which accounts for

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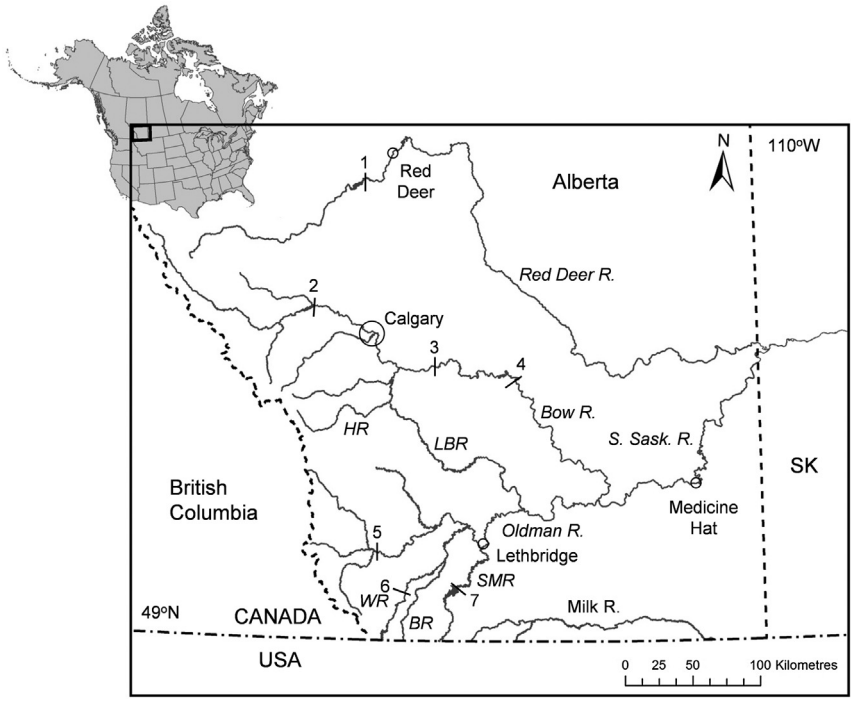

Figure 1 Map of southern Alberta showing the major tributaries of the South Saskatchewan River Basin, including WR – Waterton River, BR – Belly River, and SMR – St. Mary River. Numbers indicate dams: 1. Dickson, 2. Ghost, 3. Carseland, 4. Bassano, 5. Oldman, 6. Waterton, and 7. St. Mary. Other dams occur, especially in the Bow River sub-basin.

about three fourths of all water allocated in the SSRB; the amount of water consumed for this purpose is likely to increase as efficiency improvements (resulting from new or renovated infrastructure) allow for more acreage to be irrigated within existing irrigation districts. Municipal and industrial uses, while comparatively small, will likely increase as the SSRB's population continues to grow. Existing water uses have depleted flows in the Bow and the Oldman, reducing these below their 'instream flow needs' (IFNs) for fish habitat and riparian vegetation, and for water quality (Clipperton et al. 2003).

Climate change may further challenge the system by decreasing river flows and water supplies. The overall annual river flows are progressively declining, probably due partly to increasing watershed evaporation and transpiration (Rood et al. 2005; Shepherd et al. 2010; St. Jacques et al. 2015). Winter warming may increase the proportion of rain versus snow, reducing the winter snowpack and summer snowmelt (Lapp et al. 2005). As a consequence there is substantial change in river flow seasonality, with slightly increasing winter flows and more substantially decreasing summer flows (Rood et al. 2008; St Jacques et al. 2010). This particularly reduces water availability during the peak demand of the irrigation season and has prompted some recommendations to expand reservoir storage to compensate for the declining natural seasonal storage in mountain snowpack (Sheer et al. 2013).

Alberta Environment and Parks (AEP) is the provincial agency primarily responsible for allocating and managing water in the SSRB, and its current powers and duties are laid out in the Alberta Water Act. The Water Act provides for the adoption of water management plans that are tailored and applicable to particular areas, and AEP – after an extensive public process – adopted an Approved Water Management Plan for the SSRB (the SSRB Plan) in 2006 (Pentney and Ohrn 2008). The SSRB Plan changed and strengthened the water management framework in the basin in significant ways. Most importantly, it closed the Bow, Oldman and South Saskatchewan sub-basins of the SSRB to new allocations, except for certain uses as approved under a 'Crown Reservation' of the remaining unallocated water. It also established 'Water Conservation Objectives' (WCOs): volumes or flows necessary to protect the aquatic environment within and along the SSRB's rivers. While the new WCOs, of around 45% of the natural flow, called for higher flow levels than those previously established, the SSRB Plan provided that the old levels would continue to apply to all existing allocations and facilities, thereby making it unlikely that the more protective WCO levels would actually be met (AEP [Alberta Environment and Parks] 2006).

In order to provide reliable water supplies, primarily for irrigation, the federal and provincial governments built a number of water projects in the SSRB during the twentieth century. Today, these projects are owned by AEP, which remains responsible for their operation. The provincially owned water projects include dams and reservoirs, major diversion structures and large-capacity canals. These projects vary in size, in the design and function of the facilities, and in the purposes they serve. One of the largest is the St. Mary Project, which diverts water from the Oldman's southern tributaries, stores it in a set of reservoirs (the largest of which are St. Mary and Waterton) and supplies it to a number of irrigation districts south of the Oldman River. On the Bow River, a major project built by the government diverts water from the river at Carseland Headworks and conveys that water to the McGregor and Travers reservoirs, which release water to irrigate lands between the Bow and Oldman rivers. On the Red Deer, the main project is Dickson Dam, which stores water in Glennifer Reservoir and releases it to meet a variety of downstream needs, including sufficient winter flows for aquatic health, and also provides a measure of flood control for downstream communities (especially Red Deer and Drumheller). Each of these projects also provides some additional benefits, including boating and fishing on the reservoirs.

Most of the large projects in the SSRB were constructed at a time when environmental concerns were at most a low priority. Environmental issues became important by the 1980s, however, so when the Alberta government decided to build a major new dam on the Oldman River – the last big project of its kind in the province – environmental concerns were a major reason the project was highly controversial (Glenn 1999; de Loë 1999). In the end, environmental concerns did not prevent the Oldman River Dam, but did strongly influence how the project would operate (Rood et al. 1998; Glenn 1999). The Oldman River Dam's operations plan – that is, the plan that specifies the operating guidelines for the storage and release of water by the reservoir – is substantially geared to meeting environmental needs downstream of the dam (Rood et al. 1998). That operations plan was developed through an inclusive process that included community members and independent scientists, as well as water users and agency officials (Rood and Vandersteen 2010).

Most AEP water supply projects are operated under older, less detailed plans that were not developed with consideration for environmental concerns including channel-forming flows and seasonal flow patterns for fish or riparian vegetation. Their operating practices often have negative effects on downstream aquatic and riparian ecosystems, and some of these effects have been severe or even devastating (Rood et al. 1995). AEP could help mitigate those negative effects by reviewing the operations of its existing projects with an objective of environmental improvement. Thus far, the agency has made temporary operational changes for downstream benefits, but has not revisited its official project operating plans. AEP thus has fallen somewhat short in implementing its own SSRB Plan, which recognizes the potential environmental benefits of even 'minor changes in dam operating practices', and recommends that the agency 'hold discussions with Government and other dam owners to investigate opportunities to optimize operation of the facilities' (AEP 2006, 16).

Significance beyond Alberta: The role of dams and reservoirs in a changing world

This analysis focuses on water projects in Alberta's SSRB, and addresses the legal, institutional and policy framework for project operations in that basin. Other jurisdictions have their own unique frameworks for determining project operations, so this article's conclusions and recommendations regarding Alberta must be evaluated in light of the specifics within each jurisdiction. What is broadly applicable, however, is the basic principle of revisiting the long-term operating plans of existing water projects. This idea relates directly to three recurring themes regarding water management.

Environmental restoration of dammed rivers. In recent decades, science has produced a much clearer picture of the environmental impacts of dams on downstream rivers. Impacts of dam operations may include high fluctuations in daily flows, changes in water quality and temperature, alteration of natural seasonal flow patterns, scouring or down-cutting of the river channel, and negative impacts on native aquatic and riparian species caused by habitat loss (Collier et al. 2000). Recognizing these impacts, water policy scholars have called for changes in dam operating practices to improve water management and mitigate environmental impacts (Richter and Thomas 2007; Pittock and Hartmann 2011; Benson 2017). Much of the focus to date has been on hydropower projects, where operational changes have benefited downstream fish populations and other resources (Locke et al. 2008).

Adaptation to climate change in managing water. Advances in science and climate modelling have led to stronger projections about the implications of climate change for water supply, demand and management at the scale of major river basins. While the projected effects vary from place to place, much of western North America is expected to experience continued warming; changes in the volume and timing of runoff, especially in snowmelt-driven systems; changes in the number and intensity of extreme events (e.g. droughts and floods); and growing stress on riparian and aquatic ecosystems (Dettinger et al. 2015; St. Jacques et al. 2015; Rood et al. 2016). These observed and expected impacts of cli-

mate change have prompted scholars to call for water policy changes that could allow for adaptations in water management (Abrams and Hall 2010; Saunders 2014).

Flow restoration in fully allocated systems. Water policy scholars have stressed the difficulty of restoring flows necessary for environmental quality on river systems where water supplies have been fully allocated to offstream uses (Gillilan and Brown 1997; Percy 2005). This problem is particularly acute in jurisdictions such as Alberta and the western United States, which manage water under a system that gives priority to the oldest water uses in times of shortage (Poirier and De Loë 2011; Benson 2012). In many water-short areas, environmental flow protections – if they exist at all – were established relatively recently, and are therefore ineffective at ensuring adequate flows in dry periods when older offstream uses get priority access to the available water (Kwasniak 2006; Wilkinson 2006). Scholars and advocates have called for policy reforms that can help restore environmental flows where they have been depleted by established uses (MacDonnell 2009; Kwasniak 2010).

This review builds on the existing literature by focusing on the potential for modified dam operations to help address downstream environmental impacts, promote climate change adaptation and improve environmental flows. This paper recommends that Alberta proceed with this effort by initiating public reviews of the operating plans of all of the provincially owned water storage and supply projects in the SSRB. These reviews would utilize high-quality river operations models, scientific input from a range of disciplines, and projections on the potential impacts of climate change (St. Jacques et al. 2015). They would also rely on public participation in developing and evaluating potential changes in operating practices. The result would be updated, long-term strategies for operating the projects in ways that serve the interests of existing beneficiaries (i.e. water users) while also addressing other values such as environmental conservation and restoration, flood risk reduction and water-based recreation (Sheer et al. 2013).

Alberta's water projects and their operations

Alberta's dams: Purposes, benefits and impacts

With its fertile soils, limited local precipitation and sizable rivers fed by Rocky Mountain snowmelt, southern Alberta was ideally suited to the development of irrigation agriculture. Such a development was a key strategy in promoting western settlement and economic expansion, but large-scale irrigation required major infrastructure to store and deliver water. Storage was crucial because the natural flows of Alberta rivers depend primarily on snowmelt, and are commonly low in mid- to late summer when irrigation demands are highest. Large reservoirs could store enough water during high-runoff intervals to eliminate this seasonal mismatch between supply and demand. They could also provide carry-over storage from one year to the next, helping buffer water supplies from the impacts of short-term drought. Fundamentally, these dams altered the river system to serve human objectives, capturing water when nature provides it and releasing it when farmers need it.

Because of the capital cost of large projects, government agencies played a major role in building them in southern Alberta. The federal Prairie Farm Rehabilitation Agency (PFRA) built the St. Mary Project, and assisted in expanding the Bow River Project. The PFRA subsequently transferred its dams to provincial control (Klassen and Gilpin 1999) and the province then built projects including Dickson Dam, and gained ownership of other developments. Today, all but one of the 13 provincial irrigation districts receive water through provincial infrastructure. The SSRB also has dams built by non-governmental agencies, including Bassano on the Bow River, which supplies water for the Eastern Irrigation District (EID), and a network of dams on the upper Bow River and its tributaries, which generate hydropower for the utility TransAlta (Sheer et al. 2013).

Each dam was designed and constructed to serve a specific need or set of needs, which are referred to as project purposes. A dam that has been used for storage and water supply could be used instead for flood control, but that shift would be contrary to the designated purposes. A multi-purpose dam may serve a range of uses such as water supply, recreation, flood control and hydropower, each with its own schedule for storage and release of water. Dams in the SSRB have served their purposes and provided important benefits, including storing and supplying water for irrigation and other uses, reducing the magnitude of downstream floods, generating hydropower, regulating river flows for various downstream needs, and providing reservoir recreation.

Storage reservoirs very purposely alter river flow patterns below the dam, reducing downstream flow during naturally high runoff periods and increasing flows when they would naturally be low. These alterations to the flow regime often stress native plants and animals that are adapted to the natural flow regime (Poff et al. 1997). In addition, reservoirs trap sediments, and sediment-impoverished 'hungry water' is released downstream altering the channel form and aquatic habitats (Kondolf 1997). Dams also alter downstream water temperatures, often by releasing water that is cooler in the summer and warmer in the winter.

These hydrophysical changes can dramatically alter downstream ecosystems. Native fish often suffer, but some of the cool tail water zones below dams are very suitable for trout, favored sportfish in southern Alberta and western North America. The dams have also nega-

tively affected riparian forests, since native cottonwoods and willows are adapted to the naturally dynamic flow patterns (Bradley and Smith 1986; Rood and Mahoney 1990).

Licenses and other legal factors affecting project operations

Every water project in Alberta operates under a water allocation license issued by the province, authorizing the licensee to divert and use water according to the terms provided. The license prescribes each project's basic operating priorities by stating – with varying specificity – the project purposes. For example, the license for St. Mary and Waterton reservoirs states that they will be used to 'impound and divert water for water management, flood control, erosion control, flow regulation and recreation' (AEP 1991b, 1); the license for the Carseland Headworks on the Bow River states that its purpose is to 'divert, impound and release water for water management, water supply (including irrigation), flow regulation, conservation and recreation' (AEP 1996, 1). The provincial Dickson Dam might have the most general license of all: it simply states a purpose of 'storage', and refers to 'the water resources management purposes of the project' without stating what they are (AEP 1986, 3).

Every license contains a set of conditions, and while some are standard, the conditions and their wording vary with the nature of the project and the age of the license. For example, licenses for dams specify the capacity of the associated reservoir(s), while licenses for canals or diversion works specify the timing and rate of diversion. Every license has a priority number tied to the date that the project commenced. Under the fundamental 'First in Time, First in Right' (FITFIR) principle of western water law, the oldest allocations get priority access when supplies are inadequate to meet the needs of all users (Kwasniak 2010).

Water project licenses also commonly contain one or more conditions requiring the project to maintain a minimum level of flow downstream of the dam or diversion works. These conditions vary widely in their degree of protection for the downstream environment, but generally they will require more water for the river in newer, lower-priority licenses than in older ones. Downstream flow requirements may specify a particular flow, such as 80 cfs (cubic feet per second; or 2.3 cubic meters per second [cms]) in the Waterton River below Waterton Dam, or may provide for downstream flows under a more complex formula, such as the '80 percent habitat fish rule curve' for diversions at the Carseland Headworks (AEP 1996, 2; AEP 1998a, 1). The flow protected by these license conditions, termed the 'Instream Objective', is typically far below the level needed to maintain the complete natural ecosystem function, which is estimated to require about 85% of the natural flow, with sustained seasonal and interannual variation (Clipperton et al. 2003). The SSRB Plan set a higher 'Water Conservation Objective' for rivers in the basin, but specified that this more protective flow level would not apply to existing licenses (AEP 2006). Nonetheless, some water project licenses specify that AEP may revise instream flow requirements, while others recognize a more general authority to alter the terms and conditions of the license.

Several provincial water projects also have license conditions relating to their operations, and these conditions vary significantly. At one end of the spectrum, the license for Dickson Dam requires only that it be operated to meet (unspecified) project purposes. The St. Mary Project license requires AEP to develop, and incorporate into the license, an operating plan that must address normal operations, flood response, emergency preparedness and instream flow releases. The Carseland Headworks license contains a similar condition that goes further, requiring the operating plan to include 'a description of endeavors to meet instream objectives', and indicating that the plan is subject to AEP's approval (AEP 1996, 4). The most detailed license is for the Oldman River Dam, which requires that the dam be operated in accordance with the strategy laid out in three specified reports, directs the licensee to provide an updated operational strategy within a year of the dam's initial filling, and allows AEP to review and revise the operating strategy.

AEP operates some of its projects, such as the St. Mary Project and the Carseland Headworks, primarily for the benefit of particular irrigation districts. AEP stores and releases water from these facilities primarily to serve the water supply needs and preferences of the irrigation district(s) receiving water from them (Jean and Davies 2016). The licenses themselves, however, do not mention any particular district or use to be served, and do not specifically require the agency to operate its facilities to supply these established beneficiaries.

Moreover, AEP takes the position that stored water is not subject to FITFIR. If water is collected at a time of flow surplus and stored in a reservoir, its subsequent use is determined by the reservoir owner/licensee, not by the priorities of downstream licenses (AEP 1998b). The agency appears to have adopted this interpretation in 1998 and to have maintained it ever since (Rood and Vandersteen 2010), but it has not been tested in court. This is important because it gives AEP flexibility in the timing and volume of stored water releases, unconstrained by the FITFIR hierarchy.

In managing SSRB water, AEP must ensure that Alberta remains in compliance with the Master Agreement on Apportionment, which apportions the water of rivers flowing from Alberta into Saskatchewan (and from Saskatchewan into Manitoba). The basic rule is that Alberta must deliver annually to Saskatchewan an

amount equal to one half the natural flow of each river that crosses the provincial border (Prairie Provinces Water Board 2009); a special rule allows Alberta to consume 2.1 million acre-feet per year from the South Saskatchewan River even if that quantity exceeds half the natural flow, provided that the flow in that year never falls below 1500 cfs (42 cms) at the provincial line. AEP coordinates the operation of its reservoirs throughout the SSRB so as to ensure that apportionment requirements are met and impacts on Alberta users are minimized, but provincial reservoirs rarely have had to release water solely for compliance (interview with J. Mahoney, Lethbridge, AB, 17 November 2015).

In sum, each provincial water project has a water allocation license that provides the primary legal framework for operation of that project, reflecting the project's purposes. While project licenses impose various requirements, they also leave considerable flexibility for AEP in operating its projects. Most project licenses are not very prescriptive regarding the actual operating priorities of a project, making operating plans all the more important.

Current project operating plans

Several provincial water supply projects include a license provision requiring that the licensee, AEP, provide an operations plan to the Controller (also an AEP official, now called the Director under the 1999 Water Act). Where a project license includes this condition, AEP must develop and file an operations plan for that project. Provincial officials have said that all of their projects do have operations plans, but it is difficult to describe the contents of these plans because AEP does not make them available to the public. In contrast to licenses, which are easily found online through the agency website, AEP does not make project operating documents readily accessible.

The operating regimes for provincial water projects vary considerably in their approach to downstream flow patterns. AEP has operated Dickson to ensure 16 cms through the winter months to sustain dissolved oxygen levels under ice. The Carseland Headworks operating regime is far more detailed regarding downstream flows, specifying instream objectives ranging from 40 to 100 cms on a weekly basis from April through October, depending on the Bow River inflow (AEP 1998a). More detailed still is the Oldman River Dam and Reservoir Operational Strategy, produced 'in accordance with' a license condition requiring an updated operational strategy for the dam within a year of the initial filling of the reservoir (AEP 1994, 1).

The more detailed and prescriptive the operating plan, the less discretion remains for the project operator regarding the rate and timing of storage and releases. The less detailed plans for some of the projects leave a good deal of discretion, and provincial officials have used this to make modest changes to operating practices (as explained below). Regardless of the age of the project or the contents of the operating plan, one thing holds true for the provincial water supply projects: operating plans are not regularly reviewed and revised, at least in any public or official way.

AEP has not established a policy or program for reviewing reservoir operations, even though it considers new information and meets with major water users in making its operating decisions (D. Ardell and S. Gnanakumar, interview in Calgary, AB, 2 December 2015). Nothing requires review or revision of the operating plan for most projects; an exception is the Oldman River Dam operating plan, which calls for a review at the 10-year mark. The Oldman River Dam operations plan is also exceptional for the process by which it was developed.

A structured process for determining dam operations: The Oldman River Dam

Spurred by the controversy surrounding the Oldman River Dam, the provincial government committed to develop an operations plan for that new multi-purpose dam. That planning required a sufficient water balance model that incorporates the various water demands and considers the seasonal and interannual variation in water supply. For the Oldman River Dam, this model was the 'Oldman Dam Operations' model, ODO5, which simulated flows and withdrawals along the mainstem Oldman River and also for its tributaries, including the extensively allocated southern tributaries. ODO5 model runs allowed for the deliberate consideration of different Oldman Dam operations, assessing their effects on irrigation water supplies, aquatic ecosystems, riparian woodland ecosystems and water quality.

The Oldman River Dam operations plan was remarkable both for the process and for the outcome. The process relied heavily on an Oldman River Dam Environmental Advisory Committee that included representatives from various interests in the Oldman Basin, including proponents and opponents of the project, and involved both stakeholder meetings and public hearings (Rood and Vandersteen 2010). This inclusive process ensured that a wide range of interests – including the downstream Piikani First Nation and conservation groups who had opposed the dam – had the opportunity to be heard as the plan was developed. The resulting plan directs Oldman Dam operations to balance a range of interests, delivering water supply benefits for irrigators and other users, and also providing instream flows to support fish, water quality, recreation and riparian forests (AEP 1994; Rood and Vandersteen 2010).

AEP followed a similar process in developing operations plans for two later projects in the SSRB. The Pine Coulee Project on Willow Creek (1996 to 2000) and the Little Bow/Highwood River Project that resulted in the Twin Valley Dam (2000 to 2004) were much smaller and less controversial than the Oldman River Dam. Like the Oldman project, however, both involved open reviews with joint federal and provincial environmental assessment committees. These examined a broad range of considerations including environmental impacts at the project sites and extending along the river corridors, along with direct and indirect social, cultural and economic impacts. Thus, AEP recognized the value and importance of a comprehensive and inclusive approach to operations planning for new water projects, but it has not yet engaged in a similar process to review and renew its plans for existing projects. It has, however, made notable changes in the operating plans and practices at some projects, as explained in the following section.

Doing things differently: Revising water project operations

Official changes in water project operating requirements

Although there is no regular review of project operations in Alberta, provincial officials have made significant changes in the operating rules for several projects. In each case these changes increased the minimum flow levels below an important piece of water supply infrastructure, with the goal of mitigating downstream environmental problems.

AEP took a major step in 1991, in association with the implementation of the Oldman River Dam Project. Planning for that new dam involved analyses of water allocation and management for the Oldman River Basin, including its southern tributaries. This revealed insufficient flow conditions and prompted the increase in minimum flows below the provincially owned and operated reservoirs on the St. Mary and Waterton rivers. The St. Mary and Waterton dams had been constructed decades earlier, and until the mid- to late 1980s had always operated with a minimum flow ~1 cms. In the dry years of the 1980s, however, those meager levels proved inadequate to meet the needs of licensed users downstream, and the regional water manager for AEP requested larger releases for that purpose (D. McGee, interview in Pincher Creek, AB, 16 October 2015). Such releases were not officially required, however, until a 1991 regulation set new minimums of 2.3 cms below Waterton Reservoir and 2.8 cms below St. Mary Reservoir (AEP 1991a). These flow increases did provide environmental benefits (Foster and Rood 2017), but they were established at levels that would have minimal impacts on consumptive uses, and were not intended to fully meet all instream flow needs below the projects (D. McGee, interview in Pincher Creek, AB, 16 October 2015).

AEP effectively established a higher minimum flow on the lower portion of the Bow River in connection with a 2002 license amendment for the EID. EID owns and operates Bassano Dam on the Bow River, where it diverts water for irrigation. Under a license issued in 1963, EID had to ensure a minimum flow of 2.8 cms in the Bow below the dam; that license also capped EID's diversion rate at 85 cms, with lesser rates for low-flow periods and for the non-irrigation season. The license amendment allows EID to divert at a higher rate of 96 cms at any river stage, so long as it releases no less than 11.3 cms at Bassano Dam.

Similarly, a new license for an existing irrigation diversion resulted in a higher minimum flow for the reach of the Bow River upstream of Bassano Dam, which is one of Canada's most renowned trout fisheries (McLennan 2002). A diversion facility, the provincially owned and operated Carseland Headworks, had been in service for decades, diverting water from the Bow River primarily to fill off-channel reservoirs used by Bow River Irrigation District (BRID). In connection with a canal expansion that would allow an additional 10 cms to flow from the weir to the reservoirs, the province applied for a license allowing diversions at Carseland at the new maximum rate. AEP approved the license, which allowed diversion at the higher rate only when flows in the river below the weir met instream objectives. Minimum flows are based on a weekly schedule, and during the irrigation season they vary with natural variation of the Bow but never drop below 40 cms. BRID initially objected to the establishment of these flows, but AEP responded that they were based on the best available science (AEP 1998a), and the district later came to accept them as an operating condition.

In revising these instream flow requirements, AEP addressed each project on an ad hoc basis, rather than working systematically to revise and update operating plans for existing facilities. The new requirements strongly suggest that in each case AEP recognized a basic reality: operational changes at existing projects could reduce downstream environmental impacts.

Informal changes in project operating practices

As noted above, the SSRB Plan recognized the potential benefits of 'minor changes to dam operating practices', and also recommended that AEP 'investigate opportunities to optimize operation' of existing dams (AEP 2006, 16). In the decade following adoption of that plan, AEP has not made comprehensive, basin-wide changes toward optimization, but has implemented small, but important and beneficial, changes in the operations of provincially

owned reservoirs (Rood and Mahoney 2000; Foster and Rood 2017).

AEP has a record of fine-tuning operations to reduce impacts on downstream fish populations and improve conditions for riparian woodlands. Providing such functional flows is not included in the dams' operating plans, and there is no official policy for doing so; rather, AEP officials have described their approach as 'we do what we can, when we can' (J. Mahoney, interview in Lethbridge, AB, 17 November 2015). They have employed this approach most notably at St. Mary and Waterton dams, where they have gradually ramped down flows after peak releases in wetter years to promote vegetation recruitment and restore riparian forests downstream (Rood and Mahoney 2000). This practice slightly increases the risk of future shortages for irrigation districts that receive St. Mary stored water, but following from the demonstrated environmental benefits the districts have come to accept and even support the practice (J. Mahoney, interview in Lethbridge, AB, 17 November 2015).

This brings up two key points regarding Alberta's irrigation districts. First, the districts play a crucial role in decisions about water management and project operations because they hold water licenses that are both large and senior, giving them priority access to most of the allocated water in the Bow and Oldman river basins. Although these licenses may someday face legal or legislative challenges, under current law they give the districts a strong claim to the lion's share of water in the SSRB. Second, the districts have shown a willingness to 'share the water' with other users when supplies are short. Thus, districts in the southern tributaries of the Oldman Basin helped develop and implement a landmark agreement in the severe drought of 2001, whereby shortages were shared equally by all participating users regardless of their legal priorities (Rood and Vandersteen 2010). Similarly, the districts collectively have issued a 'Human Use Declaration' pledging to share some of their water with those needing it for human or livestock use in times of drought (AIPA [Alberta Irrigation Projects Association] 2010). Specific to project operations, a notable example occurred during the dry summer of 2015: the general manager of St. Mary River Irrigation District urged AEP to release more water *to protect fish* in the St. Mary River – specifically, an additional 1 to 2 cms to lower water temperatures during a major heat wave (T. Lazarus, interview in Lethbridge, AB, 15 October 2015).

Provincial dams and reservoirs have not been the only subject of discussions in Alberta regarding water project operations. TransAlta's hydropower projects in the upper Bow River system above Calgary have also been a major focus. Stakeholders in the Bow basin have sought various operational reforms of these projects since at least the 1990s, but TransAlta has sought compensation for such reforms, and until recently the provincial government proved unwilling to produce sufficient funds (or apply sufficient pressure) for TransAlta to make changes. Following the major Bow River flood of 2013, however, the provincial government put greater emphasis on flood control, and did pay TransAlta for an agreement to make a portion of Ghost Reservoir available for flood control storage in 2015 (D. Ardell and S. Gnanakumar, interview in Calgary, AB, 2 December 2015). AEP and TransAlta announced a similar but broader 5-year agreement in 2016, extending beyond Ghost to the utility's reservoirs on the Kananaskis River, a major tributary of the Bow (AEP 2016). The agreement gives AEP limited control of operations in more of the Bow River system, primarily for flood control, but also considering recreational and environmental values. AEP's engagement with TransAlta, while focused mostly on flood control, shows that the agency can effectively pursue significant operational changes when it places a high enough priority on them.

These developments offer some lessons that relate directly to future dam operations. Most fundamentally, they show that water management in southern Alberta is evolving away from an exclusive focus on licenses and toward a greater emphasis on public needs and values, including environmental quality. They also demonstrate that AEP does have some flexibility in operating its water projects, and even in approaching other dam owners about their operations. The next section recommends that AEP use this flexibility to implement a program of reviewing and revising the operations plans of its projects in the SSRB.

Considering alternatives: A proposal for operational review of provincial projects

While AEP's water project operators constantly take into account new information in making operating decisions, they make these decisions under an established operating regime or plan for each project. But the agency has not undertaken to revise or update those plans, at least not through any open, public process. Provincial water operations managers have offered several reasons for this position. Perhaps most significantly, project operators are concerned about losing too much of their discretion to make decisions on how best to operate facilities based on changing circumstances. In addition, the agency is concerned about the time and expense that may be required for public involvement in an operations review process (J. Mahoney, interview in Lethbridge, AB, 17 November 2015). And since AEP operations officials maintain that they are already operating provincial projects in a way that accords with the public good, they are not convinced that a public review of project operat-

ing plans would produce benefits that would outweigh the costs (D. Ardell and S. Gnanakumar, interview in Calgary, AB, 2 December 2015). Thus, AEP officials have responded to suggestions for reservoir optimization by essentially asking, Why do it?

The case for review of existing project operations

For older projects where operations have not changed significantly in many years, review of the operating plans provides an opportunity to update the scientific and technical information on which operating decisions are made. It may be possible to improve the river operations model, potentially benefiting both regular operations and evaluations of alternative scenarios (Jean and Davies 2016). By bringing in recent and relevant science from various disciplines, the review may advance understanding of trade-offs posed by various operating regimes, and may also identify beneficial practices that present little risk to existing users. And despite the difficulty in projecting the impacts of climate change at the watershed level, the review should consider the operational implications of expected changes such as more winter precipitation falling as rain, earlier snowmelt, longer and warmer growing seasons, and the potential for more extreme events.

One of the main reasons to review operations is the downstream environment, which could reap significant benefits from a more favorable flow regime. Science has continued to improve the understanding of environmental flow needs, moving beyond 'minimum flows' for fish survival, and recognizing the long-term importance of seasonal and interannual variations in river levels (Stromberg et al. 2007). While restoring the natural flow regime (Poff et al. 1997) may be unrealistic, even a heavily developed river system like the SSRB may benefit from 'functional flows' targeted to specific environmental outcomes (Rood et al. 2016); for example, modified dam releases in wet years have been shown to support riparian cottonwoods in southern Alberta (Foster and Rood 2017). While the results of revised dam operations have varied from place to place, there have certainly been some environmental success stories (Richter and Thomas 2007; Locke et al. 2008; Pittock and Hartmann 2011).

Even operational changes with major benefits must be carefully considered because there are always trade-offs. Ideally, a review of operations would identify beneficial changes posing minimal risks to existing water users such as the irrigation districts. Options presenting greater risks, but also significant benefits, will make for more difficult policy choices. In some cases, water users may be willing to accept some risk if a change is paired with a benefit, as was the case at Bassano and Carseland. Even without such a package deal, irrigators may choose to be flexible for the sake of strengthening their 'social license', as they were with the Human Use Declaration. Thus, an irrigation district may accept an operational change that could cost it some water if that change has meaningful support in the local community.

AEP may find a useful template for operating plan reviews in neighboring British Columbia, where the major provincial utility BC Hydro engaged in a complicated but ultimately successful effort to address issues posed by its hydropower facilities. This 'water use planning' (WUP) process reached consensus in developing recommendations for operations and other changes at all but one of 23 projects reviewed. The WUP process involved intensive stakeholder engagement through teams representing various interests in the area affected by the project, and consideration of various operational changes through the use of modelling runs and other analytical tools. WUP also provided for public involvement, with the resulting recommendations subject to final review and approval by the relevant provincial agency (Mattison et al. 2014). 'Previously the water management planning process had been confrontational and acrimonious; the new plan turned it into one of the most successful in Canada' (Locke et al. 2008, 9).

The most important reason for reviewing project operations, simply stated, is that approaches that have worked reasonably well in the past may not work as well in the future. While Alberta's future water challenges are uncertain, some interrelated long-term trends seem likely. Climate change will affect both water supplies and demands, reducing flows in the late summer while potentially increasing irrigation demands by extending growing seasons. Extreme events might become more common and more intense and demand for flood protection may increase, especially in population centers along the Bow and Red Deer rivers. Irrigated areas within some districts will expand further, and as efficiency and acreage increase, return flows will decrease. Population in the SSRB will continue to grow, as will the push to diversity Alberta's economy. And environmental and recreational values will be increasingly important over time, especially as the growing population is increasingly urban. All of these factors will put increasing pressure on southern Alberta's limited water resources.

The proposal: Review of long-term operating plans for provincial water projects

AEP should develop and implement a program to review and revise the operating plans of its major water supply projects. The initial focus should be on large, on-stream structures that do not have recently developed operations plans. The St. Mary Project on the southern tributaries of the Oldman River could receive early consideration; while the flow needs of riparian and aquatic ecosystems

have been partially addressed through informal changes in operations, a more established regime could be beneficial. Another candidate would be the multi-purpose Dickson Dam on the Red Deer River, and while there are advantages to operating it based primarily on a simple set of rule curves, a public review with updated information, might improve the overall mix of benefits provided by that facility. Other projects should be prioritized based on their potential for beneficial operational changes, and on the age and comprehensiveness of their current operating documents. Ideally, coordinated operations of multiple projects within a river system such as the Bow River could be considered within a single review. While involving multiple projects would complicate the review process, it could maximize flexibility, fairness and the overall benefits.

Such reviews could build upon recent efforts, led by Alberta WaterSMART, that have engaged many key stakeholders throughout the SSRB (Sheer et al. 2013). These efforts produced river operations models for the Bow, Oldman/South Saskatchewan and Red Deer subbasins, and an integrated model for the entire basin.

The models became powerful tools for stakeholder discussions to evaluate potential water development and management options within the SSRB, assessing their effects on a range of performance metrics including river flows, reservoir levels, water supply shortages and environmental measures. The stakeholders were then able to discuss options for the basin based on realistic projections of the likely benefits and costs. After a series of meetings, the participants eventually sorted the options into three categories based on their perceived feasibility of implementation in the near term. WaterSMART issued its final report on the SSRB-wide process in December 2015, and the report identifies a range of high- and medium-feasibility options, many of which involve changing the operations of existing water projects in the basin (Alberta WaterSMART 2015).

An operations review process will necessarily be tailored to the issues and interests surrounding a particular project, but some general points are more universal. A high-quality, well-accepted river operations model is crucial, allowing for realistic evaluation of the potential risks and benefits of various operating scenarios. The best available science, drawn from a range of disciplines, is an essential ingredient; while science alone cannot determine operational priorities it can allow choices based on more complete information than was available when the project was built. The potential implications of climate change must be considered in terms of water supplies, water demands, flood risks and environmental changes. Robust public participation throughout the process is key, involving not only familiar stakeholders such as water users, local governments and riparian property owners, but also others with environmental, recreational and other less-recognized interests in the affected area. Consultation with potentially affected First Nations, whose long-neglected interests in water were identified as a high priority under the SSRB Plan (AEP 2006), is also essential. And AEP, the project owner and licensee, must ultimately make a decision based on all these inputs, and on its years of experience in operating the project … but also on its duty to act in the overall public interest in managing Alberta's water.

While the new plans will be more detailed than the current operating regimes for most provincial projects, every plan must leave the project operator with some discretion. Operating a water supply project, especially for multiple purposes, is a complex undertaking, requiring the exercise of informed professional judgment under changing circumstances. AEP's project operators will retain that role, necessarily and appropriately, but they will make decisions within a revised framework.

Revising project operations could provide major benefits, but would not represent a 'silver bullet' for resolving the increasingly challenging water issues facing Alberta. Water projects are only one part of a complex water allocation and management system, the essential features of which have remained in place for over a century. This system was designed to promote human activity, not to preserve environmental integrity, and it is far better in protecting established water uses than in meeting the needs of changing times. Ensuring enough water for ecosystem needs is a major problem in this system, especially in heavily allocated basins such as the Bow and the Oldman. So long as it remains difficult to restore environmental flows on rivers such as these, water project operations may be one of the best places within the system to find real flexibility.

Conclusion

This article addresses the operation of dams in the SSRB of southern Alberta, focusing on the water supply projects owned and operated by AEP. Recognizing the environmental problems posed by historic operating practices, the agency has revised these practices over time, using an approach described as 'We do what we can when we can'. While this approach is a step in the right direction, the AEP should be encouraged to conduct official reviews of long-term operating plans for all of its dams. These reviews would employ the best available models and scientific information to allow for informed choices about alternative operating practices, and would provide opportunities for public participation in making those choices. AEP should lead these reviews, but the agency could build on the recent efforts to develop models and engage stakeholders in the SSRB.

Alberta is certainly not the only part of the world that could benefit from changing dam operating plans and

practices. Addressing environmental problems caused by existing dams is an unresolved issue in the United States, particularly for government projects that are not subject to any form of periodic review (Benson 2017). Other nations facing challenges associated with existing dams include Australia, China, and some in Europe and Africa (Pittock and Hartmann 2011). A program to review provincial projects in the SSRB could provide a useful model, particularly as applied to water supply dams where water scarcity is a significant concern. Especially where dams were built decades ago for a specific use, operational changes might allow these dams to continue serving their intended purpose but reduce downstream impacts and increase net public benefits. In an era of climate change, increasing water demands and evolving public values toward rivers, it is more important than ever to have a flexible and forward-looking approach to dam operations.

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