

Capacity for watershed cumulative effects assessment and management in the South Saskatchewan Watershed, Canada

Bram Noble & Prajwal Basnet

To cite this article: Bram Noble & Prajwal Basnet (2015) Capacity for watershed cumulative effects assessment and management in the South Saskatchewan Watershed, Canada, Canadian Water Resources Journal / Revue canadienne des ressources hydriques, 40:2, 187-203, DOI: [10.1080/07011784.2015.1019568](https://doi.org/10.1080/07011784.2015.1019568)

To link to this article: <https://doi.org/10.1080/07011784.2015.1019568>



Published online: 09 Apr 2015.



Submit your article to this journal [↗](#)



Article views: 754



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 3 View citing articles [↗](#)

Capacity for watershed cumulative effects assessment and management in the South Saskatchewan Watershed, Canada

Bram Noble^{a*} and Prajwal Basnet^b

^a*School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Canada;* ^b*Clear Environmental Solutions, Calgary, Canada*

(Received 21 October 2014; accepted 11 February 2015)

Canada's watersheds are under increasing pressure from the cumulative effects of human development. There is a recognized need to assess and manage cumulative effects to Canada's watersheds, but there has been limited assessment of the current capacity for cumulative effects assessment and management. This paper assesses the current capacity to implement and sustain watershed-based cumulative effects assessment and management in the South Saskatchewan Watershed. Eight core requisites and 40 capacity indicators for watershed cumulative effects assessment and management are assessed based on a survey of 73 watershed stakeholders. Results indicate that many of the perceived threats to the health of the South Saskatchewan Watershed are not subject to regulatory environmental assessment. Participants identified leadership and multi-stakeholder collaboration as the most important requisites for watershed cumulative effects assessment and management, but under-valued the importance of vertical and horizontal linkages to ensure that watershed plans and monitoring programs provide sufficient guidance to land uses and project development decisions. Participants believed current capacity to be lacking, or limited, across most assessment indicators, with data management and coordination and resources to ensure the long-term sustainability of watershed cumulative effects assessment and management as the most significant capacity constraints. Advancing watershed cumulative effects assessment and management in the South Saskatchewan Watershed requires a lead agency or consortium of agencies with a clear mandate for cumulative effects assessment, the legislated or regulatory means to ensure that watershed efforts influence land and water use and allocation decisions, the coordination of data and provision of specific guidance to monitoring programs, and long-term financial investment.

Les bassins versants canadiens sont sous la menace croissante d'effets cumulatifs dus aux développements humains. Il est reconnu qu'une évaluation et une gestion de ces effets cumulatifs sur les bassins versants canadiens sont nécessaires, mais peu d'études ont été menées sur l'actuelle capacité à évaluer et gérer ces effets cumulatifs. Cet article adresse l'actuelle capacité à exécuter et maintenir l'évaluation et la gestion des effets cumulatifs dans le Bassin Versant Saskatchewan Sud. Huit principaux prérequis et quarante indicateurs de la capacité à gérer et évaluer les effets cumulatifs, basés sur une étude de soixante-treize parties prenantes de bassins versants, sont évalués. Les résultats indiquent que plusieurs des menaces perçues pour la santé du Bassin Versant Saskatchewan Sud ne sont pas sujets à l'évaluation environnementale réglementaire. Les participants ont indiqué que la qualité de diriger et la collaboration de plusieurs parties prenantes sont les plus importants prérequis pour l'évaluation et la gestion des effets cumulatifs sur les bassins versants. Cependant, les participants ont sous-estimé l'importance des relations hiérarchiques et interpersonnelles, qui ont pour but de s'assurer que les plans des bassins versants et les programmes de contrôle fournissent suffisamment de directions sur l'usage des terres et sur les décisions de développement de projet. Les participants ont trouvé que la capacité actuelle fait défaut dans la plupart des indicateurs d'évaluation. Ils ont noté que la gestion et la coordination des données et des ressources, assurant la durabilité à long terme, restreignent considérablement la capacité à évaluer et gérer les effets cumulatifs. Un organisme de file de chef, avec un mandat clair sur l'évaluation des effets cumulatifs, est nécessaire pour faire progresser l'évaluation et la gestion des effets cumulatifs dans le bassin versant "Saskatchewan South Watershed." Pour s'assurer que les efforts menés sur les bassins versants influencent l'usage des terres, des eaux, et les décisions collectives, il est nécessaire que des moyens législatifs et réglementaires, une coordination des données, une mise à disposition de spécifiques conseils pour la surveillance des programmes et un investissement financé à long terme soient mis en oeuvre.

Introduction

Cumulative effects originate from the combined actions of anthropogenic and natural disturbances over space and time, and have the potential to significantly alter environmental conditions (Noble et al. 2011). Watershed cumulative effects result from changes in watershed

processes, often caused by land-use activities, in-stream use and natural disturbances (Reid 1993, 2010; Scherer 2011). As such, river system health is largely a function of the types of interactions and processes that occur on the landscape and within the boundary of the watershed (Seitz et al. 2011).

*Corresponding author. Email b.noble@usask.ca

There are two primary approaches to the assessment and management of cumulative effects in Canada's watersheds: first, project-based environmental assessment (EA), required federally under the *Canadian Environmental Assessment Act* and under the EA laws and regulations of those provinces and territories that provide for cumulative effects assessment; second, environmental effects monitoring (EEM) programs, instituted under various federal regulatory programs – e.g. for pulp mills and metal mines (Environment Canada 2010, 2011). Both have been widely criticized for their approach to cumulative effects. Project-specific EA is focused on project approval, often lacks a sound scientific basis for understanding cumulative effects and does not fully capture the interacting effects of multiple stressors over space and time, and many of the non-point sources of stress that contribute to cumulative effects do not fall within the regulatory requirements for EA (Baxter et al. 2001; Duinker and Greig 2006; Seitz et al. 2011; Ball et al. 2013a). EEM programs, focused on condition-based monitoring, are the most direct means to assess past and present changes in ecological conditions (Kilgour et al. 2007; Munkittrick et al. 2000), but they typically operate in isolation of EA and land-use planning decisions (Schindler and Donahue 2006) and do not consider the impacts of future development or disturbance conditions (Noble et al. 2014).

There has emerged in recent years a significant focus on watershed-based cumulative effects assessment and management (CEAM) so as to better understand, monitor and manage cumulative effects on river systems (Reid 1998; Culp et al. 2000; Schindler and Donahue 2006; Noble et al. 2011; Seitz et al. 2011; Ball et al. 2013b; Squires and Dubé 2013; Sheelanere et al. 2013). Watershed CEAM examines the interactions between river and landscape changes that accumulate over time and space, and river system response, and examines the outcomes of these interactions under different futures of growth and development in the watershed (Seitz et al. 2011). That said, efforts to advance watershed CEAM initiatives and programs over the past 15 years and across a range of jurisdictions have achieved only mixed success (Kristensen et al. 2013; Noble et al. 2014). The science of watershed CEAM is advancing, but much less attention has been given to the capacity to implement and sustain watershed CEAM (Noble et al. 2011; Parkins 2011; Chilima et al. 2013; Sheelanere et al. 2013).

This paper examines the current capacity for watershed CEAM in the South Saskatchewan Watershed (SSW), Canada, and identifies the primary capacity needs and opportunities for advancing watershed CEAM. Capacity is defined simply as the ability to plan for, implement and maintain watershed CEAM programs. There has been some appraisal of institutional arrangements for watershed CEAM in the Lower Fraser

(Kristensen et al. 2013), Athabasca (Noble et al. 2014) and Grand River Basins (Chilima et al. 2013), but there does not exist a suite of indicators for the systematic and quantitative evaluation of the capacity to implement and sustain watershed CEAM. A suite of capacity indicators for watershed CEAM is presented and applied to the SSW based on a survey of watershed stakeholders. Although based on the SSW context, the results are of value to assessing and understanding CEAM capacity needs in other watersheds across Canada and internationally. In the sections that follow, the study methods are introduced, followed by the survey results. Attention then turns to several key observations emerging from the results, and a discussion of the implications for advancing watershed CEAM.

Methods

Study area

The SSW, defined here as including the drainage basins of the South Saskatchewan River, is approximately 172,900 km², extending across the provinces of Alberta and Saskatchewan (Figure 1) (Oegema 2012). The population of the SSW is approximately 2.2 million, of which the majority resides in urban centers (Bruneau et al. 2009; Sheelanere et al. 2013). As of 2009, there were over 20,000 water licences and registered water uses of the South Saskatchewan River, and several hundred of these were in the South Saskatchewan sub-basin in Alberta. Groundwater consumption in the SSW represents about 2.5% of total consumption (Partners for the Saskatchewan River Basin 2009). Irrigated agriculture represents the most significant water use in the basin. Summer flows in the SSR have been reduced by 84% since the early twentieth century, and its major tributaries have all been subjected to multiple impoundments and large withdrawals (Squires et al. 2010; Sheelanere et al. 2013). In addition to municipal land use, other major land uses include mining, petroleum and natural gas development, waste management and agriculture.

There are multiple governance institutions and agencies responsible for land and water use management in the SSW at the federal, provincial and regional levels. These include, for example, Environment Canada, Fisheries and Oceans Canada, Alberta Environment and Sustainable Resource Development, the Saskatchewan Water Security Agency, numerous rural municipal governments, and several watershed boards and associations. Requirements for the assessment and management of the cumulative effects of human development are set out federally under the *Canadian Environmental Assessment Act, 2012* and in Alberta under the *Alberta Environmental Protection and Enhancement Act*. There is no legislated requirement for cumulative effects assessment in Saskatchewan.

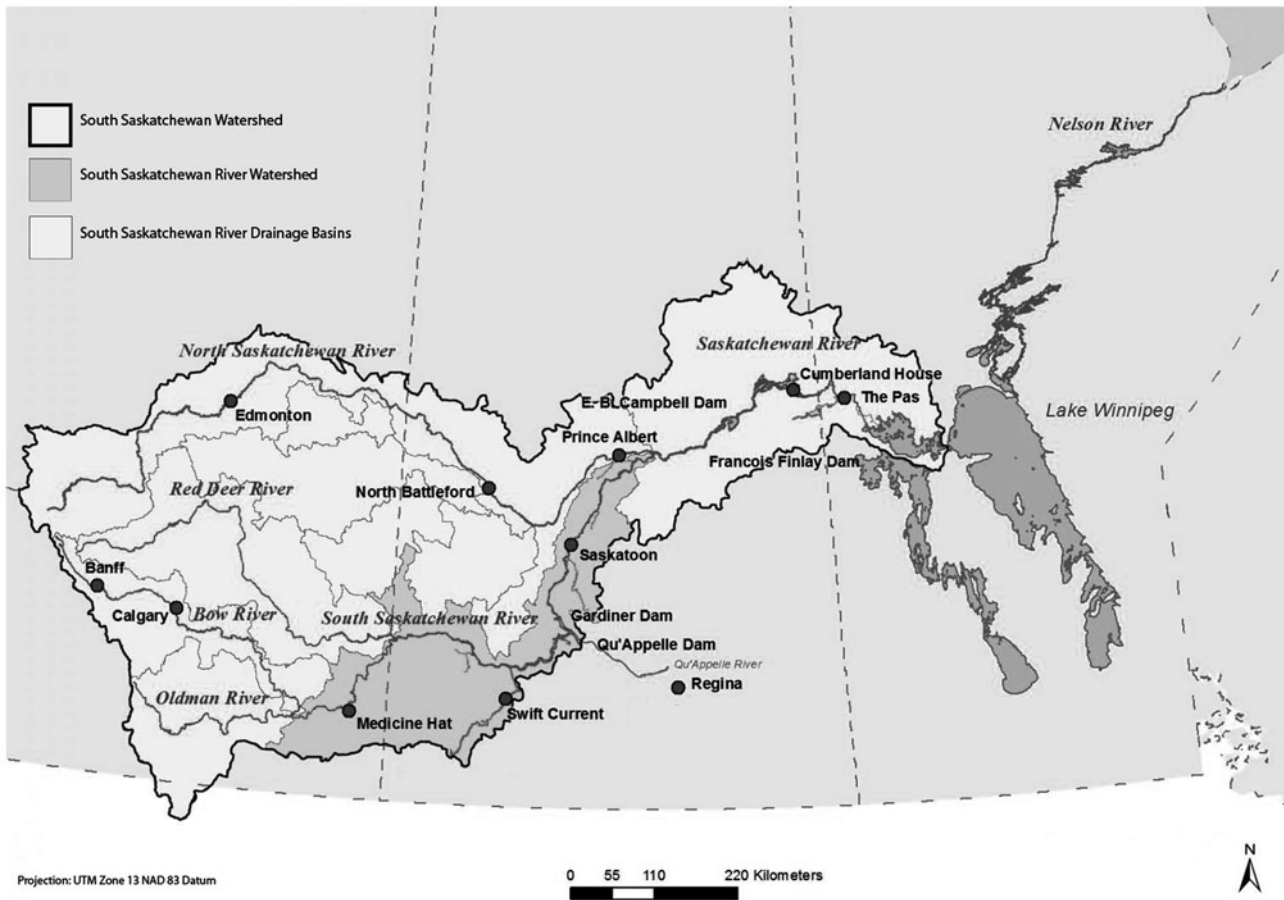


Figure 1. The South Saskatchewan Watershed.

Capacity assessment indicators

A common approach to the evaluation of capacity in any sector is the application of a set of indicator questions in an evaluative framework (United States Environmental Protection Agency [US EPA] 1998; Ivey et al. 2002; Robins 2008). Eight requisites for successful watershed CEAM were adopted for this study. These requisites were developed by Sheelanere et al. (2013) in the context of the SSW, and validated by Kristensen et al. (2013), Noble et al. (2014) and Chilima et al. (2013) in the Lower Fraser, Athabasca and Grand River watersheds, respectively, and identify the overarching conditions necessary to implement and sustain CEAM programs. For each requisite, a set of capacity indicators was developed based on a review of the scholarly literature in the fields of watershed planning and management, source water protection, regional land use planning, watershed science, environmental assessment, cumulative effects assessment, and water policy and governance (Table 1).

Data collection

Capacity and capacity needs for CEAM were assessed using an online survey of watershed stakeholders. The survey was administered using Fluid Surveys. A letter of invitation containing a link to the survey was sent to an initial list of potential study participants, many of whom were previously involved in watershed CEAM research in the SSW conducted by Noble et al. (2011). The initial list of study participants included watershed agencies, industry, cumulative effects practitioners or consultants, provincial regulators, academic researchers involved in CEAM programs in the watershed, and watershed boards or committees with an expressed interest in the watershed. Participants were asked to forward the survey to others whom they thought might be interested in participating, resulting in a snowball sampling design (see Valentine 2005). The survey was also advertised on various listserves and through the media with open access for a 5-month period.

Table 1. Requisites and capacity indicators for watershed cumulative effects assessment and management (CEAM).^a*A. Lead agency*

- (1) Clear goals and priorities have been set for the watershed, including for future land use and overall watershed health.
- (2) There is an agency or group of agencies with a leadership role in the assessment and management of cumulative effects.
- (3) There is an agency or group of agencies with the ability (formal or informal) to influence decisions about land use and development.
- (4) There is an agency or group of agencies with authority to implement and/or enforce regulations across the watershed to support CEAM.
- (5) There is an agency or group of agencies with authority to allocate resources to support CEAM initiatives (e.g. monitoring, data collection).

B. Multi-stakeholder collaboration

- (1) There is a collaborative approach to setting goals and priorities for the watershed concerning land and water use and development.
- (2) Stakeholder roles and responsibilities (e.g. industry, watershed agencies, governments) with respect to CEAM and monitoring are clearly defined.
- (3) There is willingness amongst authorities to share data and to coordinate activities related to monitoring watershed conditions and managing effects.
- (4) Industrial proponents are willing to share their data (e.g. water quality, discharge, water use) with other industries and non-industry stakeholders.
- (5) Local communities are engaged in watershed planning, monitoring, environmental assessment and related decision-making processes.

C. Watershed baselines, indicators and thresholds

- (1) There is adequate baseline data to identify past trends or changes in water quality across the watershed.
- (2) There is adequate baseline data to identify past trends or changes in water quantity/flow across the watershed.
- (3) There is adequate spatial baseline data to identify past land cover and land uses across the watershed.
- (4) There is agreement on the most appropriate indicators of watershed health.
- (5) There is a scientific understanding of thresholds (e.g. loadings, minimum flows, etc.) at which river system functions are no longer ecologically viable.

D. Multi-scaled monitoring

- (1) Monitoring programs under regulatory-based environmental assessment provide an understanding of a project's effects on watershed processes.
- (2) There are requirements for the monitoring of river system condition (e.g. water quality, flow, loadings) across the watershed.
- (3) Current monitoring programs provide a sound understanding of, and allow for detection of changes in, water quality conditions across the watershed.
- (4) Current monitoring provides a sound understanding of, and allows for detection of changes in, water quantity/flow conditions across the watershed.
- (5) Current monitoring provides a sound understanding of, and allows for detection of changes in, the dominant stressors to river system health (e.g. land use, disturbance patterns, discharge, etc.) across the watershed.

E. Data management and coordination

- (1) Data collection/monitoring are coordinated so as to allow a standardized approach to the establishment of baseline conditions.
- (2) Water quality and quantity data are available in an accessible, up-to-date and electronic format to industry, government and all watershed stakeholders.
- (3) Spatial data of land uses, disturbance or use patterns are available in an easily accessible, up-to-date and electronic format to industry, government and all watershed stakeholders.
- (4) There is consistency in project monitoring standards and indicators (used under environmental impact assessment or similar regulations/permits) for projects affecting similar components or for projects of a similar class (e.g. pulp mills, metal mines, agriculture, etc.).
- (5) Data (water quality, quantity, land use) are quality controlled such that data gaps, uncertainties or assumptions are reported and known to data users.

F. Vertical and horizontal linkages

- (1) Watershed or sub-watershed management plans influence the terms and conditions of project-specific environmental assessments.
- (2) Watershed or sub-watershed management plans influence policy and other decisions concerning land and water.
- (3) There is consistency in watershed management goals and objectives across sub-basins.
- (4) Results from project-specific monitoring are used to inform broader watershed assessment, evaluation and reporting processes.
- (5) Information generated from science programs or watershed monitoring and assessment is given due consideration in watershed management plans.

(Continued)

Table 1. (Continued)

G. Enabling legislation

- (1) There is sufficient legislation or other regulatory means to establish a watershed-based framework for CEAM.
- (2) The terms of reference for projects under regulatory-based environmental assessment provide clear direction for indicators in project monitoring.
- (3) There is sufficient legislation or regulatory means to ensure that results generated from state-of-the-watershed assessments (e.g. monitoring programs, science studies) influence decisions about land use and development.
- (4) Legislation and other regulatory instruments concerning land and water use are consistent across the watershed and between levels of government.
- (5) There is sufficient legislation or regulations to enable the protection of sensitive or vulnerable areas of the watershed from human disturbance.

H. Financial and human resources

- (1) Scientific and technical expertise to develop and implement tools for CEAM is available, through government, the private sector or academia.
- (2) Funding is available for the development and implementation of source water protection plans and projects.
- (3) Financial resources are available at the provincial level to support watershed-based CEAM programs (i.e. data collection, reporting, enforcement).
- (4) Financial resources are available at the sub-watershed level to participate in watershed cumulative effects programs.
- (5) Education and training opportunities on CEAM tools and practice are available to government, watershed managers, land use planners and other stakeholders responsible for planning and assessment.

Note: ^aRequisites based on Sheelanere et al. (2013). Indicators based on: Peterson et al. (1987); Parker and Cocklin (1993); Reid (1993, 1998); Grindle and Hilderbrand (1995); Griffiths et al. (1998); Dubé and Munkittrick (2001); Braat (2002); de Loë et al. (2002); Kennett (2002); de Loë and Kreutzweiser (2005); Duinker and Greig (2006); Ivey et al. (2002, 2006); Schindler and Donahue (2006); Dubé et al. (2006); Therivel and Ross (2007); Timmer et al. (2007); Heathcote (2009); Zhao et al. (2009); Canter and Ross (2010); Davies and Hanley (2010); Noble (2010); Squires et al. (2010); Brinson and Eckles (2011); Canter and Atkinson (2011); Connelly (2011); Seitz et al. (2011); Noble et al. (2011); Ball et al. (2013a); Kristensen et al. (2013); Sheelanere et al. (2013); Noble et al. (2014).

A total of 73 individuals participated in the survey: 29 (39.7%) from Alberta and 42 (57.5%) from Saskatchewan. Two participants indicated that they were from neither Alberta nor Saskatchewan, but worked in or conducted research in the SSW in one of the provinces. Approximately 41% of participants were government, followed by academic and non-government organizations (e.g. watershed boards, environmental organizations), and the private sector (e.g. industry, consultants; Table 2). The desired response pool was approximately 50 from each of Alberta and Saskatchewan, a likely sufficient number to achieve a statistical power > 0.8 assuming moderate (0.6) to large (0.8) effect sizes (Cohen 1988), estimated based on Warachan's (2011) testing of Likert scale response data and non-parametric statistical power for low to highly skewed distributions at $\alpha = 0.05$. Observed power ranged from 0.42 to 0.96 based on actual effect and sample size. Based on Gerard et al. (1998), Hoenig and Heisey (2001) and O'Keefe (2007), confidence intervals were used to examine the meaningfulness of statistical test results between participant groups.

The survey consisted of three parts: (1) stakeholder views about the current health of the SSW, specifically regarding water quality and quantity, and primary threats; (2) an assessment of the relative importance of the requisites to ensuring successful watershed CEAM; and (3) an assessment of current capacity in the SSW to implement

and sustain watershed CEAM. Capacity assessment was based on a 9-point response scale, whereby for each of the 40 capacity indicator statements (Table 1) participants were asked to rate, based on their experience and expertise, the extent to which each indicator was evidenced in the SSW. A 9-point scale was used based on Nunnally's (1978) observation that adding scale steps provided increasing reliability, up to an 11-point scale, and based on Saaty's (1977) work in mathematical psychology identifying that people's cognitive ability to compare objects is typically 7 ± 2 . Responses were analyzed using the Statistical Package for the Social Sciences (SPSS) software, applying non-parametric and exploratory techniques for testing of statistical significance and confidence interval analysis. Confidence intervals about the median were calculated using Tukey's hinges (Krzywinski and Altman 2014). Qualitative responses, where provided, were coded thematically, and by participant affiliation, using NVivo-QSR software for qualitative analysis.

Results

Perspectives on the current state of the SSW

Participants were asked to comment on the overall health of the SSW, based on whether they perceived it as "1 = unhealthy," "2 = healthy but with problems," or "3 = healthy." The majority of participants (84.9%)

Table 2. Study participants, by professional affiliation.

Current affiliation	n ^a		%
Government sector	30	Federal government – 1.4 Provincial government – 35.6 Municipal government – 4.1	41.1
Academia and NGOs	29	Watershed agency – 4.1 NGOs – 26.0 Academia – 9.6	39.7
Private sector	13	Consultant – 11.0 Other – 6.8	17.8

Note: NGOs: non-governmental organizations.

^aOne missing response.

classified the SSW as “healthy but with problems” (Table 3). There were no significant differences between Alberta and Saskatchewan participants ($U = 613$, $p = 0.727$), or based on participant professional affiliation ($H = 2.966$, $p = 0.227$).

Participants were also asked whether and how the overall health of SSW has changed in the past 10 years. The majority of participants, 49.3%, said that overall health has declined, 42.5% said that it remained about the same and only 4.1% said that the health of the SSW has improved (Table 4). The distribution of responses was similar across participant sub-groups, with no significant differences found between Alberta and Saskatchewan participants ($U = 549$, $p = 0.896$), or based on participant professional affiliation ($H = 3.848$, $p = 0.146$).

When asked to identify whether the cumulative effects of human actions in the SSW posed a threat to water quality or quantity, participants “somewhat agreed” to “strongly agreed” (Table 5). There were no significant differences between Alberta and Saskatchewan participants, or based on participant affiliation.

Participants were also asked to identify what they perceived to be the primary threats to water quality and quantity in the SSW. A total of 127 different threats to water quality were reported, which could be categorized into five types or sources of stress (Table 6). Activities associated with agriculture were identified most frequently, cited by 43 participants and comprising 33.85% of all responses, closely followed by stresses from urban settlements.

A total of 107 different threats to water quantity were reported, which could be categorized into five types or sources of stress (Table 7). Climate change was the most frequently reported threat to water quantity, identified by 26 participants and comprising 24.29% of all responses. This was closely followed by stresses from agriculture/irrigation use and poor land use planning and management practices.

Relative importance of the requisites for watershed CEAM

Participants were provided with the eight requisites for watershed CEAM (Table 1, A to H; see also Sheelanere et al. 2013), and asked to assign a total of 80 points across the set of eight requisites based on their relative importance(s) to ensuring “successful” watershed CEAM. Multi-stakeholder collaboration was identified as the most important requisite, with the highest total points assigned, followed by the presence of a lead agency for watershed CEAM, and available financial and human resources (Table 8).

There were no significant differences between Alberta and Saskatchewan participants in the distributions of point assignments for each of the eight requisites, with the exception of “lead agency.” Participants from Saskatchewan (median = 12 ± 1.0) assigned more importance to the presence of a lead agency as a requisite for successful watershed CEAM than did Alberta participants (median = 10 ± 1.2 ; $U = 728.000$, $p = 0.039$). Overall, across eight requisites, the highest percentage of points (16.2%) was

Table 3. Current health of the South Saskatchewan Watershed.

Response category	Total ^a		Alberta		Saskatchewan	
	n	%	n	%	n	%
1 = unhealthy	6	8.2	2	6.9	4	9.8
2 = healthy but with problems	62	84.9	26	89.7	33	80.4
3 = healthy	5	6.9	1	3.4	4	9.8

Note: ^aIncludes those participants who identified themselves as from neither Alberta nor Saskatchewan.

Table 4. Change in the health of the South Saskatchewan Watershed over the past 10 years.

Response category	Total ^a		Alberta		Saskatchewan	
	n	%	n	%	n	%
1 = declined	36	49.3	14	51.8	20	50.0
2 = remained about the same	31	42.5	11	40.8	19	47.5
3 = improved	3	4.1	2	7.4	1	2.5

Note: ^aIncludes those participants who identified themselves as from neither Alberta nor Saskatchewan; n includes three missing responses.

Table 5. Perceived threat of cumulative effects to water quality and quantity in the South Saskatchewan Watershed.^a

There is a current threat to:	Aggregate	Province		Professional affiliation		
		AB	SK	Government	NGOs and academia	Private sector
(a) Water quality	8.0 ± 0.50 ^b	8.0 ± 0.50	7.0 ± 0.50	7.0 ± 1.00	8.0 ± 0.75	8.0 ± 1.00
(b) Water quantity	8.0 ± 0.50	8.0 ± 0.50	8.0 ± 0.75	7.5 ± 1.00	8.0 ± 0.75	7.0 ± 1.00

Note: NGOs: non-governmental organizations.

^aResponses scale of 1–9, where 1 = strongly disagree; 3 = somewhat disagree; 5 = neither agree nor disagree; 7 = somewhat agree; 9 = strongly agree; 2, 4, 6, 8 = intermediate responses.

^bMedian and 95% confidence interval.

Table 6. Primary threats to water quality in the South Saskatchewan Watershed.

Primary threat	AB (n) ^a	%	SK (n)	%	Total (n)	(%)
Agriculture/intensive livestock operations and runoff (e.g. pesticides, fertilizers)	15	31.9	28	35	43	33.85
Urban settlement (e.g. runoff, sewage, waste water discharge, pharmaceuticals)	15	31.91	24	30	39	30.70
Industrial activity (e.g. pipeline crossings, shoreline disturbance, oil and gas spills)	5	10.63	14	17.5	19	14.96
Other (e.g. climate, invasive species)	5	10.63	9	11.25	14	11.02
Flow diversion (dams, withdrawals)	7	14.89	5	6.25	12	9.44
Σ	47		80		127	

Note: ^aNumber of times the threat was identified by study participants.

Table 7. Primary threats to water quantity in the South Saskatchewan Watershed.

Primary threat	AB (n) ^a	%	SK (n)	%	Total (n)	(%)
Climate change (droughts, floods, glacier and snowpack loss)	11	26.19	15	23.07	26	24.29
Agriculture/irrigation use (withdrawals, use)	8	19.04	17	26.15	25	23.36
Poor planning and management practices (overallocation, lack of source water protection, lack of information on groundwater and use)	10	23.80	13	20	23	21.49
Industrial use (non-agriculture)	6	14.28	12	18.46	18	16.82
Other (municipal use, river diversion, loss of critical recharge areas)	7	16.66	8	12.30	15	14.01
Σ	42		65		107	

Note: ^aNumber of times the threat was identified by study participants.

allocated to “multi-stakeholder collaboration” by Alberta participants, and the lowest percentage of points (8.0%) was allocated to “vertical and horizontal linkages,” also by Alberta participants. Based on rank order, when considering the percentage of points assigned across the eight requisites, “vertical and horizontal linkages” ranked lowest overall and by province. “Multi-stakeholder collaboration” ranked highest in Alberta, whereas “lead agency” ranked highest in Saskatchewan.

Assessments of current capacity for watershed CEAM

Participants were asked to assess the current capacity in the SSW to implement and sustain watershed CEAM programs. For each of the eight requisites, participants were asked to identify their level of agreement with each indicator statement, from 1 (“strongly disagree”) to 9 (“strongly agree”), based on their knowledge and experience with water and land assessment, monitoring and

Table 8. Median weight/points assigned to requisites for watershed cumulative effects assessment and management (CEAM).^a

Province	Lead agency	Multi-stakeholder collaboration	Watershed baselines, indicators and thresholds	Multi-scaled monitoring	Data management and coordination	Vertical and horizontal linkages	Enabling legislation	Financial and human resources
AB	10	10.0	10.0	10.0	10.0	8.5	9.0	10.0
95% CI	± 1.2	± 1.8	± 0.6	± 0.6	± 0.3	± 1.5	± 1.3	± 0.7
Total points	291	374	332	257	284	185	289	297
(%)	(12.6%)	(16.2%)	(14.4%)	(11.1%)	(12.3%)	(8.0%)	(12.5%)	(12.9%)
Rank	4	1	2	7	6	8	5	3
SK	12	10.0	10.0	10.0	10.0	8.0	10.0	10.0
95% CI	± 1.0	± 0.8	± 0.6	± 0.3	± 0.6	± 1.8	± 0.8	± 0.5
Total points	480	458	410	398	379	295	403	457
(%)	(14.6%)	(14.0%)	(12.5%)	(12.1%)	(11.6%)	(9.0%)	(12.3%)	(13.9%)
Rank	1	2	4	6	7	8	5	3
Overall	10.0	10.0	10.0	10.0	10.0	8.0	10.0	10.0
95% CI	± 1	± 0.9	± 0.6	± 0.5	± 0.5	1.6	0.8	0.4
Total points	771	832	742	655	663	480	692	754
(%)	(13.8%)	(14.9%)	(13.3%)	(11.7%)	(11.9%)	(8.6%)	(12.4%)	(13.4%)
Rank	2	1	4	7	6	8	5	3

Note: ^aAB = Alberta, SK = Saskatchewan; 95% CI = 95% confidence interval for the median.

management in the SSW. Participants were also given an opportunity to provide additional qualitative assessments for each indicator. Assessment results are summarized in Table 9 and presented in the sections that follow for each requisite.

Lead agency

Median responses were relatively neutral across all indicators, but there was diversity in views about current leadership for watershed CEAM in the SSW. On A1, for example, 39.4% indicated that clear goals and priorities for future land use and watershed health had been established, and an approximately equal percentage (37.9%) disagreed (Table 9). There were no significant differences between Alberta and Saskatchewan participants, or based on participant affiliation, but Alberta participants specifically commented on the need for a lead agency and the creation of coherent legislation for better land-use management and to monitor and enforce thresholds to improve watershed health. Eight Saskatchewan participants commented that there was no governance structure or strategy to address cumulative effects in the SSW. Only on A5 was there any agreement, with 51% of participants agreeing (median = 6.5 ± 0.4) that there is an agency or group of agencies in the SSW with the authority to allocate resources for CEAM. That said, there were comments from several Saskatchewan participants (government, non-governmental organization [NGO] and academia) that the Saskatchewan Water Security Agency lacked the authority to drive a watershed CEAM process – including the means to integrate across provincial

agencies and the capacity to deliver on overall watershed monitoring and management.

Multi-stakeholder collaboration

Multi-stakeholder collaboration in the SSW to support CEAM was assessed much lower than leadership (Table 9). Only 20.3% of participants (the majority of which were Alberta participants) indicated that communities are engaged in watershed activities (B5), and 53.1% did not believe that stakeholder roles are sufficiently defined to support CEAM (B2). There were no significant differences between Alberta and Saskatchewan participants, with the exception of B5 ($U = 259$; $p = 0.005$). Saskatchewan participants assessed the state of community engagement (median = 3.0 ± 0.8) much lower than Alberta participants did (median = 5.0 ± 1.2). Several Saskatchewan participants commented that there has not yet been significant collaboration regarding watershed CEAM and, when stakeholders do collaborate to identify quality and quantity risks, the system fails because the agencies responsible do not have the capacity and resources to deliver. There was also a difference between NGO and private sector participants ($U = 227.500$, $p = 0.020$) concerning whether industrial proponents are willing to share their data with other industries and non-industry stakeholders (B4), with NGO participants indicating that proponents are typically unwilling to do so (median = 5.0 ± 0.4). There was a considerable range in responses amongst private-sector participants (median = 3.0 ± 1.8).

Watershed baselines, indicators and thresholds

The overall state of watershed baseline data, and agreement on indicators and thresholds for cumulative effects, was assessed as relatively weak (Table 9). Only 20.3% indicated that there is consensus on the most appropriate indicators of watershed health for the SSW (C4), and 40.6% said that there is adequate baseline data to identify past trends or changes in water quantity/flow across the watershed (C2). Only 39.1% said that there is adequate spatial baseline data to identify past land cover and land uses across the watershed (C3). There were no significant differences between Alberta and Saskatchewan participants, with the exception of available baseline data for water quality (C1; $U = 294.500$, $p = 0.021$): Alberta participants were neutral on whether there is adequate baseline data on water quality (median = 5.0 ± 1.4), whereas Saskatchewan participants provided a much lower assessment (median = 3.0 ± 1.8). A participant from the Saskatchewan government commented that there is limited understanding in the variability of known thresholds in the SSW, and several others reported that data are limited regarding historical water quality, and that monitoring data have significant gaps and challenges in terms of consistency. That said, a number of participants from the private sector and academia commented that, despite data gaps, there is still sufficient data to make informed land-use planning decisions that will have positive impacts on watershed health.

Multi-scaled monitoring

There were no significant differences in median responses between Alberta and Saskatchewan participants, or based on participant affiliation. Approximately 54% of respondents did not believe that current monitoring programs in the SSW provide a sound understanding of, and allow for the detection of changes in, water quality conditions across the watershed (D3; median = 3.0 ± 0.4 ; Table 9). Similarly, 58.7% did not believe that monitoring programs currently provide a sound understanding of, and allow for the detection of changes in, the dominant stressors to river system health (D5; median = 3.0 ± 0.4). One government participant commented that most of the monitoring programs in the SSW are project-specific, and that monitoring for individual projects is not that useful for assessing the cumulative effects from multiple non-project-related activities. Another government participant commented:

I don't think we have a monitoring system in the South Saskatchewan River watershed that provides the science base needed to understand where we are currently at and what we need to know to address future threats.... We monitor water quality and flows, but not the aquatic biota or stressors adequately. Stressors may be both

natural (precipitation, fire, mountain pine beetle, etc.) and human caused (land use, effluent, etc.) and [we] have not done a good job of defining relationships between the stressors and the conditions of the aquatic environment.

Data management and coordination

Data management and coordination was assessed as a particular capacity challenge (Table 9). Several participants from both Alberta and Saskatchewan reported that data management and coordination was one of the biggest obstacles to watershed CEAM. It was noted that there was a wide range of data that could potentially be used for watershed CEAM in the SSW, but it needs to be better coordinated and accessible from a single point. Approximately 60% of participants did not believe that data concerning water quality and quantity are available in an easily accessible, up-to-date and electronic format to industry, government and other watershed stakeholders (E2). Results were similar regarding the availability of spatial data of current and past land uses, disturbance and use patterns (E3). The majority of participants also did not believe that there was a coordinated approach to data collection and monitoring in the SSW (E1), or that there was consistency in monitoring standards for project proponents subject to impact assessment or other regulatory standards (E4). There were no significant differences between Alberta and Saskatchewan participants; however, private-sector participants were relatively neutral as to whether there is a coordinated approach to data collection/monitoring (E1; median = 5.0 ± 1.2), whereas government (median = 3.5 ± 0.8 ; $U = 210$, $p = 0.009$) and NGO (median = 3.0 ± 0.6 ; $U = 210$, $p = 0.009$) participants provided significantly lower assessments. Response patterns and differences between these three groups were similar concerning whether water quality and quantity data are easily accessible, up-to-date and available to all watershed stakeholders (E2; government, median = 3.0 ± 0.6 ; NGO, median = 3 ± 1.4 ; private sector, median 5.50 ± 1.2).

Vertical and horizontal linkages

There was little consensus regarding the state of vertical and horizontal linkages to support watershed CEAM (Table 9). For example, 35% of participants agreed that watershed management plans influence the terms and conditions for project developments in the watershed (median = 5.0 ± 0.8), and an equal percentage disagreed (F1). The response pattern was similar across indicators, with no clear consensus as to the status of vertical and horizontal linkages between and across watershed management plans and monitoring programs. There were no significant differences between Alberta and Saskatchewan

Table 9. Participant assessment of watershed cumulative effects assessment and management (CEAM) capacity indicators in the South Saskatchewan Watershed.^a

Requisites and indicator statements	Disagree.....Agree				Median	95% CI
	1-3	4-6	7-9			
A. Lead agency						
A1. Clear goals and priorities have been set for the watershed, including for future land use and overall watershed health.	37.9%	22.7%	39.4%	5.0		± 0.8
A2. There is an agency or group of agencies with a leadership role in the assessment and management of cumulative effects.	24.2%	30.3%	45.5%	6.0		± 0.8
A3. There is an agency or group of agencies with the ability (formal or informal) to influence decisions about land use and development decisions.	19.7%	31.8%	48.5%	6.0		± 0.8
A4. There is an agency or group of agencies with authority to implement and/or enforce regulations across the watershed to support CEAM.	25.7%	30.3%	44%	6.0		± 0.8
A5. There is an agency or group of agencies with authority to allocate resources to support CEAM initiatives (e.g. monitoring, data collection).	21.7%	27.3%	51%	6.5		± 0.4
B. Multi-stakeholder collaboration						
B1. There is a collaborative approach to setting goals and priorities for the watershed concerning land and water use and development.	39.1%	25%	36%	5.5		± 0.8
B2. Stakeholder roles and responsibilities (e.g. industry, watershed agencies, governments) with respect to CEAM and monitoring are clearly defined.	53.1%	25%	21.9%	3.0		± 0.8
B3. There is willingness amongst authorities to share data and to coordinate activities related to monitoring watershed conditions and managing effects.	32.8%	35.9%	31.3%	5.0		± 0.8
B4. Industrial proponents are willing to share their data (e.g. water quality, discharge, water use) with other industries and non-industry stakeholders.	39.1%	39.1%	21.9%	4.5		± 0.6
B5. Local communities are engaged in watershed planning, monitoring, environmental assessment and related decision-making processes.	43.7%	35.9%	20.3%	4.0		± 0.8
C. Watershed baselines, indicators and thresholds						
C1. There is adequate baseline data to identify past trends or changes in water quality across the watershed.	42.2%	31.3%	26.5%	4.0		± 1.0
C2. There is adequate baseline data to identify past trends or changes in water quantity/flow across the watershed.	25%	34.4%	40.6%	6.0		± 0.8
C3. There is adequate spatial baseline data to identify past land cover and land uses across the watershed.	23.4%	37.5%	39.1%	5.0		± 0.6
C4. There is agreement on the most appropriate indicators of watershed health.	43.8%	36%	20.3%	4.0		± 0.6
C5. There is a scientific understanding of thresholds (e.g. loadings, minimum flows, etc.) at which river system functions are no longer ecologically viable.	39.1%	26.5%	34.4%	4.0		± 0.8
D. Multi-scaled monitoring						
D1. Monitoring programs under regulatory-based environmental assessment provide an understanding of a project's effects on watershed processes.	34.9%	31.8%	33.3%	5.0		± 0.8
D2. There are requirements for the monitoring of river system conditions (e.g. water quality, flow, loadings) across the watershed.	22.2%	44.4%	33.3%	5.0		± 0.6
D3. Current monitoring programs provide a sound understanding of, and allow for detection of changes in, water quality conditions across the watershed.	54%	34.9%	11.1%	3.0		± 0.4
D4. Current monitoring provides a sound understanding of, and allows for detection of changes in, water quantity/flow conditions across the watershed.	41.3%	38.1%	20.6%	4.0		± 0.6
D5. Current monitoring provides a sound understanding of, and allows for detection of changes in, the dominant stressors to river system health (e.g. land use, disturbance patterns, discharge, etc.) across the watershed.	58.7%	28.8%	12.7%	3.0		± 0.6
E. Data management and coordination						
E1. Data collection/monitoring are coordinated so as to allow a standardized approach to the establishment of baseline conditions.	51%	38.7%	10.3%	3.5		± 0.6
E2. Water quality and quantity data are available in an accessible, up-to-date and electronic format to industry, government and all watershed stakeholders.	59.7%	24.2%	16.1%	3.0		± 0.6
E3. Spatial data on land uses, disturbance or use patterns are available in an easily accessible, up-to-date and electronic format to industry, government and all watershed stakeholders.	59.7%	32.3%	8.1%	3.0		± 0.6
E4. There is consistency in project monitoring standards and indicators (used under environmental impact assessment or similar regulations/permits) for projects affecting similar components or for projects of a similar class (e.g. pulp mills, metal mines, agriculture, etc.).	50%	38.7%	11.3%	3.5		± 0.6
E5. Data (water quality, quantity, land use) are quality controlled such that data gaps, uncertainties or assumptions are reported and known to data users.	46.8%	41.9%	11.3%	4.0		± 0.6

(Continued)

Table 9. (Continued).

Requisites and indicator statements	Disagree.....Agree			Median	95% CI
	1-3	4-6	7-9		
F. Vertical and horizontal linkages					
F1. Watershed or sub-watershed management plans influence the terms and conditions of project-specific environmental assessments.	35%	30%	35%	5.0	± 0.8
F2. Watershed or sub-watershed management plans influence policy and other decisions concerning land and water.	28.3%	36.6%	35%	5.0	± 0.8
F3. There is consistency in watershed management goals and objectives across sub-basins.	37.3%	42.4%	20.3%	5.0	± 0.6
F4. Results from project-specific monitoring are used to inform broader watershed assessment, evaluation and reporting processes.	35%	45%	20%	5.0	± 0.6
F5. Information generated from science programs or watershed monitoring and assessment is given due consideration in watershed management plans.	23.3%	45%	31.6%	5.0	± 0.6
G. Enabling legislation					
G1. There is sufficient legislation or other regulatory means to establish a watershed-based framework for CEAM.	21.3%	62.3%	16.4%	5.0	± 0.4
G2. The terms of reference for projects under regulatory-based environmental assessment provide clear direction for indicators in project monitoring.	47.5%	39.3%	13.1%	4.0	± 0.6
G3. There is sufficient legislation or regulatory means to ensure that results generated from state-of-the-watershed assessments (e.g. monitoring programs, science studies) influence decisions about land use and development.	47.5%	31.1%	21.3%	4.0	± 0.8
G4. Legislation and other regulatory instruments concerning land and water use are consistent across the watershed and between levels of government.	49.2%	27.9%	22.9%	4.0	± 1.0
G5. There is sufficient legislation or regulations to enable the protection of sensitive or vulnerable areas of the watershed from human disturbance.	39.3%	36.01%	24.6%	4.0	± 1.0
H. Financial and human resources					
H1. Scientific and technical expertise to develop and implement tools for CEAM is available, through government, the private sector or academia.	13.6%	20.3%	66.1%	8.0	± 0.6
H2. Funding is available for the development and implementation of source water protection plans and projects.	63.3%	21.7%	15%	3.0	± 0.6
H3. Financial resources are available at the provincial level to support watershed-based CEAM programs (i.e. data collection, reporting, enforcement).	60%	26.6%	13.3%	3.0	± 0.6
H4. Financial resources are available at the sub-watershed level to participate in watershed cumulative effects programs.	55%	33.3%	11.7%	3.0	± 0.8
H5. Education and training opportunities on CEAM tools and practice are available to government, watershed managers, land use planners and other stakeholders responsible for planning and assessment.	49.2%	32.2%	18.6%	3.5	± 0.6

Note: "Response scale of 1-9, where 1 = strongly disagree; 3 = somewhat disagree; 5 = neither agree nor disagree; 7 = somewhat agree; 9 = strongly agree; 2, 4, 6, 8 = intermediate responses. For ease of presentation, after completion of statistical analysis, response scale was condensed to three categories: disagree (1-3); neutral (4-6); agree (7-9).

participants; and no significant differences based on participant affiliation. An Alberta government participant reported that monitoring data have been used in the development of watershed management plans, but only when the science is known and shared. The participant went on to explain that this is often an ad hoc process with little consistency. In the Saskatchewan context, one government participant commented that watershed management plans could provide direction for project-specific impact assessments; however, additional effort in data collection and monitoring is necessary to understand the degree of impacts that may occur from a project and, as a result, there is little linkage between initiatives at the watershed scale and decisions about projects at the local scale, and vice versa.

Enabling legislation

Only 16% of participants agreed that there is sufficient legislation or other regulatory means to establish a watershed-based framework for CEAM (G1; Table 9). Further, more than 47% did not believe that the terms of reference developed for projects under regulatory-based EA provide clear direction for monitoring indicators (G2), that there was sufficient legislation to ensure that results generated from state-of-the-watershed assessments influence decisions about land use and development (G3), or that current legislation and other regulatory instruments concerning land and water use are consistent across the watershed and between different levels of government (G4). There were no significant differences between Alberta and Saskatchewan participants and, with the exception of indicator G3 ($H = 6.907$, $p = 0.032$), there were no differences based on participant affiliation. Median responses for government and private sector participants were 4.0 ± 0.8 and 5.0 ± 1 , respectively, whereas NGOs and participants from academia rated this criterion significantly lower (median = 2.0 ± 0.8). Several government participants reported that regulatory assessment in the SSW provides clear direction for cumulative effects, and that there is legislation and the regulatory means to ensure the protection of the most sensitive or vulnerable areas of the watershed. Other participants, from NGOs and academia, and a small number of private-sector participants, commented that legislation and regulatory means do exist, but there are limited resources or political desire to enforce the laws and regulations.

Financial and human resources

Participants indicated that the scientific and technical expertise to develop and implement tools for CEAM are available (H1, median = 8.0 ± 0.6), but there is a lack of funding for source water protection planning (H2), a lack

of financial support for watershed cumulative effects monitoring (H3), limited resources available to support local engagement in watershed CEAM programs (H4), and a lack of available training programs on CEAM tools and practices (H5; Table 9). There were no significant differences between Alberta and Saskatchewan participants on any of the indicators. There were also no differences based on participant's professional affiliation, with the exception of government participants ($\bar{x} = 5.95$; $H = 6.250$, $p = 0.044$) who were neutral in their response as to whether there existed sufficient scientific and professional expertise to support watershed CEAM (H1, median = 6.5 ± 0.8). Two government participants from Alberta reported that much of the necessary expertise is available for CEAM, particularly at the provincial level, but in limited amounts due to competing priorities elsewhere. Government participants from Saskatchewan similarly commented that expertise is available for CEAM, but it lacks the organization and financial resources to ensure implementation.

Discussion

Study participants characterized the SSW as a river system that was "healthy, but with problems." Cumulative effects were identified as a concern for water quality and quantity, particularly those effects associated with landscape disturbances, urban settlement, water withdrawals and diversions, pipelines and river crossings, agricultural runoff and climate change. The perceived sources of cumulative effects to the SSW were not surprising (Pomeroy et al. 2005; Schindler and Donahue 2006; Seitz et al. 2011). The problem is that regulatory EA is currently the *de facto* instrument for assessing and managing cumulative effects in the SSW – an instrument which is narrowly focused on individual project developments (Quinn et al. 2004). Further, the majority of threats to the SSW identified by participants are either not included within the scope of regulatory assessment (e.g. agricultural operations), or are considered too small (e.g. pipelines and river crossings), individually, to trigger EA processes (Noble et al. 2011).

The need for watershed-based CEAM has been well argued (e.g. Reid 1993; Schindler and Donahue 2006; Kilgour et al. 2007; Squires and Dubé 2013), and is broadly supported by stakeholders in the SSW (Noble et al. 2011). Building the capacity to implement and sustain watershed CEAM, however, is a complex and multi-dimensional challenge; focusing narrowly on one aspect only (e.g. data or monitoring) may prove to be ineffective if other aspects are neglected or overlooked (Ivey et al. 2002). The results of this research showed that stakeholders believed current capacity to be lacking, or limited, across most requisites and indicators – perhaps

with the exception of the available scientific and technical expertise for CEAM (Table 9).

The highest ranked requisites by study participants may be considered the fundamental requirements for developing CEAM programs, namely multi-stakeholder collaboration, leadership, and financial and human resources. These requisites were closely followed by several means requirements for CEAM implementation and ongoing operations, including baseline data and indicators, enabling legislation, and data management and coordination. All eight requisites proposed by Sheelanere et al. (2013) for watershed CEAM are important to its success (Kristensen 2013; Noble et al. 2014), but the results of this study suggest several priority needs for watershed CEAM in the SSW context. These are needs that reach beyond simply “more data” or “more monitoring,” and illustrate that not all of the requisites for watershed CEAM are independent. Each of these is discussed briefly below.

Ensuring collaboration without compromising leadership

A major challenge to CEAM is ensuring collaboration amongst proponents, regulatory agencies and watershed stakeholder groups regarding the monitoring, mitigation and management of cumulative effects (Canter and Ross 2010). Multi-stakeholder collaboration is necessary as CEAM is beyond the responsibility of any single land user or development proponent (Connelly 2011), and cumulative effects require solutions that involve the combined actions of multiple stakeholders (Therivel and Ross 2007). Study participants identified multi-stakeholder collaboration as one of the most important requisites for CEAM in the SSW (Table 8). This was not surprising – particularly in Alberta, given its experience with the Cumulative Environmental Management Association (www.cemaonline.ca) and the Regional Aquatics Monitoring Program (www.ramp-alberta.org), and given the wealth of literature in recent years emphasizing the need for collaborative approaches to water governance.

However, without an agency or group of agencies with a mandate to implement watershed CEAM programs and the authority to enforce impact management and monitoring requirements, there is likely to be little direct influence of watershed CEAM on regulatory decisions about land and water use allocation (Creasey 2002; Noble et al. 2011). Qualitative feedback from study participants indicated that individual or collaborative efforts by various organizations to advance CEAM in the SSW serve only to raise awareness in the absence of a lead agency with a clear mandate by the province(s) to address cumulative effects at the watershed scale. There are clearly benefits from increased awareness and

multi-stakeholder engagement in CEAM (Therivel and Ross 2007; Canter and Ross 2010); however, key regulatory decision making on CEAM issues affecting watersheds, particularly for those decisions that concern land-use plans, project licensing, and water withdrawals, rests with governments.

Watershed CEAM in the SSW, and generally, cannot be driven solely from the bottom up, and government(s) must lead watershed CEAM activities. Sheelanere et al. (2013) and Seitz et al. (2011) argue that provincial government agencies, or a government-led consortium, must serve as the lead agency to oversee, and ensure the proper resourcing of all aspects of, watershed CEAM, since only government has the regulatory authority to allocate resources and ensure implementation and compliance. Results from this research indicate that leadership for CEAM in the SSW is poorly defined, that watershed CEAM has not been within the purview of provincial or regulatory authorities, and that there is a need to reassess current institutional arrangements to ensure leadership for watershed CEAM and for watershed planning and management generally (see Carter et al. 2005; Noble et al. 2011).

Tiering and influence

Participants identified vertical and horizontal linkages as the least significant of the eight requisites for ensuring successful watershed CEAM (Table 8), and there was considerable variability in the assessments of its key indicators (Table 9). Opinions were diverse as to whether there was consistency across sub-watershed objectives or monitoring programs, and whether watershed monitoring programs or sub-watershed management plans influence the terms and conditions of project-specific EAs. The relatively lower importance assigned to vertical and a horizontal linkage is not consistent with recent CEAM literature (Kilgour et al. 2007; Magee and Carroll 2006; Kristensen et al. 2013); neither is it consistent with recent assessments of the state of practice in the SSW (Noble et al. 2011; Ball et al. 2013a). Vertical linkages in particular, or tiering, are essential if watershed CEAM is to influence decision making about land and water use and development proposals (Magee and Carroll 2006; Noble 2008; Conservation Ontario 2012). Magee and Carroll (2006) explain that broad-scale CEAM provides the context for land-use plans in relation to the broader region and to each other, and support the establishment of relative priorities for monitoring and management within the region. The result, explain Magee and Carroll (2006, 218), is that a tiered approach “can begin a systematic process of stepping down science findings through finer-scaled assessments that inform equivalent levels of planning a decision making.” Ball et al. (2013a) report that the lack of such a tiered approach,

providing guidance for project developers, is a major constraint to understanding and successfully mitigating cumulative effects in the SSW.

Ensuring influence through tiered assessment is a challenging task. There have been several watershed CEAM programs initiated across Canada, but there is often no one to tell about the results and limited ability to influence lower-level decisions or actions (Parkins 2011; Sheelanere et al. 2013). Participants were relatively neutral as to whether there is sufficient legislation or other regulatory means for CEAM in the SSW (Table 9, G1); however, supporting legislation is necessary to ensure that specific CEAM procedural obligations are followed (Gibson et al. 2010). There are concerns that legislated CEAM may be too rigid to accommodate the diversity of watershed contexts and CEAM needs, but a strictly policy-based approach or approach grounded solely in multi-stakeholder collaboration does not provide authoritative guidance for legally specified project-level assessments and decisions. A combined law- and policy-based approach may be best for ensuring watershed CEAM influence, where the core process and substantive requirements for CEAM (e.g. responsibilities, input to terms of reference, data sharing) are set out in legislation with more flexible requirements, expectations and guidance (e.g. specific indicators) provided through policy-based instruments (Gibson et al. 2010).

Coordination of monitoring and assessment programs

A result of the lack of tiering and leadership in watershed CEAM is the limited coordination of watershed monitoring and assessment programs. Study participants indicated that current monitoring programs do not provide for a sufficient understanding of, or allow for detection of changes in, water quality, water quantity or the dominant stressors to river system health across the SSW (Table 9, D3–5). This is not surprising; all CEAM programs need more monitoring and more data. However, more monitoring and more data are of limited value to watershed CEAM if there is no coordination and consistency in monitoring programs, indicator use and data reporting, and if those data are not readily available to data users. Study participants assessed data management and coordination as the weakest of the eight watershed CEAM requisites (Table 9, E1–5), including consensus on the most appropriate indicators for CEAM.

In their review of regulatory environmental assessment in the SSW, Ball et al. (2013a) examined a sample of 35 project impact statements that assessed potential impacts to the aquatic environment, and found projects falling under the same regulatory authority and affecting the same aquatic components having no consistency in the indicators used for assessment and monitoring. Nearly half of the participants in this study also did not

believe that the terms of reference for projects under regulatory-based environmental assessment provide such direction (Table 9, G2). This is not so much poor practice on behalf of the project proponents, but rather poor strategic oversight and coordination of monitoring programs and data. At a minimum, there is need for watershed CEAM to result in terms of reference for individual development projects or sub-watershed monitoring programs so as to provide clear direction on indicators and actions that support CEAM (Canter and Ross 2010). Ball et al. (2013a) suggest the identification of a few, ecologically based parameters that are useful for understanding cumulative effects at multiple scales and across projects, which may be watershed specific, but they must be non-negotiable for land or water users seeking development authorizations in those watersheds, and must be a mandatory part of monitoring and reporting programs.

Exacerbating data challenges is the fact that the data required for watershed CEAM, including data on land use, water quality and quantity, when collected, are not easily accessible. Many watershed stakeholders, particularly industry, were said to be unwilling to share their data. This is not unique to watershed CEAM or to the SSW (Kilgour et al. 2007; Seitz et al. 2011). The viability of a watershed-based approach requires that both land use (i.e. spatial) and water (i.e. quality/quantity) data are available to stakeholders and data end users (Piper 2000; Squires et al. 2010). Aquatic data in Canada's watersheds is collected, managed and assessed by different jurisdictions and by different programs within each jurisdiction, which has resulted in fragmentation, a lack of consistency and limited data access (Dubé 2003). Environment Canada's national water data archive, HYDAT, is publicly available but is not spatially comprehensive and does not house spatial land-use data. Sheelanere et al. (2013), Ball et al. (2013b) and Conservation Ontario (2012) suggest that a centrally managed information repository is needed to support watershed CEAM, and that shared accessibility and standardized data are essential. The EU water framework is one example, where data and information on water are reported to the European Environment Agency through the EuroWater-net information system – although based on voluntary participation (Water Framework Directive [WFD] 2001). Such a framework could serve to ensure that data collected for assessment and management actions and decisions at one scale (e.g. local project developments) are useful for river system and watershed monitoring, planning and management, and vice versa.

Resourcing and commitment

Long-term investments in watershed science (e.g. monitoring and assessment) and land-use planning (e.g. landscape modeling) are necessary to support watershed

CEAM (Ivey et al. 2002; Parkins 2011; Sheelanere et al. 2013). However, more than half of the participants in this study identified a lack of financial resources to implement and sustain WCEA programs in the SSW, particularly monitoring programs, reporting, enforcement and source water protection planning. Available scientific and technical expertise was not identified as a capacity constraint, but available education and training programs on CEAM tools and practice were identified as limited.

Securing long-term financial resources to support CEAM programs is an enduring challenge, since the lifespan of such programs must outlast the political commitments of elected governments (Noble 2008). However, Parkins (2011, 20) describes CEAM programs to date, supported largely by government-based research programs, as “short-term bursts of activity” and “short-lived organizational commitments” that come up short in meeting the demands and expectations for CEAM.

The results of this study, combined with lessons learned to date from CEAM initiatives elsewhere, suggest the need to pursue alternative means to ensure the long-term viability of watershed CEAM. Specifically, there is a need to explore the potential for introducing data access user fees for industrial proponents when filing applications for development in a watershed, and whether unloading from individual project proponents some of the responsibility for assessing cumulative effects may offset such fees. Other options may include increased water customer rates to offset the costs of protecting source water supplies (Timmer et al. 2007), or the creation of an arm’s-length foundation, housed at universities and supported by government and industry, taking advantage of the economies of scale of university-led research programs, playing a leadership role in data management and distribution.

Conclusion

Over the past 15 years, efforts to advance watershed CEAM initiatives in Canada have achieved only mixed success across a range of jurisdictions (Dubé et al. 2006; Schindler and Donahue 2006; Noble et al. 2011). Several studies have focused on capacity building and institutional arrangements for watershed management or source water protection (de Loë et al. 2002; Ivey et al. 2006; Heathcote 2009); however, notwithstanding advances in watershed CEAM science and increasing demands for watershed based approaches to CEAM (Culp et al. 2000; Schindler and Donahue 2006; Seitz et al. 2011), there is limited understanding of the institutional arrangements and capacity needs to implement and sustain watershed CEAM. This paper proposed a suite of indicators for the systematic and quantitative evaluation of the capacity to implement and sustain watershed CEAM. In addition to

identifying current capacity, and capacity needs, for CEAM in the SSW, the indicators are broadly applicable for the rapid assessment of watershed CEAM capacity conditions and needs in other regions.

The results of this research suggest the need for considerable capacity building across all requisites if watershed CEAM is to advance and be sustained in the SSW. The primary tool for assessing and managing the cumulative effects in the SSW is currently project-based EA; however, the primary threats to water quality and quantity were identified as broad-scale stress (e.g. agricultural runoff, effluent, urban settlement), the majority of which are not subject to project-specific EA regulations. Building capacity to ensure successful watershed CEAM requires more than collaborative efforts and more data, important though they are; it also requires leadership, the legislated or regulatory means to ensure that watershed efforts actually influence land and water use and allocation decisions, the coordination of data and provision of specific guidance to monitoring programs, and long-term financial investment. As the pressures of human development on Canada’s watersheds continue to increase, there is a need to further test the requisites and indicators identified in this study in other watersheds, so as to identify areas of common capacity constraints and opportunities for knowledge and resource sharing.

Acknowledgements

This research was funded by the Social Sciences and Humanities Research Council of Canada, Canadian Environmental Issues Grant – Institutional Arrangements for Watershed Cumulative Effects Assessment and Management. We wish to acknowledge the valuable contribution of the study participants.

References

- Ball, M., B. F. Noble, and M. Dubé. 2013a. Scaling-up valued ecosystem components for watershed cumulative effects assessment: An analysis of environmental impact assessment practice in the South Saskatchewan River watershed, Canada. *Integrated Environmental Assessment and Management* 9(3): 469–479.
- Ball, M. A., G. Somers, J. E. Wilson, R. Tanna, C. Chung, D. Duro, and N. Seitz. 2013b. Scale, assessment components, and reference conditions: Issues for cumulative effects assessment in Canadian watersheds. *Integrated Environmental Assessment and Management* 9(3): 370–379.
- Baxter, W., W. Ross, and H. Spaling. 2001. Improving the practice of cumulative effects assessment in Canada. *Impact Assessment and Project Appraisal* 19(4): 253–262.
- Braat, T. 2002. *Regional cumulative effects management framework for Cold Lake, Alberta*. Ottawa, ON: Canadian Environmental Assessment Agency.
- Brinson, M. M., and S. D. Eckles. 2011. US Department of Agriculture conservation program and practice effects on wetland ecosystem services: a synthesis. *Ecological Applications* 21(Suppl. 1): S116–S127.

- Bruneau, J., D. R. Corkal, E. Pietroniro, B. Toth, and G. van der Kamp. 2009. Human activities and water use in the South Saskatchewan River basin. *Prairie Forum* 34: 129–152.
- Canter, L., and F. Atkinson. 2011. Multiple uses of indicators and indices in cumulative effects assessment and management. *Environmental Impact Assessment Review* 31(5): 491–501.
- Canter, L., and B. Ross. 2010. State of practice of cumulative effects assessment and management: The good, the bad and the ugly. *Impact Assessment and Project Appraisal* 28(4): 261–268.
- Carter, N., R. D. Kreutzwiiser, and R. de Loë. 2005. Closing the circle: Linking land use planning and water management at the local level. *Land Use Policy* 22: 115–127.
- Chilima, J., J. Gunn, B. F. Noble, and R. Patrick. 2013. Institutional considerations in watershed-scale cumulative effects assessment. *Impact Assessment and Project Appraisal* 31 (1): 74–84.
- Cohen, J. 1988. *Statistical power analysis for the behavioral sciences*. 2nd ed. Hillside, NJ: Lawrence Erlbaum Associates.
- Connelly, R. 2011. Canadian and international EIA frameworks as they apply to cumulative effects. *Environmental Impact Assessment Review* 31: 453–456.
- Conservation Ontario. 2012. *Integrated watershed management: Navigating Ontario's future*. Newmarket, ON: Conservation Ontario.
- Creasey, R. 2002. Moving from project-based cumulative effects assessment to regional environmental management. In *Cumulative effects assessment in Canada: From concept to practice*, ed. A. Kennedy, 3–16. Calgary, AB: Alberta Society of Professional Biologists.
- Culp, J., K. Cash, and F. Wrona. 2000. Cumulative effects assessment for the Northern River Basins Study. *Journal of Aquatic Ecosystem Stress and Recovery* 8: 87–94.
- Davies, H., and P. T. Hanley. 2010. *2010 state of the watershed report*. Regina, SK: Saskatchewan Watershed Authority.
- de Loë, R., D. Di Giantomasso, and R. Kreutzwiiser. 2002. Local capacity for groundwater protection in Ontario. *Environmental Management* 29: 217–233.
- de Loë, R., and R. Kreutzwiiser. 2005. Closing the groundwater protection implementation gap. *GeoForum* 36(2): 241–256.
- Dubé, M. 2003. Cumulative effect assessment in Canada: A regional framework for aquatic ecosystems. *Environmental Impact Assessment Review* 23: 723–745.
- Dubé, M., B. Johnson, G. Dunn, J. Culp, K. Cash, K. Munkittrick, I. Wong, et al. 2006. Development of a new approach to cumulative effects assessment: A northern river ecosystem. *Environmental Monitoring and Assessment* 113: 87–115.
- Dubé, M. G., and K. Munkittrick. 2001. Integration of effects-based and stressor-based approaches into a holistic framework for cumulative effects assessment in aquatic ecosystems. *Human Ecological Risk Assessment* 7: 247–258.
- Duinker, P., and L. Greig. 2006. The impotence of cumulative effects assessment in Canada: Ailments and ideas for reemployment. *Environmental Management* 37(2): 153–161.
- Environment Canada. 2010. Integrated watershed management. <http://www.ec.gc.ca/eau-water/default.asp?lang1/4en&n1/413D23813-1> (accessed October, 2014).
- Environment Canada. 2011. National Environmental Effects Monitoring Office. <http://www.ec.gc.ca/esee-eem/default.asp?lang1/4En&n1/4453D78FC-1> (accessed October, 2014).
- Gerard, P. D., D. R. Smith, and G. Weerakkody. 1998. Limits of retrospective power analysis. *The Journal of Wildlife Management* 62(2): 801–807.
- Gibson, R., H. Benevides, D. Meinhard, and D. Kirchhoff. 2010. Strengthening strategic environmental assessment in Canada: An evaluation of three basic options. *Journal of Environmental Law and Practice* 20(3): 175–211.
- Griffiths, A., E. McCoy, J. Green, and G. Hegmann. 1998. *Cumulative effects assessment: Current practices and future options*. Calgary, AB: Macleod Institute.
- Grindle, M. S., and M. E. Hilderbrand. 1995. Building sustainable capacity in the public sector: What can be done? *Public Administration Development* 15: 441–463.
- Heathcote, I. W. 2009. *Integrated watershed management: Principles and practice*. New York, NY: John Wiley and Sons.
- Hoenig, J., and D. Heisey. 2001. The abuse of power: The pervasive fallacy of power calculations for data analysis. *The American Statistician* 55(1): 19–24.
- Ivey, J. L., R. de Loë, and R. Kreutzwiiser. 2002. Groundwater management by watershed agencies: An evaluation of the capacity of Ontario's conservation authorities. *Journal of Environmental Management* 64: 311–331.
- Ivey, J. L., R. de Loë, R. Kreutzwiiser, and C. Ferreyra. 2006. An institutional perspective on local capacity for source water protection. *Geoforum* 37: 944–957.
- Kennett, S. 2002. Lessons from Cheviot: Redefining government's role in cumulative effects assessment. In *Cumulative effects assessment in Canada: From concept to practice*, ed. A. Kennedy, 17–29. Calgary, AB: Alberta Society of Professional Biologists.
- Kilgour, B., M. Dubé, K. Hedley, C. Portt, and K. Munkittrick. 2007. Aquatic environmental effects monitoring guidance for environmental assessment practitioners. *Environmental Monitoring and Assessment* 130: 423–436.
- Kristensen, S., B. F. Noble, and R. J. Patrick. 2013. Capacity for watershed cumulative effects assessment and management: Lessons from the Lower Fraser River Basin. *Canada. Environmental Management* 52(2): 360–373.
- Krzywinski, M., and N. Altman. 2014. Points of significance: Visualizing samples with box plots. *Nature Methods* 11: 119–120.
- Magee, J., and P. Carroll. 2006. Using tiered assessments to focus land use plans and management investments on the highest priorities. *Environmental Practice* 8(4): 218–227.
- Munkittrick, K., M. McMaster, G. Van Der Kraak, C. Portt, W. Gibbons, A. Farwell, and M. Gray. 2000. *Development of methods for effects-driven cumulative effects assessment using fish populations: Moose River project*. Pensacola, Florida: Society of Environmental Toxicology and Chemistry.
- Noble, B. F. 2008. Strategic approaches to regional cumulative effects assessment: A case study of the Great Sand Hills. *Canada. Impact Assessment and Project Appraisal* 26(2): 78–90.
- Noble, B. F., P. Sheelanere, and R. Patrick. 2011. Advancing watershed cumulative effects assessment and management: Lessons from the South Saskatchewan River watershed. *Journal of Environmental Assessment Policy and Management* 13(4): 1–23.
- Noble, B. F., J. Skwaruk, and R. Patrick. 2014. Toward cumulative effects assessment and management in the Athabasca watershed. *Canada. The Canadian Geographer* 58(3): 315–328.
- Nunnally, J. 1978. *Psychometric theory*. New York, NY: McGraw-Hill.
- Oegema, B. 2012. South Saskatchewan River. In *The Encyclopedia of Saskatchewan*. http://esask.uregina.ca/entry/south_saskatchewan_river.html. Regina, SK: Canada Plains Research Centre.

- O'Keefe, D. J. 2007. Post hoc power, observed power, a priori power, retrospective power, prospective power, achieved power: Sorting out appropriate use of statistical power analyses. *Communication Methods and Measures* 1(4): 291–299.
- Parker, S., and C. Cocklin. 1993. The use of geographical information systems for cumulative environmental effects assessment. *Computers, Environment and Urban Systems* 17: 393–407.
- Parkins, J. R. 2011. Deliberative democracy, institution building, and the pragmatics of cumulative effects assessment. *Ecology and Society* 16(3): 20.
- Partners for the Saskatchewan River Basin. 2009. *Summary of the state of the Saskatchewan River Basin*. Saskatoon, SK: Partners for the Saskatchewan River Basin.
- Peterson, E. B., Y. H. Chan, N. M. Peterson, G. A. Constalbe, R. B. Caton, C. S. Davis, R. R. Wallace, and G. A. Yarranton. 1987. *Cumulative effects assessment in Canada: An agenda for action and research*. Hull, QC: Canadian Environmental Assessment Research Council.
- Piper, J. M. 2000. Cumulative effects assessment on the middle Humber: Barriers overcome, benefits derived. *Journal of Environmental Planning and Management* 43(3): 369–387.
- Pomeroy, J. W., D. de Boer, and L. W. Martz. 2005. *Hydrology and water resources of Saskatchewan*. Saskatoon, SK: Centre for Hydrology.
- Quinn, M. S., G. Greenaway, D. Duke, and T. Lee. 2004. *A collaborative approach to assessing regional cumulative effects in the trans-boundary crown of the continent*. Ottawa, ON: Canadian Environmental Assessment Agency.
- Reid, L. M. 1993. Research and cumulative watershed effects. General Technical Report. GTR 141. Albany, CA: Forest Service, US Department of Agriculture.
- Reid, L. M. 1998. Cumulative watershed effects and watershed analysis. In *River ecology and management: Lessons from the Pacific coastal ecoregion*, ed. R. J. Naiman, and R. E. Bilby, 476–501. New York: Springer-Verlag.
- Reid, L. M. 2010. *Understanding and evaluating cumulative watershed impacts*. RMRS-GTR-231. Albany, CA: Forest Service, US Department of Agriculture.
- Robins, L. 2008. Making capacity building meaningful: A framework for strategic action. *Environmental Management* 42: 833–846.
- Saaty, T. 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology* 15: 243–281.
- Scherer, R. 2011. Cumulative effects: A primer for watershed managers. *Streamline, Watershed Management Bulletin* 14 (2): 14–20.
- Schindler, D., and W. Donahue. 2006. An impending water crisis in Canada's western prairie provinces. *Proceedings of the National Academy of Science of the United States* 103: 7210–7216.
- Seitz, N., C. Westbrook, and B. F. Noble. 2011. Bringing science into river systems cumulative effects assessment practice. *Environmental Impact Assessment Review* 31(3): 172–179.
- Sheelanere, P., B. F. Noble, and R. Patrick. 2013. Institutional requirements for watershed cumulative effects assessment and management: Lessons from a Canadian trans-boundary watershed. *Land Use Policy* 30: 67–75.
- Squires, A., and M. Dubé. 2013. Development of an effects-based approach for watershed scale aquatic cumulative effects assessment. *Integrated Environmental Assessment and Management* 9(3): 380–391.
- Squires, A., C. Westbrook, and M. Dubé. 2010. An approach for assessing cumulative effects in a model river, the Athabasca River Basin. *Integrated Environmental Assessment and Management* 6(1): 119–134.
- Therivel, R., and W. Ross. 2007. Cumulative effects assessment: Does scale matter? *Environmental Impact Assessment Review* 27: 365–385.
- Timmer, D. K., R. de Loe, and R. Kreutzweiser. 2007. Source water protection in the Annapolis Valley, Nova Scotia: Lessons for building local capacity. *Land Use Policy* 24: 187–198.
- United States Environmental Protection Agency (US EPA). 1998. *Guidance on implementing the capacity development provisions of the Safe Drinking Water Act amendments of 1996*. Washington, DC: US EPA, Office of Water.
- Valentine, G. 2005. Tell me about using interviews as a research methodology. In *Methods in human geography*, eds. R. Flowerdew and D. Martin, 110–126. London, UK: Pearson Education Limited.
- Warachan, B. 2011. Appropriate statistical analysis for two independent groups of Likert-type data. PhD thesis in Mathematics, American University: Washington, DC.
- Water Framework Directive (WFD). 2001. *Common implementation strategy for the Water Framework Directive 2001*. Strategic Document as Agreed By The Water Directors Under Swedish Presidency 2 May 2001.
- Zhao, M., D. R. Becker, and M. A. Kilgore. 2009. Assessing cumulative impacts within state environmental review frameworks in the United States. *Environmental Impact Assessment Review* 29: 390–398.