ASSESSING SUSTAINABLE REMEDIATION FRAMEWORKS USING SUSTAINABILITY DISCOURSE

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This is dedicated to the memory of Mark Kroeker.
September 21, 1989 - May 11, 2014

He left his thesis unfinished.
So I finished mine for him.

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Abstract

The remediation industry has grown exponentially in recent decades. International organizations of practitioners and remediation experts have developed several frameworks for integrating sustainability into remediation projects; however, there is no accepted definition or universal framework for sustainable remediation. Literature on sustainable remediation is only recently beginning to emerge, and there has been limited attention to how sustainability is best-integrated and operationalized in sustainable remediation frameworks and practices – or whether sustainability plays any meaningful role at all in sustainable remediation. This thesis examines the role of ‘sustainability’ in recently emerging sustainable remediation frameworks. More specifically, it presents the results of an analysis of how sustainability is defined, integrated and operationalized in sustainable remediation frameworks. Methods are based on a review of a sample of six leading remediation frameworks against a set of normative principles and criteria for sustainability integration adapted from sustainability assessments. Recommendations are made for improving the integration of sustainability in sustainable remediation frameworks, and how to better operationalize sustainability practices.

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List of Abbreviations

ASTM	American Society for Testing & Materials
BMPs	Best Management Practices
BR	Brownfield Revitalization
CSM	Conceptual Site Model
EIA	Environmental Impact Assessment
FCSAP	Federal Contaminated Sites Action Plan (Canada)
GHGs	Greenhouse Gases
GR	Green Remediation
GSR	Green Sustainable Remediation
LCA	Life Cycle Assessment
RPO	Remedial Process Optimization
SBMPs	Sustainable Best Management Practices
SCSM	Sustainable Conceptual Site Model
SDT	Sustainable Development Tool
SR	Sustainable Remediation
SuRF-UK	Sustainable Remediation Forum-United Kingdom
SuRF-US	Sustainable Remediation Forum-United States of America
US EPA	United States Environmental Protection Agency
WGSR	Wisconsin's Green Sustainable Remediation Framework

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Chapter 1
Introduction

The impacts of natural resource development on the environment, economies and communities are often intertwined, complex, long-term and long lasting. Industrial impacts are present from the start of resource development initiatives, lasting throughout the project life cycle and post-operation. The majority of environmental assessment's attention on the life cycle of natural resource development has focused on pre-development impacts and impacts within the immediate vicinity of a project, with much less attention to the effects that persist post-project operation (Morrison-Saunders and Arts, 2004; Laurence, 2006; Tukker, 2000). Currently in Canada, for example, there are over 21,000 sites listed as contaminated due to some form of industrial land use (Government of Canada, 2014). There are an estimated 294,000 sites listed in the United States, and over 300,000 ha of known industrial contaminated sites in United Kingdom (Hou and Al-Tabbaa, 2014). As resource extraction and development expand into new geographic regions, generating both positive and adverse impacts to environments and local communities (Noble and Hanna, 2015), there is need for greater attention to the full life cycle of impact assessment practice including the decommissioning and remediation of project development sites (McHaina, 2001; Camenzuli et al., 2013).

The remediation industry was born at around the time of the US National Environmental Policy Act in 1969, following highly publicized discoveries of contaminated sites in America, such as the 1969 Cuyahoga River Fire in Ohio (Ellis and Hadley, 2009; Ohio History, 2005). Since then, internationally, the remediation industry has grown to an estimated worth of over $30 billion (Industry Canada, 2012). With multiple levels of government emphasizing the importance of remediation activities of both active and abandoned sites as part of growing commitments to sustainable resource development (Government of British Columbia, 2009; Environment Canada, 2012; United States Environmental Protection Agency, 2014), the remediation industry continues to grow nationally and on an international scale.

The remediation industry can be characterized as the end cycle of resource extraction projects. Remediation or reclamation often includes decommissioning, which involves a cessation of all activities and physical dismantling of the plant and associated infrastructure. Remediation is broadly defined as the process of reducing environmental contamination to safe levels within the ecosystem, protecting human health, and restoring hydrological functions in the surrounding environment (Environment Canada, 2012; Diamond et al., 1999). Reclamation is the process of restoring the soil, aquatic environment, and vegetation in an area that was previously disturbed (Oil Sands Alberta, 2013). In practice, remediation is commonly referred to the decontamination of impacted media, where as reclamation equates to restoring previously disrupted functions. Both processes are often referred to simply as remediation and the terms often used interchangeably in an international context; however, remediation will be the term adopted in this research and is the process of interest. There are different types of remediation technologies: phytoremediation, dig and dump, soil washing, and other biological, physical, and chemical remediation (Ellis and Hadley, 2009). Historically, 'dig and dump' involved hauling contaminated materials away from the site to a treatment facility or storage; this process is associated with large impacts. This is due to the large machinery, large areas of land, and significant travel to safe storage. *In-situ* remedial work is becoming more commonplace as it is associated with lower GHG emissions (Ellis and Hadley, 2009). *In-situ* or bioremediation often requires less energy but may be technologically expensive (Ellis and Hadley, 2009; Diamond et al., 1999).

Notwithstanding the recognized linkages between environmental and social and economic impacts, the majority of attention in remediation literature and practice has focused on the biophysical environment (e.g. Ellis and Hadley, 2009; Favara et al., 2011; Fortuna et al., 2011). Relatively less consideration has been given to the inclusion of socio-economic factors in the remediation process, and in recent remediation guidance, resulting in the underutilization of socio-economic indicators in remediation practice (Bardos et al., 2009; Bardos et al., 2011). In recent years, remediation practitioners globally have joined forces to create international organizations that are dedicated to *sustainable* remediation practices. The Sustainable Remediation Forum (SuRF), for example, created in 2006, now has organizations in the USA, Canada, the UK, the Netherlands, Italy, China, New Zealand and Australia (see, surfanz.com.au).

These SuRF organizations promote sustainable practices in remediation; however, what characterizes or defines *sustainable* remediation (SR) is variably defined. Sustainable remediation is defined by the SURF USA as a remedy or combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources (Ellis and Hadley, 2009). The SURF UK defines sustainable remediation as a process based on sustainable development principles, as defined by the Brundtland Report, and incorporates transparency of decision-making processes with balanced outcomes for social, economic and environmental realms (Bardos et al., 2011; United Nations, 1987). The mandate of SURF Canada (2011) is to ensure consideration of the three dimensions of sustainability (social, economic and environment) in decision-making for the rehabilitation and management of contaminated sites. Other differences in definitions between organizations are also evident: for example, SURF USA focuses on the limited use of non-renewable resources; whereas, SURF UK emphasizes the inclusion of social, economic and environmental factors as its most basic practice (Bardos et al., 2011).

The adoption of sustainability in remediation may be good intentioned, with practitioners leading the way in SR research and industry adopting SR practices. Many SuRF publications, however, note the discrepancies between SR frameworks and the lack of agreement or universal acceptance of SR principles. Sometimes adding the sustainability label to a policy framework, guidance document, or even a product, can be a tactic to market better business practices, to procure contracts, or to boost corporate image (Darnall and Aragon-Correa, 2014; GreenBiz.com, 2011; Hou, Al-Tabbaa, and Guthrie, 2014). Trust and believing the efficacy is a major barrier with eco-labeled products and services (Darnall and Aragon-Correa, 2014). As the SR industry continues to grow, there is a need to critically examine and understand the adoption, integration and use of sustainability in SR frameworks if sustainability is to have any real influence toward an effective remediation industry.

1.1 Research Purpose and Objectives

The overall purpose of this research is to critically examine the role of sustainability in SR frameworks, with particular emphasis on the consideration of social and economic factors in remediation. This will be achieved based on the development of a normative (as in ideal) framework of sustainability principles and the application of those principles to examine a set of international remediation frameworks. Specifically, the three objectives of this research are:

1. To examine how sustainability is integrated into remediation frameworks.
2. To examine how sustainability is operationalized in remediation frameworks.
3. To make recommendations to improve the integration of sustainability into remediation frameworks and practice.

This thesis is presented in six chapters. Chapter 2 presents a review of sustainability remediation literature, and the major sustainability principles that influenced the review criteria adopted in this research. The research methods, including a brief description of each of the six remediation frameworks examined, and the criteria used for examining those frameworks, are described in Chapter 3. Chapter 4 presents the results of the framework evaluations, the significance of which are then discussed in Chapter 5. The thesis concludes with Chapter 6, which outlines recommendations for improving the use of sustainability in remediation frameworks and practices.

Chapter 2
Literature Review

This chapter reviews the present state of research and practice of remediation. First, the nature of remediation and sustainability remediation are introduced, including a discussion of the sustainable remediation forum (SuRF). This is followed by a review of major sustainability principles found in recent literature, which are important to understanding and advancing sustainability in remediation frameworks and practices.

2.1 Remediation

In most jurisdictions in Canada, laws require some form of site or land remediation following industrial use. In Saskatchewan, under the *Environmental Management and Protection Act, 2002* anyone who contaminates land must take all reasonable measures to remedy it. In Alberta, for example, project owners must clean up contaminated lands on which their projects or operations were located, and “return the land to a functionally equivalent state” that existed prior to development (Alberta Energy Board, 2014). Similarly, Manitoba legislation requires remediation or **“**the management of a contaminated site or an impacted site in order to prevent, minimize or mitigate damage to human health or the environment or to restore all or part of the site to a useful purpose” (Manitoba Government Legislation, “Contaminated Sites Remediation Act”, 2014). Such remediation activities are typically done separately from the initial project development environmental assessment or licensing processes carried out to assess the project’s impacts and secure development authorizations. However, federally, under the Canadian Environmental Assessment Act, certain decommissioning and abandonment of designated development-related infrastructure may require an additional environmental assessment (Minister of Justice, 2013). The ‘end-life-cycle’ assessment is thus often separate from the initial project approval assessment, or ‘early-life cycle’. This approach to project licensing and post-project impact management often separates the management of industrial development into separate industries – pre-project impact assessment, and post-project reclamation. As such, in neither stage of project assessment is the whole life-cycle of impacts fully considered.

Private companies are often the responsible parties for cleanups (Government of Canada, 2014). However, in the event that contaminated land is abandoned, such as legacy sites, or if land is owned or leased by government, then the appropriate government jurisdiction is responsible for remediation activities (Government of Canada, 2014). Often industrial sites can be large, complex, expensive, and have a suite of impacts associated with cleanup activities (Cundy et al., 2013; Hou and Al-Tabbaa, 2014). For example, a remediation project in New Jersey was estimated to have potentially emitted 2.7 million tonnes of CO_2, should a traditional remediation method of dig and dump been used (Hou and Al-Tabbaa, 2014). Accounting for secondary impacts, or the impacts due to site remediation itself, is a major driver for a more efficient remediation industry (Ellis and Hadley, 2009; Favara et al., 2011; Hou and Al-Tabbaa, 2014). Ellis and Hadley (2009) identify several other drivers or reasons to increase resource efficiency and maximize the benefits of remediation projects (Table 2.1). Increasingly, stakeholders, government, and practitioners are aware of the multifaceted drivers and benefits to more sustainable approaches to planning for, and implementing, remediation projects (Cundy et al., 2013; Hou and Al-Tabbaa, 2014; McHaina, 2001; SuRF Australia, 2009).

Table 2.1: Social, environmental and economic drivers for remediation

Social	**Environment**	**Economic**
Industry desire to improve corporate image	Pending climate-change legislation	Brownfield re-development incentives
Enhance social responsibility and improve shareholder value	Legislation requiring the implementation of sustainable practices.	Increases to real estate values
Improve community relations	International influence, and regulations and law in other countries where remediation is mandated	Long-term environmental liability management and minimization
NGO advocacy pressure	Realization of net environmental benefits	Cost savings through resource use efficiency
Public awareness of sustainability issues and requests to implement more sustainable practices	Minimization of harmful emissions	Economic spin-off opportunities through the remediation industry.

2.2 Sustainable Remediation

There are various definitions of SR, most have a "general resemblance in that [SR] goes beyond risk control and must consider the overall benefits and impacts of remediation" (Hou and Al-Tabbaa, 2014). According to SuRF US, SR process is a remedy or combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources (Ellis and Hadley, 2009). SR is said to be based on sustainable development principles defined by the Brundtland Report, and to incorporate transparency of decision-making processes with balanced outcomes for social, economic, and environmental conditions (Bardos et al., 2011; Beames et al., 2014; Fortuna et al., 2011). However, the principles identified in the Brundtland Report are not easily translated to operational practice, which makes realizing these principles often difficult in any assessment or evaluation framework (Schädler et al., 2013; White and Noble 2013). Overall, SR frameworks are intended to integrate sustainability parameters and provide structure in assessing alternative remediation treatment methods (Beames et al. 2014). Current international debate surrounding SR focus on how such sustainability benefits can be assessed and maximized, and how negative consequences can be avoided or limited. The broad concepts of SR are based on the achievement of net benefits overall, across the range of environment, social, and economic concerns, which are judged to be representative of sustainability (Cundy et al., 2013).

Several authors indicate that there is currently no universal framework for SR (Ellis and Hadley 2009; Bardos et al., 2009; Fortuna et al., 2011; Hou and Al-Tabbaa, 2014). The lack of a consistent, comprehensive framework with agreed-upon indicators is a key barrier to integrating sustainability principles in remediation frameworks and practices (Ellis and Hadley, 2009). In 2008, SURF UK held a forum as an attempt to consolidate a comprehensive list of indicators that were used in past remediation projects (Bardos et al., 2009). The forum assessed 113 remediation projects, the majority of them from the UK, and identified several indicators based in 18 major categories balanced between the three pillars of sustainability (Bardos et al., 2009). A total of 2,421 indicators were identified across the 113 frameworks, 46% were of environmental considerations, 21% economic, and 33% social indicators. The report lists the indicators used, but there are no specifics on the background or history of the projects detailing the rationale or appropriateness of when or how to use such indicators, particularly how to integrate social, economic and environmental indicators in a single SR framework. The study indicated that socio-economic aspects are variably considered in SR projects, although not as widely adopted as biophysical components.

In 2009, SuRF US published a Sustainable Remediation White Paper (Ellis and Hadley, 2009). This included current practices (at the time), impediments, barriers, and recommendations. Ellis and Hadley (2009) report that SR has the potential to improve land use planning and, although methods have not been fully developed to support SR, the evolution of remediation industries has made quantum leaps. SURF organizations are encouraging national and international awareness for sustainable remediation to help decision makers. In 2011, for example, SuRF US published its framework for incorporating sustainability into remediation projects (Holland et al., 2011). The framework offers a theoretical perspective on integrating sustainable processes into each stage of remediation; however, the framework identifies limited indicators for SR application.

Several authors note the need to better include economic and social indicators in SR, but fail to provide details or specific guidance on how to accomplish this (see Bardos et al., 2011; Ellis and Hadley, 2006; Holland et al., 2011). There appears to be a significant operational gap in the integration of social and economic aspects with environmental issues in SR frameworks. In order to label a SR project or approach ‘sustainable’, it must consider social and economic components as part of the environmental system. Without proper social and economic remediation considerations, the ability to achieve sustainability through SR may be difficult. Additional research and development is needed to develop a coherent methodology in the remediation industry for the utilization of social and economic indicators in SR project planning and design. The outcome of a balanced and articulate SR approach could greatly benefit local and regional governments, communities, landowners, and industrial proponents.

2.3 Fundamental Principles of Sustainability for Remediation Frameworks

A major component of this research is to analyze how sustainability is defined, integrated, and operationalized in remediation frameworks. This does pose some challenges, based solely on the concept of using “sustainability” as a criterion in any assessment or evaluation study: first, there is no universal definition of sustainability (Dimitrov, 2010); second, there is no single process or set of criteria for assessing the effectiveness of sustainability integration (Bond and Morrison-Saunders, 2013; Hacking and Guthrie, 2008; Morrison-Saunders and Therivel, 2006; Pope et al., 2004). The concept of sustainability is interpretative and can be highly subjective. Sustainability can adopt different definitions depending on its user and the context (Dimitrov, 2010), and it will always reflect institutional and cultural values (Bond et al., 2013). The concept of sustainability means many different things to different people (Mascarenhas et al., 2015); however, the diversity of definitions could be argued as a point of strength rather than a point of weakness, because sustainability speaks of a globally shared paradigm (Dimitrov, 2010).

The concept of sustainability arose from the idea that the global situation (e.g. population growth, waste generation, resource depletion) was not viable in the long run and the reasons for wanting to change was as much social and economic as environmental and ecological (Gibson, 2006b). The starting point of many discussions around sustainability is the Brundtland Report (Dimitrov, 2010). *Our Common Future,* also known as *The Brundtland Report,* was a United Nation's Commission chaired by Gro Harlem Brundtland. It is arguably the most commonly referred to interpretation of sustainability, and perhaps the most accepted – it is sufficiently generic and it emerged at a time when society at large was becoming increasingly aware of the limits to growth and, in particular, the different environmental and socio-economic conditions faced in developed versus developing countries.

The Brundtland Report explained the concept of sustainable development as a framework for the integration of environmental policies and development strategies; intertwined concepts of the environment, and how it co-exists within each country (United Nations, 1987). Sustainable development is commonly seen as the integration of social, economic, and environmental pillars into decision-making, project plans, and progressive development. *The Brundtland Report* notes that for development to be sustainable it:

> Meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept… does not imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on

> environmental resources and the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth… sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life (section 1, paragraph 27).

Sustainability is no different than any other socially constructed concept. Most things have rules, there are always exceptions to the rules, rules and principles are always changing, and with that comes various meanings and interpretations. Originally, Brundtland's interpretation of sustainability was about ecological preservation and that development should aim to be equitable for all members of society. Brundtland's understanding was not only that human well-being is connected to the environment; but that the two are "necessary to each other and both were likely to fail if not addressed together" (Gibson, 2006a, p. 261). Slowly, Brundtland's campaign of a two pillar approach (poverty reduction and ecological preservation) was subsumed in the more modernized three-pillar, or three legged-stool model, which placed equal emphasis ecological preservation and well-being (Pope et al., 2004), while also introducing economics.

The three pillared-approach arguably reflects a reductionist perspective by separating complex relationships into silos. This does, however, facilitate trading between them, such as trading the environment for human-made capital (Bond and Morrison-Saunders, 2009), which makes 'sustainability' operable in the eyes of decision makers. In is because of trade-offs, however, and the compromise made when trading-off environment or economics or economics for well-being, that let to a shift away from a three-pillared approach toward emphasis on win/win/win approaches to enhance all aspects of sustainability (Pope et al., 2004). The notion behind reducing trade-offs in sustainability was to help ensure a more holistic understanding of sustainability, but arguably it still deviates from the original platform of sustainability based solely on equity and ecological preservation. The result of this evolution in sustainability thinking is that social and economic sustainability should be nested within the environment (Pope et al., 2004).

Several models conceptualizing sustainability have since emerged, including, for example, the five pillar model (ecological, economic, political, social and cultural) (Gibson, 2006b), and five capitals model (natural, human, social, manufactured, and financial) (Hacking and Guthrie, 2008; Sala et al, 2012b). To help achieve a better representation of sustainability in practice, and to operationalize it, several suites of sustainability indicators and principles have also emerged, making post-Brundtland sustainability far more integrative and far more complex than originally indented (Gibson, 2006a). The first set of sustainability indicators, for example, was introduced in 1995 by the United Nations Division for Sustainable Development (Rinne et al., 2013), comprised of 134 indicators and a related methodology to help achieve sustainability. From this, many other organizations and scholars followed suit, such as the Bellagio Principles of 1997, the BellagioSTAMP of 2009 (László et al., 2012), the EU SD strategy of 2001 (Rinne et al., 2013), Gibson et al. (2005), Bell and Morse (2008), and recently Bond et al. (2013).

Gibson (2006b) states that much literature on sustainable development attempts to define sustainability objectives, identify appropriate indicators (Rinne et al., 2013), and apply sustainability considerations. Recent literature however clearly indicates that there is much difficulty in constructing a framework for sustainability (Bond and Morrison-Saunders, 2009; Pope el al, 2004): projects are always specific, there is a unique complexity associated with any assessment, and sustainability should strive to reflect such uniqueness (Morrison-Saunders and Pope, 2013; Richter et al. 2015). As such, notwithstanding the growth in scholarly literature on sustainability, translating the broad concept of sustainable development, or sustainability, to operational practice has been a persistent challenge. White and Noble (2013), for example, report that assessment and evaluation frameworks often adopt the language of sustainability, but provide little by way of substance in terms of operationalizing sustainability and struggle to advance such a broad concept to a specific practice.

In order to understand the extent to which remediation frameworks incorporate and address sustainability, it is necessary to first identify the fundamental principles of sustainability that ought to inform remediation frameworks and practices. Several scholars have provided various adaptations of sustainability principles (e.g. Gibson 2006b; Bond et al., 2013). In the sections that follow eight core principles are identified that, arguably, characterize any framework designed based on sustainability considerations. The first principle consists of three sub-categories or sub-principles. The eight principles are as follows:

1a) Integrative in approach: Sustainability is identified as a guiding principle.

1b) Integrative in approach: Relationships between the three pillars of sustainability are acknowledged.

1c) Integrative in approach: Sustainability is present in the framework beyond the statement of a guiding principle.

2) Specific tools or indicators are identified for assessing sustainability.

3) Life cycle principles or tools are identified or encouraged.

4) Future land use and Design is part of the remedy alternative selection process

5) Encourages intra-generational land use and design.

6) Encourages inter-generational land use and design.

7) Encourages engagement in a culturally appropriate context.

8) Public participation is integrated throughout the framework's prescribed process.

These principles are drawn from a review of the vast literature on sustainability (e.g. Bell and Morse, 2008; Dimitrov, 2010; Pintér et al., 2012; United Nations, 1987), including emerging literature on sustainability frameworks and sustainability assessment (e.g. Bond et al., 2013; Gibson et al., 2005; Hacking and Guthrie, 2008; Moreno Pires and Fidélis, 2014; Pope et al., 2004).

2.3.1 Integrative in approach

Sustainability cannot be defined by one definition as sustainability inherently represents various contexts, cultural beliefs, and institutional values (Martin, 2015). There are many different views or models of sustainability, including social sustainability, economic sustainability, ecological sustainability, and the numerous 'three pillar' or intersecting Venn diagrams that depict the numerous conceptualizations of the relationships between these components. The wide interest in sustainability has caused various differing, overlapping - and even competing- definitions of these multidimensional concepts and their sub-components (Richter et al., 2015).

Definitions and diagrams do not create a 'sustainable' project; but they can assist in setting a context for achieving a sustainable project and, most importantly, set the dialogue for sustainable decision-making. Integrating sustainability within any single assessment or evaluation framework, and across levels of decision-making, is identified in the literature as essential to achieving sustainability, "particularly through trans-disciplinary approaches that avoid compartmentalizing sustainability planning and practices into discreet "pillars" (Stuart et al., 2014, p.3). Pope et al. (2004) explain, "that the term 'integration' implies that integrated assessment should be more than the sum of separate environmental, social and economic assessment" (p. 601). Pope et al. continue on to suggest that assessment and evaluation frameworks should not only consider the environmental, social, and economic implications of proposals, but should also examine the interrelations between them.

The traditional three-pillar or three-legged stool view of sustainability is not a sufficient, or perhaps even an appropriate approach to sustainability. Even, as most illustrations of the concept still involve a three-legged stool or a Venn diagram of the three elements (Bond and Morrison-Saunders, 2013), socio-ecological systems by their very nature are interconnected, and recognizing these interconnections and complexities is essential to any framework that claims to integrate or consider sustainability (Richter et al., 2015). Consensus has emerged on the view that sustainability must move beyond the three-pillar approach to "foster and preserve socio-ecological systems . . . that are dynamic and adaptable, satisfying, resilient, and therefore durable" (Stuart et al., 2014, p.3).

2.3.2 Identifies supporting assessment tools (i.e. indicators)

Sustainability is a concept that is difficult to operationalize, as in it is difficult for the application of a theoretical concept, which has many definitions. Any framework designed to consider sustainability issues, or to assess the sustainability of actions, must provide the necessary tools to do so – specifically guidance on appropriate indicators for understanding contributions to or detractions from sustainability (White and Noble, 2013). There is no uniform consensus on metrics or indices for sustainability, but there is a need for guidance on tools for practitioners when adopting and applying an assessment or evaluation framework in any given context goals (Fortuna et al., 2011; White and Noble 2013). In the context of remediation, such guidance helps a practitioner or decision maker assess the best form of remedial treatment options for a project

(Beames et al., 2014). The tools may take form of special calculations, specific processes/pathways, or simplified checklists or matrices (e.g., Baker and Rapaport, 2009).

Equally important, however, is guidance on the selection and use of indicators to represent whole system management. Sustainability indicators are quantitative or qualitative, and bring together multiple areas of concern regarding social, environmental, economic, institutional and spatial development (Fourtuna et al., 2011; Moreno Pires and Fidélis, 2015; Rinne et al., 2012). The use of indicators can help remediation practitioners and decision-makers operationalize sustainability, and also act as a benchmark to assess whether a project achieved sustainability (Mascarenhas et al., 2015). Moreno Pires et al. (2014) note the last two decades, various sustainability indicator systems have grown in popularity because of its belief that they will aid in decision-making. But, Moreno Pires et al. note the continuous growth has not resulted in a consensus around methodology, conceptual frameworks, or standardized options to measure sustainability. Frameworks adopting sustainability indicators must also provide guidance on the selection of indicators so to avoid overwhelming and confusing intended users, and to avoid redundancy (Mascarenhas et al., 2015).

2.3.3 Adopts a life cycle approach

Any approach based on sustainability principles must capture the entire life cycle of an activity. Sustainability extends from the present into the future infinitely. For any project to be sustainable, this temporal aspect must be addressed with adequate and relevant scope (Pintér et al., 2012). Life cycle thinking (LCT) is a concept described as ‘the cradle to grave’, that can help achieve sustainability goals through the application of life cycle-based methodologies (Bjørn and Hauschild, 2012; Fredga and Mäler, 2010; Traverso et al., 2012; Sala et al., 2012a; Sala et al., 2012b). Due to the systematic approach of LCT, it is considered to provide a valuable support in integrating sustainability into the design, development and evaluation of products and services (Sala et al., 2012b). The advantageous use of LCT, in terms of sustainability, is that overall project impacts and benefits (social, environment, and economic) are comprehensively weighted for the entire life cycle.

Life cycle assessment (LCA), a common and practical approach to LCT, is a compilation and evaluation of the inputs and outputs, and potential environmental impacts, of a project or product throughout its life cycle (Favara et al., 2011). LCA offers a systematic approach for evaluating product-based systems, traditionally in the manufacturing and processing sectors (Diamond et al., 1999), and typically uses a specific unit (e.g., carbon emissions, water consumption, or fuel usage) to quantify the total amount used or emitted throughout the life cycle of that product, project or alternative (CL:AIRE, 2010; Sala et al., 2012b). LCA can provide the conceptual framework for a comprehensive comparative evaluation of a project (Fredga and Mäler, 2010), as it considers impacts from operations, construction and decommissioning, and the environmental burdens of upstream and downstream processes (Fredga and Mäler, 2010). Using LCA can create a fluid, deep, and transparent critique of any industrial development or site rehabilitation. Previous research by Niederl-Schmidinger and Narodoslawsky (2008), Manuilov et al. (2009); Jeswani et al. (2010) and Tucker (2000) argue that LCA should be part of impact assessment and other evaluation frameworks, as it generates comprehensive and holistic data that can contribute to better project design. For these reasons, Bardos et al. (2011) and Holland et al. (2011) suggest that LCA could be partially extended to all remediation projects, arguing that including LCA in remediation can reduce uncertainties by assessing each component in a quantifiable and transparent manner, and take into account all relevant effects over the life cycle of remedial actions (Tukker, 2000). However, even proponents of LCA recognize its complexities and note the application requires substantial analytical know-how, additional time, and financial resources (Jeswani, 2010).

2.3.4 Considers future land uses

The consideration of how land will be used post-remediation is an imperative to sustainability and effective remediation. Land is a scarce and valuable resource, ecologically, economically, and socio-culturally (Hou and Al-Tabbaa, 2014). Inherently, remediation supports sustainability by addressing contaminated and dilapidated land issues by reducing toxins, rehabilitating, and restoring ecological functions to soil and water (Hou and Al-Tabbaa, 2014). More importantly, by planning for future land use in conjunction with remediation treatment technologies, redundancy of treatment options can be avoided and, in particular, adequate risk reduction of contaminants can be ensured for future land use. Obviously, the relationship between the site and its potential future uses are connected to its location, and proximity to urban or rural populations. A contaminated site with low risk of emitting low concentrations, may not require remediation, but may still be viable for new land use and regeneration. Alternatively, a site with high-risk of dispersion and high-level of toxicity, regardless of remoteness, may need remedial work, regardless of the site ever being used. All sites will need to give careful considerations to the range of suitable future land uses given the level of contamination and risks associated.

In the context of non-remote sites, either rural or urban, many remediation scholars and organizations have focused on the potential benefits of land reuse and sustainability (Barkemeyer et al., 2015; CABERNET, 2006; Cundy et al., 2013; Hou and Al-Tabbaa, 2014; Schädler et al., 2013). Contaminated lands that lie unused and unproductive, known as brownfields (National Round Table on the Environment and the Economy (NRTEE), 2003), detract or are likely to detract from the amenity, character or appearance of a landscape (Cabernet.org.uk, n.d.) and, thus, detract from social sustainability.   Remediation in this context, brownfield revitalization (BR), can provide both environmental protection while boosting the local economy, enhancing social fabric, and contribute to sustainable urban development (Schädler et al., 2013) Table 2.2 discusses the various social, economic, and environmental benefits to regenerating brownfields, mainly in populated areas like rural or urban settings, remote sites may not be applicable.

Table 2.2: Social, economic, and environmental benefits of brownfield regeneration

Social Benefits	Economic Benefits	Environmental Benefits
Revitalization to and surrounding neighbourhoods	Increased tax revenue for municipality	Reduce pressure for greenfield development
Improvement in health, safety and security	Use of existing infrastructure	Reduce urban expansion
Development of social housing	Increased employment infrastructure	Improve urban air quality by reducing traffic commuter
Redevelopment of historical buildings	Greater investment in further development of area	Removal or lowered contamination of site
Improvement in quality of life	Increase property value of neighbourhood	Restoration of ecological and hydrological zones
Redevelopment of historical buildings	Increase property value of surrounding area	Improve groundwater, storm water drainage
Improvement in quality of life in the neighbourhood	Reduced liability for property owner	Improving green space, zenoscaping
More sustainable and livable communities	Economic opportunities for developers	Retrofitting existing buildings for decreased energy usage
Improve connectivity and transit	Create jobs	New building with LEED certification
Reduce traffic	Reduce new infrastructure needs	Improve mass-transit
Create new gathering spaces	Increase income for individuals	Reducing Urban footprints

Source: Adapted from CABERNET, 2006; City of Saskatoon, 2009; NRTEE, 2003

2.3.5 Considers intra-generational issues

An over arching principle of sustainable development is supporting intra-generational equity (Gibson, 2005; Gibson, 2006b; Petri, 2007). The first principle of sustainable development proposed by *The Brundtland Report*, for example, is that all human beings have the fundamental right to an environment adequate for their health and well being (United Nations, 1987, Annexe 1). Therefore, any sustainable decision-making process must attempt to address this fundamental principle, by promoting social equality (Stuart et al., 2014). Broadly speaking, intra-generational equity is correlated with social 'well-being', which is a deep-rooted belief that humans can live harmoniously along side nature (Dimitrov, 2010). But, it also goes beyond that with measurable quality of life indexes, assurance of good health, preservation of cultural identity, and the guarantee of personal security and freedom of choice (Dimitrov, 2010).

Gibson (2005) describes intra-generational equity as to "ensure that sufficiency and effective choices for all are pursued in ways that" reduce gaps of inequality of health, security, social recognition, political influence (p. 101). In other words, intra-generational equity emphasizes effective public choice pertaining to development, in this case the development and reuse of contaminated lands, while reducing gaps between different socio-economic or cultural groups or gender (Stuart, 2014). Gibson (2006b) provides illustrative implications of why intra-general considerations are fundamental to sustainability: the need to ensure equitable livelihoods; practical livelihood choices; and, the power to choose those livelihoods.

2.3.6 Considers inter-generational issues

The second principle of sustainable development outlined in *The Brundtland Report* is inter-generational equity, or "conserve[ing]… the environmental and natural resources for the benefit of present and future generations" (United Nations, 1987, Annexe 1). Gibson (2005), p 103) further explains that this means "favour[ing] present options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably" (Gibson, 2005, p. 103). Brundtland's emphasis on inter-generational equity supports the desire to not destroy the regenerative capacity of natural capital, nor irreversibly stress the natural systems (Petri, 2007). In the context of remediation there are explicit benefits to ecological services given the improvement of previously contaminated land. Additionally, there can be an implied socio-economic benefit from site restoration in an appropriate urban/rural context. But, this requires a framework that endorse practices that attempt to return socio-ecological systems and their functions, to levels that are safely within the perpetual capacity to provide resources and services likely to be needed by future generations; and to build the integrity of socio-ecological systems to maintaining the diversity, accountability, broad engagement and other qualities required for long-term adaptive adjustment (Pintér et al., 2012).

2.3.7 Provides for a culturally sensitive approach

What is considered sustainable is, in part, a function of cultural values (Bond et al, 2013) and sustainability means many different things to different people (Mascarenhas et al., 2015). As such, any assessment or evaluation framework that is intended to support sustainability must be accommodating of the range of cultural perspectives that exist (see Dimitrov, 2010). The twentieth principle of *The Brundtland Report* discusses equal access and treatment, meaning that proponents "shall grant equal access, due process and equal treatment in administrative and judicial proceedings to all persons who are or who may be affected…" by development actions (United Nations, 1987, Annexe 1). Providing equal voices to marginalized communities or disenfranchised groups is a difficult process; however, assessment and evaluation frameworks must be sensitive to the inherent complexities surrounding socio-cultural positions. A sustainable process must place at least some emphasis, even in only a recognition, that sustainability can be socially and culturally constructed and, as such there must be an opportunity to ensure appropriate representation regarding gender balance, and a fair geo-spatial representation of impacted populations within the engagement model (Datta, 2015; Nakamura, 2015). In the Canadian context, in particular, any project wishing to fulfill the obligatory sustainability requirements must explicitly address provisions for the cultural and spiritual concepts of the Indigenous peoples (Datta, 2015). Sustainable remediation frameworks must introduce the idea that Indigenous communities have a fundamentally different relationship with nature, land, and its resources (Datta, 2015; Dimitrov, 2010), and ensure an opportunity for the inclusion of those perspectives.

2.3.8 Participatory by design

Finally, assessment and evaluation frameworks for sustainability must be participatory by design. Principle six of *The Brundtland Report* states that proponents "shall inform in a timely manner all persons likely to be significantly affected by a planned activity" (United Nations, 1987, Annexe 1). In more recent years, however, due process and informing stakeholders has morphed into a process of collaboration with stakeholders for the purpose of ensuring meaningful public involvement (United Nations Economic Commission for Europe (UNECE), 1998; Pintér et al., 2012). Sinclair and Diduck (2009) use the term 'meaningful public participation' as capturing "all of the essential components of participation, from information sharing to education, including the active and critical exchange of ideas among proponents, regulators, and participants" (p. 59). The extent of public participation in any process can be varied, but fundamentally involves the active engagement of the affected public in the design and decision-making process of a particular plan or activity (Sinclair and Diduck, 2009).

This means that equal opportunities should be given to all communities to have a voice in the design of a remediation process, including the range of future viable uses of the remediated site. “Sustainability cannot be quantified in absolute terms. Consequently, stakeholder engagement is crucial to… allow stakeholders to provide their perspectives on the balance of potential impacts and benefits… [and] control or feedback is integral to informing better land management decisions” (Joint position statement # 4, NICOLE and Common Forum, 2013). Providing a forum for stakeholders to collaborate in selecting indicators, such as indicators for alternative site remediation targets or future uses, can provide an influx of new ideas and perceptions on the project (Rinne et al., 2012), and can lead to increased perceptions of achieving sustainability (Filder, 2010). Indicators (or methodology) that do not resonate with stakeholders may not be considered useful or needed; therefore the indicator development process should be a transdisciplinary action (Mascarenhas et al, 2015). Additionally, a participatory remediation process allows for a feeling of ownership and commitment towards decision-making and the project (Mascarenhas et al, 2015). Engagement is thus required, as a broadly inclusive and a continuous process throughout the remediation project (Cundy et al., 2013), thus ensuring more viable remediation projects and equitable outcomes (Pintér et al., 2012).

2.4 Research Gap

There is no universal framework for incorporating sustainability in remediation projects (Ellis and Hadley, 2009; Bardos et al., 2009; Fortuna et al., 2011; Hou and Al-Tabbaa, 2014). International consensus is starting to emerge on the purpose of SR – to reduce impacts and maximize the long-term benefits of remediation projects, and ensure an overall net benefit among the three aspects (social, economic, biophysical) that are deemed to represent sustainability (Cundy et al., 2013). However, no specific directive has been finalized for ensuring sustainability integration in SR, and the lack of consistent framework, indicator list and process for integration is a barrier to realizing sustainability in remediation practice (Ellis and Hadley, 2009). Indeed, these barriers are recognized broadly in the international sustainability literature (see Dimitrov, 2010; Pintér et al., 2012). This research fills a gap in current understanding of how sustainability is best integrated in SR frameworks, and proposed a set of principles for examining the integration and operations of sustainability within remediation frameworks.

Chapter 3
Research Methods

This chapter describes the research methods. The criteria adopted to evaluate SR frameworks are first presented, followed by a description of the review approach. The six remediation frameworks that were chosen and analyzed in the research are then briefly introduced.

3.1 Sustainability Review Criteria

Eight core sustainability principles identified from the literature were adapted as review criteria to guide the assessment of how sustainability is integrated within remediation frameworks (Table 3.1). The criteria were selected from the scholarly work on sustainability assessment, with supporting scholarly work from impact assessment and relevant fields. Other materials consulted were the Brundtland Report, Bellagio Principles and other institutional research centers. The criteria are subjective, as sustainability is such; however, the criteria represent broad principles that are generally agreed-upon in the scholarly literature as capturing the meaning of 'sustainability' (Dimitrov, 2010; Moreno Pires and Fidélis, 2015; Petrie, 2007; Pintér et al., 2012; United Nations, 1987). The first criterion, an integrative approach to sustainability, was divided into three sub-criteria to capture the full extent of sustainability integration in an assessment framework: i) sustainability as an overarching or guiding principle; ii) integrative of social, biophysical and economic aspects and the relationships between them; and iii) sustainability is evident throughout each of the different phase or steps of assessment. All criteria were assumed to be of equal importance.

Table 3.1: Sustainability review criteria for SR frameworks

	Criterion	Sources
1	Integrative approach to sustainability: a) Sustainability is identified as a guiding principle b) Relationships between the three pillars of sustainability are acknowledged c) Sustainability (e.g. guidance, indicators, or criteria) is present in the framework beyond the statement of a guiding principle.	Bell and Morse (2008); Bond et al. (2013); Gibson (2006a); Hacking and Guthrie (2008); Pope et al. (2004); Richter et al. (2015); Stuart et al. (2014); United Nations (1987).
2	There are specific tools or indictors identified for assessing sustainability.	Beames et al. (2014); Bell and Morse (2008); Gibson (2006a); Mascarenhas et al. (2015); Moreno Pires and Fidélis (2015).
3	Life cycle principles or tools are identified or encouraged.	Bell and Morse (2008); Diamond et al. (1999); Favara et al. (2011); Jeswani et al. (2010); Manuilov et al. (2009); Niederl-Schmidinger and Narodoslawsky (2008); Pintér et al. (2012); Tukker (2000).
4	Future land use and design is identified as part of the remedy alternative selection process.	Barkemeyer et al. (2015); CABERNET (2006); Cundy et al. (2013); Ellis and Hadley (2009); Fourtuna et al. (2012); Hou and Al-Tabbaa (2014); McHaina (2001); Schädler et al. (2013).
5	Encourages intragenerational considerations.	Bell and Morse (2008); Dimitrov (2010); Gibson et al. (2005); Petrie (2007); Stuart et al. (2014); United Nations (1987).
6	Encourages intergenerational considerations.	Bell and Morse (2008); Gibson et al. (2005); Petrie (2007); Pintér et al. (2012); United Nations (1987).
7	Encourages engagement in a culturally appropriate context.	Bell and Morse (2008); Bond et al. (2013); Datta (2015); Gibson et al. (2005); Nakamura, (2015); United Nations (1987).
8	Public engagement is integrated throughout the framework's prescribed process	United Nations (1998); Bell and Morse (2008); Bond et al. (2013); Sinclair and Diduck (2009); Gibson et al. (2005); Mascarenhas et al. (2015); McHaina (2001); United Nations (1987).

3.2 Application of the Sustainability Review to Remediation Frameworks

The eight sustainability criteria were used to guide an analysis of the content of six remediation frameworks. The sample of remediation frameworks is described below in Section 3.3. Each remediation framework was reviewed and analyzed for the representation of and specific guidance on how to operationalize each criterion by a document analysis. Benefits to document analysis, as a research method, outlined by Bowen, include a low-cost, unobtrusive and nonreactive way to obtain data and the opportunity to revisit the document and reorganize and recode data in different ways. Documents can be treated as data in such that they can be examined and interpreted to elicit meaning and gain understanding (Bowen, 2009). Bowen (2009) outlines two methods of document analysis by using content analysis, by organizing information into pre-determined categories, or by a thematic analysis, which is a form of pattern recognition found within the data. The latter process requires a careful, more focused re-reading and review of data (Bowen, 2009).

The data was sorted into quotes, definitions, methodology, and directives, which were further organized into major themes, and categorized based on the set of eight evaluation criteria. Specific examples illustrating sustainability principles, as discussed in the literature, were noted. First, detailed notes were taken on each framework in a Word document. These notes were on the layout, organization, key themes, and terminology used (e.g., public *consultation* versus *collaboration)*. Second, each framework was analyzed specifically for each criterion; keywords and notes were entered into an Excel table recording what was found. Third, once the criteria and frameworks were exhausted, a comparative review was done between the frameworks to see how the different frameworks compared in terms of meeting each criterion. This allowed an understanding of the relative strengths and limitations of each framework in meeting sustainability principles. Results were then synthesized and entered into a table to summarize the overall results for each of the review criteria.

Rather than adopt a point-based system to score each framework, which perhaps makes little sense given the subjective nature of sustainability in general, the data are presented qualitatively. However, an overall assessment is presented for each framework on the basis of each criterion being fully met, partially met, not met, or there being insufficient information in the framework to make a determination. Although qualitative in design, similar approaches have been used by Dalal-Clayton and Sadler (2005), Döberl et al., (2013), and Noble (2009) to present the results of national and international evaluations of environmental assessment frameworks.

3.3 Selection of Remediation Frameworks

Six frameworks were selected for review (Table 3.2). The frameworks reflect current best remediation practices in Canada[1], United Kingdom and United States of America. The authors of the reports range from state level agencies to federal agencies, and to national-level organizations with collaboration between practitioners, academics, and regulatory bodies. Three of the frameworks are specifically labeled as incorporating 'sustainability' into the decision making process. Two of the frameworks are labeled as incorporating both 'sustainability' and 'green remediation'. Only one framework included was a general remediation framework. This range of frameworks was selected so as to gauge whether 'sustainability' plays any meaningful role. The majority of the frameworks used were from the United States, this was because of the proliferation of remediation frameworks in that region. There is a large push from the current United States government for sustainable remediation, and many other federal and state government organizations have released documents supporting this transition (Hou and Al-Tabba, 2014). Currently, United States' federal law has several components and funds established specifically for remediation projects (e.g., CERCLA, superfund and EPA). The frameworks were chosen also because of their availability, international recognition, and being complete frameworks that are useful for comparison. Each of these frameworks is described briefly below.

[1] Note: Both SuRF Canada and FCSAP are releasing updated literature and frameworks, respectively. At the time this research was completed they were not publicly released.

Table 3.2: Remediation frameworks included in this study

Frameworks	Industry Type	Country of Origin	Organization Type
ASTM International (2013). Standard Guide for Integrating Sustainable Objectives into Cleanup. Designation E2876- 13	Sustainable Remediation	United States of America	Professional Association
Government of Canada (2013). Federal Contaminated Sites Action Plan (FCSAP): Decision-Making Framework. Isbn 978-1-100-22157-1	General Remediation	Canada	Federal Government; Environment Canada
United Kingdom Sustainable Remediation Forum (Bardos et al.) (2011). Applying Sustainable Development Principles to Contaminated Land Management Using the SuRF-UK Framework. Doi 10.1002/rem.20283	Sustainable Remediation	United Kingdom	Collaborative Organization of Practitioners, Academics, and Regulators
United States National Environmental Protection Agency (2008). Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites. EPA 542-R-08-002	Green Remediation	United States of America	Federal Government Agency
United States Sustainable Remediation Forum (Holland et al.) (2011). Framework for Integrating Sustainability into Remediation Projects. Doi 10.1002/rem.20288	Sustainable Remediation	United States of America	Collaborative Organization of Practitioners, Academics, and Regulators
Department of Natural Resources, Wisconsin Initiative for Sustainable Remediation and Redevelopment (2012). Green & Sustainable Remediation Manual: A Practical Guide to Green and Sustainable Remediation in the State of Wisconsin. Pub-RR-911	Green and Sustainable Remediation	United States of America	State Government

3.3.1 American Standard International

In 2013, American Standard International (ASTM) released a framework for sustainable remediation. The *Standard Guide for Integrating Sustainable Objectives into Cleanup* presents an opportunity for users to address sustainability aspects within cleanup projects. The "spirit and intent of the guide promotes improvements in cleanup through the integration of sustainable objectives" (ASTM International, 2013, p. 5). The framework claims that the users may use this guide to integrate social, economic, and environmental objectives along side regulatory aspects of remediation projects (ASTM International, 2013). ASTM employs "sustainable best management principles" (sBMPs), which is said to provide the project an overarching, consistent, transparent and scalable framework (ASTM International, 2013, p.1). The document notes that its use should be congruent with technical tools and policy to encourage a broad range of clean up activities that align with end-use goals (ASTM International, 2013).

The framework design reflects a traditional impact assessment project and is comprised of eight sections: scope, sustainable objectives, and sustainable aspects; terminology; significance and use; planning and scoping; selection and implementation of best management practices; quantifying results; documentation. The Framework explains the relationship between sustainable aspects, core elements, and BMPs (ASTM International, 2013), and states that remediation projects should be a collaborative process between the project team and stakeholders to identify connections of core elements, project design and end use goals (ASTM International, 2013). The framework also suggests using both qualitative and quantitative data to identify key factors that guide decision-making components (ASTM International, 2013).

3.3.2 Federal Contaminated Sites Action Plan

In 2005, the Government of Canada created the Federal Contaminate Sites Action Plan (FCSAP) to oversee the remediation of contaminated sites within Canada (Government of Canada, 2014). In 2013, the program released the *FCSAP Decision-Making Framework.* This document includes a linear 10-step process for federal custodians to help in various stages of a remediation project. The framework is broken into individual segments to help custodians consider critical decisions about their site (Government of Canada, 2014). The typical steps associated with a remediation project are shown, and the types of decisions that must be made. The ten steps are: identify suspect site; historical review; initial testing program; classify site (optional); detailed testing program; re-classify site; develop remediation/risk management strategy; implement remediation/ risk management strategy; confirmatory sampling and final reporting; long-term monitoring (if required). The framework includes a flow chart of management decisions that are illustrated to highlight their importance. Supporting documents and regulatory agencies are included in each relevant step. For example, it is recommended to contact Fisheries and Oceans Canada, and Health Canada experts to provide advice on various federal regulations that may impact project performances.

Appendix A to the framework discusses the role of cost/benefit analysis, and recommends a cost/benefit analysis be done for all remediation project alternatives. Several approaches are then provided for the comparison of alternatives, including matrices, checklist methods, pairwise comparisons, and Guidance and Orientation for the Selection of Technologies (GOST) and Sustainable Development Tool (SDT). GOST is a technology database that contains individual attributes of various technologies/approaches to contaminated land management. The user enters soil types, water bodies, the properties of contaminants, and then GOST recommends which approach or technology would be most suitable for the site-specific attributes (Government of Canada, 2013).

3.3.3 Sustainable Remediation Forum United Kingdom

In 2011, a multi-stakeholder initiative of United Kingdom remediation practitioners collaboratively created the *Applying Sustainable Development Principles to Contaminated Land Management Using the SuRF-UK Framework*. The Sustainable Remediation Forum United Kingdom (SuRF UK) outlines processes for sustainable management and sustainable assessments to be used as support for SR. SuRF UK acknowledges the need for a shift in ideology, from any future use to end related use; which sets the context for the remediation industry to pursue SR options (Bardos et al., 2011). The purpose of the framework is to support greater development by “better by design” (Bardos et al., 2011, p. 78). SuRF UK defines SR as the application of the principles of sustainable development, as described by Brundtland, to risk-based contaminated land management. As such, SR is said to encompass four aims: achieving risk-based land management; ensuring the wider effects of risk management actions are acceptable; ensuring the engagement of stakeholders and the transparency of the decision-making process; and supporting balanced outcomes in terms of the environmental, social, and economic elements of sustainable development (Bardos et al., 2011). SuRF UK promotes six principles as underpinning SR: protection of human health and the wider environment; safe working practices for workers and communities; consistent, clear and reproducible evidence-based decision making; recordkeeping and transparent reporting; good governance and stakeholder involvement; and decisions should be made on sound science.

SuRF UK also provides guidance on how to reduce complexity for sustainable management practices (Bardos et al., 2011), suggesting that decisions and assessments should be considered in a structured way; that consistent boundaries must be used in decision-making and sustainable development (boundaries include life cycle or time boundaries and geographic boundaries); and that assessing sustainability is essentially a subjective process and it needs to be accepted as such. This means that a SR approach should be about using a relevant, balanced, and customized process for each particular project (Bardos et al., 2011), and that results are based on six criterions, which are: consultation; transparent; reproducible; verifiable; documented; and appropriate. SuRF-UK also asserts that a sustainable assessment is a consultative process that seeks to find consensus between the different project stakeholders (Bardos et al., 2011), and emphasizes the approach should describe tools and techniques to aggregate different findings from individual considerations into an overall understanding of sustainability (Bardos et al., 2011).

3.3.4 Sustainable Remediation Forum United States of America

In 2011, the United States Sustainable Remediation Forum (SuRF US) published its *Framework for Integrating Sustainability into Remediation Projects*. This document provides direction on how to employ sustainability parameters into remediation projects, emphasizing the integration and balance of sustainability parameters throughout the life cycle of a project. The purpose of this document is to enhance cleanup from goal-based (regulatory requirements) to a process-based cleanup (informed decision-making) (Holland et al., 2011). SuRF US sees this as a transition from meeting clean up targets to a value-added land use system (economic returns and social investments) alongside the paramount objective: reducing residual environmental contaminants to a safe level (Holland et al., 2011).

The framework provides a systematic process-based approach to the integration of sustainability parameters into project development for remediation, and states that implementation of sustainability should be done in each phase of a remediation project (Holland et al., 2011). The framework encourages a tiered sustainability evaluation based on various parameters relevant to the project, then arranging the data into a conceptual site model (CSM) to illustrate the project. The process starts broad with qualitative parameters, then moves to semi-quantitative data, and ends with project specific detailed quantitative data. Metrics are then identified for each of the measurable values that correlate to the parameters being evaluated, such as greenhouse emissions, jobs created, or energy use. This stage helps illustrate the conceptual site model phase of the framework. With emphasis on a CSM, the premise is that these aspects can then be integrated with the whole site impact reduction model.

3.3.5 United States Environmental Protection Agency

The Unites States Environmental Protection Agency (US EPA), in 2008, published *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*. As a 'technology primer', this document serves to provide a topical introduction, rather than instructional guidance (US EPA, 2008, p. i), and is mainly focused on biophysical components of remediation. The framework focuses on the core elements that represent aspects of sustainability to be considered in all stages of project planning. The US EPA claims that "strategies for green remediation rely on sustainable development, whereby environmental protection does not preclude economic development, and economic development is ecologically viable today and in the long run" (US EPA, 2008, p. 2). Through a series of objectives, best management practices (BMPs) and six core elements, the US EPA presents a process aimed at six core elements: energy requirements; air emissions; water requirements and impacts on water resources; land and ecosystem impacts; material consumption and waste generation; and long-term stewardship actions (US EPA, 2008).

A key component of the US EPA framework is energy considerations. A major part of the framework, for example, is dedicated to giving proponents a series of alternative 'active' energy solutions and 'passive' energy techniques for a site cleanup (US EPA, 2008). The framework suggests that feasibility studies should include comparisons of environmental footprints expected from project alternatives including energy sources and carbon use (US EPA, 2008). The framework also suggests the integration of new renewable energy technology in site remediation because it can offset total energy usage, with potential for near- and long-term savings (US EPA, 2008). The framework also identifies the potential opportunities that exist for new energy markets and job creation when combined with site revitalization (US EPA, 2008).

3.3.6 Wisconsin Initiative for Sustainable Remediation and Redevelopment

The Wisconsin Initiative for Sustainable Remediation and Redevelopment, part of Wisconsin's Department of Natural Resources, developed a guide for the state's remediation projects. In 2012, *Green & Sustainable Remediation Manual: A Practical Guide to Green and Sustainable Remediation in the State of Wisconsin* (WGSR) was released. The purpose of WGSR is to develop meaningful sustainability performance metrics that provide both qualitative and quantitative measures of sustainable remediation options (Wisconsin Department of Natural Resources, 2012). The performance metrics and methods are based on five of the core elements identified by US EPA – it does not include the core element of long-term stewardship.

The WGSR's overall goal is to ensure remediation activities reduce the environmental footprint within five core elements, and subsequently to reduce economic costs. This process is encouraged by the state so as to reduce resources and capital investment in remediation by informed decision-making. This is evident by the frequent metrics, tools, and methods proposed that proponents could utilize in several stages of the planning process. The rationale for adopting GSR is for lower economic cost, and environmental impacts (Wisconsin, 2012). The framework provides multiple tools to analyze segments of a remediation project, but does not present a process to look at the project holistically. The decision-making seems to be in separate silos, which may lead to redundancy and impede efficiency. The overall message of the framework is the reduction of consumption for each the five core elements, cost savings, and avoiding environmental impacts.

Chapter 4
Results

Results of the framework analyses are synthesized in Table 4.1 and presented on the basis of each criterion in the sections that follow. The frameworks were given a score of ‘fully met’ criterion, ‘partially met’ criterion, and ‘criterion not met’. For some criteria, there was not enough information available in the framework documentation to make a judgment, so a rating of ‘insufficient information’ was used. Each rating has a corresponding symbol attached to it. The most right column of table 4.1 has the total scores for each criterion. The bottom row of table 4.1 has the total ratings of criterions for each framework.

ASTM ‘fully met’ all but one criteria, while SuRF UK met seven. SuRF US met four criteria, WSGR met 3, and US EPA met 2. FSCAP was the framework with the least number of criteria met. There was considerable variability across the criteria, some frameworks did not directly address sustainability, but referred to it implicitly. Public participation showed considerable agreement across the frameworks, yet the rationale and process of integration was varied.

There were few common tools identified across the frameworks for assessing or integrating sustainability in remediation practices, although three frameworks did propose or recommend different types of metrics to assess sustainability – ranging from quantitative to quantitative approaches (e.g., ASTM). All frameworks emphasized future land use planning. Life cycle assessment, and intergenerational considerations were found to have a strong presence in most frameworks.

Table 4.1: Syntheses of framework performance based on sustainability evaluation criteria[1]

Criteria	ASTM Int., 2013	FCSAP, 2013	SURF UK, 2011	SURF US, 2011	US EPA, 2008	WGSR, 2012	Overall Rate
[1a] Integrative approach: Sustainability presented as a guiding principle.	⊙Suggests a holistic view to remediation, using sustainability as a guiding principle.	⊘Sustainability is presented only as ‘sustainable development’ under the category of "other" a table of potential evaluation criteria.	⊙Sustainability is presented as an overarching management concept and as series of principles.	○’Sustainable parameters’ are to be integrated in each project step. There is no definition of sustainability and few ‘parameters’ to guide the user.	○Sustainability is implicitly encouraged from the use of BMPs and six core elements.	⊘Sustainability is presented as a screening tool to enhance GR.	⊙⊙ ○○ ⊘⊘
[1b] Integrative approach: The three pillars of sustainability are addressed and relationships between them acknowledged.	⊙ Pillars are integrated as core elements and BMPs, all which impact other aspects of sustainability.	⊘ Sustainability presented as a criterion in the ‘potential evaluation metrics’ in the appendix.	⊙ Sustainability presented as a series of guiding principles that expand beyond the three pillars.	○ Sustainability presented as a vague overarching ‘parameter’ to be integrated in each project phase. Pillars are presented separately.	⊘ Pillars are separate, with social and economic aspects playing a minor role relative to biophysical.	⊘ Pillars are separate, with a dominant focus on biophysical.	⊙⊙ ○ ⊘⊘⊘
[1c] Integrative approach: Sustainability present in the framework beyond the statement of a guiding principle.	⊙ Emphasis throughout the framework on holistic approach to how aspects of sustainability intersect.	⊘ No guidance for measurability or objectives achievement for sustainability.	⊙ Emphasis is on balanced decision making throughout the framework in the selection of a remediation strategy as an integral part of sustainable development.	○Encourages community collaborations, reusing land productively, and to make informed decisions based on tools provided.	○ Emphasis is on using alternative energy and minimizing energy use throughout the project.	○ Sustainability is presented as a method to lower consumption and enhance land use, with a biophysical focus.	⊙⊙ ○○○ ⊘
[2] Specific tools or indicators are identified for assessing sustainability.	⊙ Qualitative and quantitative tools are suggested to aid sustainability-based BMPs, data collection and analysis.	ⓘRecommends using the Sustainable Development Tool for remedial selection. The tool is not discussed in detail.	○ Does not provide specific tools, but refers to a list of tools to incorporate into decision-making, including a list of principles to follow.	⊙Identifies a 'sustainable conceptual site model' and additional metrics for sustainability considerations.	○BMPs are identified means to reduce impacts on the six core elements, and to encourage a ‘whole site approach’ planning.	⊘Identifies a variety of standard impact assessment tools (checklists) and metrics that could be adopted to examine the sustainability of a remedy.	⊙⊙ ○○ ⊘ ⓘ

Criteria	ASTM Int., 2013	FCSAP, 2013	SURF UK, 2011	SURF US, 2011	US EPA, 2008	WGSR, 2012	Overall Rate
[3] Life cycle principles or tools are identified or encouraged.	○Time horizons are identified as an important BMP consideration, but life cycle assessment is not presented as a suggested tool or concept.	⊘ Not present in the document.	⦿The 'system boundary' and the 'life-cycle assessment boundary' are identified as fundamental concepts or tools.	○LCA is encouraged for materials used for treatment, but not considered in the post-project design phase.	○A life cycle perspective is encouraged to evaluate chemical, biological, and economic interactions at contaminated sites.	○Suggests that calculations be done on remedial options to compare impacts.	⦿ ○○○○ ⊘
[4] Future land use and design is part of the remedy alternative selection process	⦿ Indicates that remediation should be reasonably consistent with anticipated future use, and integrate sustainability as both a long and short term consideration.	⦿The intended or future use of the site must be identified before remediation or risk management strategies are identified and evaluated.	⦿ Considers redevelopment and spatial plans as early as possible. Remediation is a small part of spatial planning.	⦿ Emphasizes a post-design model so that remedy selections ensure a fluid planning process from cleanup to end-use.	⦿Clean up and land re-use options are considered early in planning process, with an emphasis on land end use.	⦿Land is considered a limited resource. Future use of a site is promoted to aid community revitalization, through greenspace or development.	⦿⦿⦿⦿⦿⦿
[5] Encourages intra-generational consideration	⦿ Multiple BMPs that encourage the proponent to use local facilities, local labour and to train residents to meet the standard of jobs available.	⊘This is not considered.	ⓘSpecifies that having community input on all aspects of project is fundamental. But, no mention of local labour or development options.	⦿Encourages end land use that benefits all communities, such as open spaces or housing.	⦿ Emphasizes using alternative energy to benefit employment opportunities. Encourages community involvement to enhance decision-making.	⦿Encourages the use of local materials and labour. Notes re-use of sites can aid in conservation of existing green space and assist revitalization.	⦿⦿⦿⦿ ⊘ ⓘ
[6] Encourages inter-generational considerations	⦿Focuses on creating better opportunities for the community that has long lasting impacts, such as transferable skills training.	⊘This is not considered.	⦿ Encourages the proponent to think beyond the current generation, and think long-term. However, it does not specify how long into the future.	○ The framework does not specifically address temporal considerations, but it does maintain focus on long-term human health and environmental health.	○ Focused on alternative energy allows long-term community longevity. However, environmental protection is the ultimate benefit.	○ Encourages the use of alternative energy to lower GHG and energy consumption, which has positive long lasting effects.	⦿⦿ ○○○ ⊘

Criteria	ASTM Int., 2013	FCSAP, 2013	SURF UK, 2011	SURF US, 2011	US EPA, 2008	WGSR, 2012	Overall Rate
[7] Encourages engagement in a culturally appropriate context	⊙Proponents are encouraged to take cultural factors into consideration when assessing land redevelopment.	⊙Emphasis is placed on aboriginal peoples engagement and addressing psychosocial factors through capacity building and improving stakeholder relationships.	○ The framework encourages clear communication with communities, for clarity and understandability.	○ Notes that all stakeholder groups should be consulted because each community may have a unique understanding, and to use non-technical language.	⊘ This is not considered.	⊘This is not considered.	⊙⊙ ○○ ⊘⊘
[8] Public participation is integrated throughout the framework's prescribed process.	⊙A key objective is to encourage a collaborative participation and ensuring their views are considered in final decisions. Indicates stakeholders should have input on the selection of BMPs and objectives.	⊙Notes that "stakeholders can provide key information about the site history and condition, end of use, exposure pathways, and receptors, contaminants of potential concern, and safe exposure limits.	⊙Defines sustainability assessment a consultative process that seeks to find consensus between the different project stakeholders.	⊙States future end use planning should be in collaboration with stakeholders as they hold certain information about the site, and to determine unacceptable risks associated with the project, land use and to access to labour and acceptance.	⊘Instruction to solicit community involvement to increase public acceptance and awareness of long-term activities and restrictions.	⊙Notes that transparency should revolve around community involvement in the remedial process. Example methods provided for each phase of the project to incorporate public input.	⊙⊙⊙⊙⊙ ⊘
Overall Score	⊙⊙⊙⊙⊙⊙⊙⊙ ⊙ ○	⊙⊙⊙ ⊘⊘⊘⊘⊘⊘ ⓘ	⊙⊙⊙⊙⊙⊙⊙ ○○ ⓘ	⊙⊙⊙⊙ ○○○○○○	⊙⊙ ○○○○○ ⊘⊘⊘	⊙⊙⊙ ○○○ ⊘⊘⊘⊘	

⊙= criterion fully met; ○= criterion partially met; ⊘= criterion not met; ⓘ= insufficient information to determine

4.1 Integrative approach

Three sub-criteria were applied to examine the extent to which each framework encouraged an integrative approach to sustainability. Results for each of these sub-criteria are presented below.

4.1.1 Sustainability is a guiding principle

The ASTM, SuRF UK and SuRF USA frameworks all explicitly encourage the integration and inclusion of sustainable parameters; however, only ATSM and SuRF UK clearly articulate sustainability as an overarching and guiding principle. SuRF US fails to define in any meaningful way its 'sustainability parameters' as a guiding principle. One framework, FCSAP, does not discuss sustainability or sustainable remediation specifically, but refers only to the potential for sustainable development as one possible criterion to be used in evaluating remediation actions. WGSR approaches sustainability as an enhanced version of green remediation; the US EPA framework introduces sustainability only as a single concept in green remediation. Table 4.2 presents the definitions of sustainability, SR or GR found in the six frameworks examined. Four frameworks are discussed in detail below.

ASTM adopts Brundtland's *Our Common Future* (1987) definition of sustainable development, which helps set the tone. ASTM's sustainability objectives are introduced as "the overarching ideas and themes used to guide the implementation of sustainability for a project… [which] may apply to one or more of the sustainable aspects" (ASTM International, 2014, p. 4). ASTM notes that sustainability objectives may arise from outside sources, external to the remediation process, such as regional planning goals or internal corporate goals (ASTM International, 2014). The framework encourages proponents to set sustainability objectives early on in the remediation process to ensure participants fully understand the scope of remediation and sustainability commitments (ASTM International, 2013).

Table 4.2: Comparing the definitions of sustainability and sustainable remediation

	Sustainability	Sustainable or Green Remediation
ASTM	To create and maintain conditions, under which humans and nature can exist in productive harmony, fulfilling the social, economic and other requirements of present and future generations (p. 4).	Not Defined.
FCSAP	Not Defined.	Not Defined.
SuRF UK	It is commonly interpreted as those actions that take account of environmental, social and economic factors to optimize the overall benefit. (p. 77).	Sustainable Remediation is the application of the principles of sustainable development as described by the Brundtland report, to risk-based contaminated land management (p. 80).
SuRF US	Not Defined.	1) SR can be defined as a remedy whose net benefit is maximized through the judicious use of limited resources (p. 7). 2) SR reflects a more holistic approach aimed at balancing the impacts and influences of the triple bottom line, human health and environment (p. 7).
US EPA	Sustainable principles can help increase environmental, economic, and social benefits of cleanup (p.1), and SD meets the need of the present without compromising the need of future generations, while minimizing overall burdens to society (p. 2).	GR is the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions and GR relies on sustainable development principles (p. 2).
WGSR	Sustainability occurs at the nexus of the environmental, economic, and social/community pillars of the state's environmental cleanup program (p. 1-1). "Sustainability should be considered in remedy selection, but not compromise environmental protection" (p. 1-2). "Sustainability will have different meanings to different stakeholders, and different stakeholders may place an increased emphasis on a particular issue" (p. 3-9)	GR implements remedial actions in an attempt to reduce environmental effects; it does not include considering the evaluation of remedy alternatives. GR primarily involves environmental metrics. SR encompasses GR by including detailed analyses of project alternatives, and may include the evaluation of economic and societal costs and benefits (p. 2-1).

The overall goal of SuRF UK's framework is to embed balanced decision-making and integrating sustainable development principles into remediation project management (Bardos et al., 2011). SuRF UK proposes two definitions, six guiding principles, and two processes to define SR. The first definition describes SR as "the practice of demonstrating in terms of environmental, economic, and social indicators, that the benefit of undertaking remediation is greater than its impact, and that the optimum remediation solution is selected through the use of a balanced decision-making process" (Bardos et al., 2011, p. 80). The second definition of SR is an extension of the Brundtland principles into decision making for remediation, which set the tone for the proponent to follow.

SuRF US states that its framework is aimed at a holistic approach of balancing the impacts and influences of the triple bottom line of sustainability (Holland et al, 2011). However, the framework fails to provide information on what the sustainability parameters are. There is no guiding principle of what the framework hopes to achieve, beyond the definition to allow "systematic, process-based, holistic approach for the consideration, application, and documentation of sustainability parameters during the remediation process in a way that complements and builds upon existing sustainable remediation guidance documents" (Holland et al, 2011, p. 9). The framework refers to sustainability parameters but does not provide definitions for those parameters.

The US EPA framework only partially met this first criterion. The US EPA mission is to protect human health and the environment; accordingly, the framework is tailored to meet this mission. Due to the specific focus on environmental health, the primary scope of this framework is green remediation (GR). The focus of GR is largely biophysical, and is explained as "the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions" (US EPA, 2008, p.1). However, the US EPA does further explain that its strategy for "green remediation relies on sustainable development principles, which gives the undertone that the utility of the project is to fulfill greater environmental protection that does not preclude economic development, and economic development is ecologically viable today and in the long run" (US EPA, 2008, p.2).

4.1.2 Focus on three pillars and integration of pillars

ASTM focused on the interconnections between the three pillars of sustainability – social, economic, biophysical, in great detail. However, SuRF UK encourages the consideration of the interconnectedness of these pillars in order to fully understand a project's complexities. ASTM's framework, for example, encourages a proponent to consider the connections between the core elements of sustainability and ensure their integration into remediation practices through the use of BMPs (ASTM International, 2013). SuRF UK similarly presents the three pillars, and presents a series of guiding principles that expand beyond the three pillars to facilitate practitioner thinking about their potential interrelationships.

SuRF US presents sustainability as an overarching, unified theme to be integrated in each project phase, but addresses each of the pillars separately. The first definition provided by SuRF US of SR (Table 4.2) has a biophysical focus with only limited acknowledgment of the other pillars. However, the second definition of sustainability addressed in the SuRF US framework (see Table 4.2), uses discourse that enable the proponent to consider holistic thinking in its approach to the triple bottom line. Later on, the framework says to consider whole-system sustainability and the parameters that interact with each other (Holland et al., 2011).

Both the US EPA and WGSR frameworks include social, economic and biophysical components, but are primarily focused on biophysical components. The definition of SR used by WGSR, for example, focused on green remediation, and indicates that the analysis of remedy alternatives for a site "…may include the evaluation of economic and societal costs and benefits, along with traditional environmental considerations" (Wisconsin, 2012, p. 2-1). The framework includes a brief description of economic and social/community aspects, but presents a limited discussion on how or when to incorporate socio-economic aspects into the remediation project design.

FCSAP presents sustainability alongside various criteria in an appendix to the framework, and it does not articulate a three-pillar approach or address the interconnections between pillars.

4.1.3 Sustainability addressed beyond the guiding principle

Five frameworks support the integration of sustainability throughout the remediation process in varying approaches and degrees of integration. FCSAP was the only framework to not include any principles or goals in its framework. ASTM, SuRF UK, and SuRF US carried forward a sustainability principle that was more comprehensive and multifaceted than the US EPA or WGSR frameworks, focusing not only on the biophysical environment but also on social and community development issues as part of sustainability.

A significant aspect of ASTM's sustainability integration is through its use of the 'sustainable performance criteria', which are used throughout the framework for the selection of BMPs (ASTM International, 2014). Throughout the framework, ASTM suggests using indicators for investigations of short- and long-term “sustainable aspects” – a “collective term referring to the three key elements of sustainability: economic, social, and environment” (ASTM International, 2014, p. 4).

SuRF UK describes six guiding principles that should be included throughout the SR process, emphasizing that the process of “balancing of environmental, social, and economic costs and benefits in identifying the optimal remediation solution needs to be carried out while complying with this set of key principles, which should be considered by practitioners in the design, implementation, and reporting of SR schemes” (Bardos et al., 2011, p. 83). The six principles are: (1) protection of human health and the wider environment; (2) safe working practices; (3) consistent, clear, and reproducible evidence-based decision-making; (4) recordkeeping and transparent reporting; (5) good governance and stakeholder involvement; (6) based on sound science (Bardos et al., 2011, p. 83). The framework also differentiates two processes, sustainability management and sustainability assessment, as integral parts of SR. Both aspects are identified as fundamental for the application of sustainability to contaminated land and decision-making. Sustainability management is defined as integrating sustainability assessment in contaminated land management decision-making. Sustainability assessment is defined as a process of consensus building and to gain an understanding of all possible outcomes across the three elements (environmental, social, and economic) of sustainable development (Bardos et al., 2011).

The US EPA does not direct a specific methodology or set of principles for addressing sustainability throughout the remediation process. The framework does include six ‘core elements’ that are used as BMPs and are to be integrated throughout the remediation project scope and planning, but aside from “stewardship” all core elements are focused on the biophysical environment. The US EPA’s description of long-term stewardship actions is meant to include a socio-economic component to a largely biophysical framework. Several values associated with stewardship are identified: integrating an adaptive management approach to long-term controls for the site, and installing renewable energy systems to power long-term cleanup and future activities (US EPA, 2008). Similar to US EPA, WGSR is primarily focused on biophysical components and states “sustainability should be considered in remedy selection, but not compromise environmental protection” (Wisconsin, 2012).

4.2 Tools for Sustainability Appraisal

Two frameworks fully met this criterion (ASTM and SuRF US), and identified specific tools or indicators for considering or assessing sustainability in remediation. Two frameworks partially met this criterion (SuRF UK and US EPA); WGSR did not meet this criterion; and FSCAP could not be determined based on the information provided. The tools varied across the set of frameworks. Multiple tools were presented to facilitate or direct sustainability consideration in remediation practice that appear in several frameworks, yet there were no tools or processes that appeared in every framework. The use of BMPs as a means for sustainability assurance appeared in the ASTM, US EPA, and WGSR frameworks, but with varied definitions of BMPs.

Best management practices are defined by ASTM as "an activity that under most situations, improves one or more sustainable aspects (environmental, social, economic) of a cleanup at a specific site" (ASTM International, 2013, p. 2). An example would be an activity that "reduces the environmental footprint of a cleanup activity" (ASTM International, 2013, p. 2). The US EPA definition of BMPs, within the context of green remediation is actions that "help ensure that day-to-day operations during all cleanup phases maximize opportunities to preserve and conserve natural resources while achieving the cleanup's mission of protecting human health and the environment" (US EPA, 2009, p. 10). The framework goes on to report that that BMPs "help decision-makers, communities and other stakeholders identify new strategies in terms of sustainability…that complement rather than replace the process used to select primary remedies that best meet site-specific cleanup goals" (US EPA, 2009, p. 1). WGSR's framework adopts the US EPA's approach to BMPs, but in a slightly different way, explaining, "such a program would contain recommendations for sustainable remedies or concepts based on the nature of the site contamination or the remediation approach" (Wisconsin, 2012, p. 3-8). WGSR's approach to BMPs is a concept brought to aid 'smaller sites', whereas US EPA and ASTM do not differentiate BMPs and project size.

ASTM, US EPA, and WGSR suggest the use of BMPs in several phases to reduce or enhance desired impacts and benefits from the overall projects. For example, US EPA suggests BMPs should be integrated at certain project phases to enhance benefits: 1) deconstruction, demolition, and removal; 2) cleanup, remediation, and waste management; 3) design and construction for reuse; 4) sustainable use and long-term stewardship (US EPA, 2002). Additionally, US EPA suggests BMPs across the six core elements to help create a strong project (US EPA, 2009). The relationship between BMPs and sustainable core elements in the ASTM framework are varied and flexible, as the user can select which core elements will be relevant to the project, based on the past, present and future site (ASTM International, 2013). In ASTM, the connection between the concepts of sustainability and BMPs are bridged through several core elements: local community vitality; enhancement of individual human environments; materials and waste; air emissions; water impacts; energy; land and ecosystems; efficiencies in cleanup and cost saving; economic impacts to the local government; economic impacts to the local community; and community involvement (ASTM International, 2013). Under each sustainable core element there are several BMPs listed that can help maximize the benefits of the sustainable aspects (see section X1, ASTM International, 2013).

The conceptual site model (CSM) is identified in three frameworks (US EPA, SuRF US, and SuRF UK) as an important means to integrate sustainability into the remediation project. A CSM is a tool that users can illustrate the various pathways and receptors of the site to ensure the consideration of all the environmental parameters of a project are considered (Interstate Technology Regulatory Council, 2012). This tool is used to understand the synergistic and interconnected relationships that are present within a project site. US EPA encourages the use of "whole site planning," which requires project planners to develop a process to oversee all project goals so as to achieve sustainability (US EPA, 2009, p. 2). The sustainable conceptual site model (SCSM) is described by SuRF US as "a platform for illustrating how humans and the environment may be affected by impacts at the site and sustainability impacts caused by remediation activities" (Holland et al., 2011, p. 23). Traditionally, CSM concentrate on certain elements, exposure routes and pathways, and current and future land use. Sustainable CSM suggests "whole-system sustainability", which considers how different sustainability parameters interconnect to affect the remediation system as a whole. Sustainability thus becomes a driving principle within CSM as part of project management (Holland et al., 2011).

Similar to the CSM, SuRF UK also suggests an integrated planning scenario approach as part of remediation planning. SuRF UK does not label this stage as CSM, but it refers to the project-design stage as an opportunity to maximize sustainability integration. The purpose is to “look at synergies between remediation and development processes, to ensure risk management objectives have been optimized in a site specific manner for an operational site or a soft end use, like phytoremediation” (Bardos et al., 2011, p. 86). This reminds users that certain designs implemented at early stages may significantly impact on decisions at later project stage; thus, users are encouraged to make early design plans consistently throughout the project design.

Tiered sustainability evaluation is major process endorsed by SuRF US. Originally, SuRF US in 2009 created this process (see Ellis and Hadley, 2009). Since then SuRF US has built upon it considerably. The tiered approach as means of data collection can support the CSM and to help implement sustainability impact measures in a remediation project (Holland et al., 2011). The tiered sustainability evaluation has three layers; the first consists of non-project-specific and qualitative evaluation of sustainable aspects, project objectives. The second tier relies on project-specific and non-project specific information. This creates a semi quantitative evaluation for risk projections, exposure stimulations, cost-benefit analysis, and site-specific characterizations. The third tier is the most detailed by including quantitative evaluations such LCA, energy analysis models, social return on investment, and lastly, social accounting and auditing (Holland et al., 2011). As described by SuRF US, the objective of the tiered approach is to “balance parameters in a manner that increases the positive sustainability impacts of the project while reducing the negative sustainability impacts” (Holland et al., 2011, p. 17).

The WGSR framework is largely biophysical-focused; its tools emphasize a quantitative approach. The framework offers a series of matrices and checklists that are often duplicated in different remediation project phases. A major component of the framework is the remedial process optimization (RPO) - a “systematic approach for evaluating existing remediation systems with the goal of improving the performance of the remedy while reducing overall site cleanup costs” (Wisconsin, 2012, p. 5-1). WGSR goes on to say that RPO has been adopted to include energy consumption and waste reduction, specifically. Traditionally, RPO was only targeted for cleanup effectiveness and cost. The broadening approach was an important step in identifying remedial technologies that maximize benefits and reduce overall impacts. Because of the focus on sustainability, the remedy selection and design phase included in RPO is now part of the ‘sustainable options evaluation’. This is the process of using baseline data created from RPO then entered in the ‘sustainability matrix’ (Wisconsin, 2012). A sustainability matrix compares different project alternatives against each with a LCA on an annual basis (Wisconsin, 2012). These numbers are then compared with all core elements (e.g., energy, water, and cost), as well as other aspects that might impact the project. This matrix allows users to select and mitigate project designs to achieve lower impacts.

Similar to Wisconsin’s framework, FCSAP’s framework is largely biophysical in nature, but it provides limited tools. FCSAP simply suggests that a risk assessment be done in place of a generic remediation assessment and suggests a matrix type-rating scheme to characterize the impacts of project development. The Federal Government has acknowledged its framework’s deficits and limitations and has implemented a new sustainable development tool, which is a web based metric and rating scheme (available only for Federal Custodians). A publicly available document is expected to be released in the near future.

The FCSAP framework encouraged the use of two specific tools: Guidance and Orientation for the Selection of Technologies (GOST) and the Sustainable Development Tool (SDT). The GOST is a technology database that helps proponents select the most viable remediation option based on site attributes. The tool is set up like a questionnaire where the specific attributes and parameters of the site calculate for the recommended treatment (Government of Canada, 2012). The second evaluation, SDT, evaluates and compares up to five treatment options based on the three pillars of sustainability (Government of Canada, 2013). The proponents can choose the three pillars and weights assigned to each parameter are tailored to the specific site. Theses tools are not described in great detail, nor are they integrated in the framework.

4.3 Life Cycle Approach

All frameworks, except FCSAP, addressed some aspect of life cycle assessment (LCA) or approaches - as either an applied tool or as a broad concept in remediation practice. One framework, SuRF UK discusses both LCA as a concept and as a tool. The remaining frameworks presented either one concept or the other. The presentation of LCA concepts in the frameworks was primarily focused on quantifiable, biophysical properties. For example, US EPA, SuRF US and WGSR all promote LCA as a tool to test remedial design options. WGSR adopts LCA in its approach to the selection of remedy alternatives and project design (Wisconsin, 2012), suggesting the use of such parameters as restoration time, tonnes of CO_2 emissions, recycled materials, disturbed land (acres), natural gas, and water use. The US EPA's framework places considerably less emphasis on LCA processes, but it does encourage the use of "life-cycle perspectives to evaluate chemical, biological and economic interactions at contaminated sites" (US EPA, 2009, p. 9). Beyond this statement, there is limited integration of life-cycle calculations in the framework – aside from the frameworks guidance on site management practices, specifically air quality protection, that focuses on assessing overall consumption of fuel and pounds of CO_2 emissions associated with remediation practices and sites (US EPA 2009). SuRF US encourages site-specific parameters and preferred end-use to be evaluated throughout the life cycle of a remediation project (Holland et al., 2011). An essential part of the SuRF US framework is the tired evaluation of project alternatives and remedy selection, which includes LCA methodologies (Holland et al., 2011), offering site-specific, and quantitative analysis of remedial options.

SuRF UK and ASTM approach LCA as a conceptual process that includes analyzing lifetime impacts in a qualitative process that helps the users think of the project in a full temporal scale. ASTM, for example, suggests that time horizons should be applied consistently across the project design (ASTM International, 2013), enabling project management to address core elements and BMPs with the same temporal scale so as to have consistency in the reporting of impacts. ASTM notes that certain elements of the cleanup will have different time scales, and implementation will be different throughout the project life (ASTM International, 2013). SuRF UK's inclusion of LCA methodology encourages that the LCA boundary is included in the sustainability assessment of a remediation project, which "sets in effect a limit to the inputs and outputs that will be included in the assessment" (Bardos et al., 2011, p. 92).

4.4 Future Land Use

All six frameworks fully support and encourage the early planning for future land use, prior to remedial design and selection. This aspect encourages consistency, stewardship, and to reduce redundancies on steps in the remediation process (e.g., ASTM International, 2013, p. 6; Government of Canada, 2013, p. 16; Holland et al., 2011, p. 8; US EPA, 2011, p. 2). A key component of remediation options evaluation is to determine end use, as that zoning and land use will ultimately dictate the level of acceptable risk at a site (Bardos et al., 2011; Government of Canada, 2013). SuRF US states that some stakeholders may be more concerned about the end use or future use, than they are about the remediation process as a whole (Holland et al., 2011).

The ASTM framework, for example, suggests that project management should understand the relationship between end use selection and factors such as "existing infrastructure, recent development patterns, cultural factors, environmental justice, regional trends and community acceptance" (ASTM International, 2013, p. 3). The US EPA framework identifies the need to go one step further when considering future use, focusing on adding value to basic cleanup initiatives, such as alternative energy development, that can be used by the local community afterwards (US EPA, 2009). As such, value-added development is promoted as creating a holistic approach to post-site development plans, increasing community resilience and contributing to employment opportunities.

Land use, in WGSR's framework is a major driver and a core element of sustainable remediation (Wisconsin, 2012). Land is considered a scarce resource to and "considering end use or potential reuse of the impacted site will aid in the conservation of existing green space and assist in the revitalization of communities through brownfield revitalization" (Wisconsin, 2012, p. 2-3). The WGSR reports that future land use should be used in a sustainability metric in analyzing total area disturbed, and disturbed area should be enhanced by the remedy alternatives. Important future land use aspects that are identified include restoring ecological function and preservation, avoiding development of greenfields, enhancement of biodiversity, through parks and green space, and to redevelop a site which adds jobs and increased municipal tax base (Wisconsin, 2012).

4.5 Intragenerational Considerations

Four frameworks (ASTM, SuRF US, US EPA, and WGSR) encourage the consideration of intragenerational impacts to varying degrees. Two frameworks are slightly more ambiguous about the inclusion, whereas one explicitly uses the term; one framework, namely FCSAP, makes no reference to intragenerational considerations or concepts alike. SuRF UK could not be determined based on the information given.

Those frameworks that are more implicit about intragenerational considerations, such as the US EPA and WGSR, emphasize such actions as focusing on alternative energy use, maximizing employment opportunities, ensuring long-term financial benefits, and community longevity (US EPA, 2009; Wisconsin, 2012). The US EPA, for example, reports that increasing the sustainability of a site by use of alternative or passive technologies will build stronger communities and increase economic gains (US EPA, 2009). Similarly, WGSR reports that stronger communities could result through revitalization and brownfield redevelopment (Wisconsin, 2012), but never explicitly addresses intragenerational impacts or equality.

In contrast, the ASTM framework makes explicit mention of intragenerational considerations: "the framework encourages current and future sites with BMPs should consider intragenerational impacts and outcomes for the surrounding areas" (ASTM International, 2013, p.4). Two core elements of intragenerational considerations in ASTM's framework are local community vitality, and economic impacts to the local community (neighborhood) and local government (city or rural municipality). The list of BMPs recommended for these core elements by ASTM also include several steps to encourage economic stimulation to the local community during remediation implementation, such as acquiring goods and service adjacent to the remediation site, using local facilities and local labour, and training residents to maximize their potential to enter the workforce (ASTM International, 2013).

SuRF US mentions that the importance of sustainable remediation is the "ancillary benefits environmental end use benefits (e.g., open space and wildlife habitats) or socio-economic benefits for the community (e.g., alternative land use and housing)" (Holland et al., 2011, p. 15). This focus of having the site benefit the community and attempting to even socio-economic differences by allowing equitable development is an important aspect to intragenerational equity. Under SuRF UK, this aspect is left unspecified as there is no mention as to what the end use site should look like (such as SuRF US with housing and open spaces), nor is there mention of using local labour and services, such as in ASTM and WGSR. But, SuRF UK focuses on stakeholder consultation and on having communities focus on the end use in collaboration with the proponents. With an explicit focus on working with the community, and for the community, it could be assumed that equitable development for the community is the target, but this is not explicit.

4.6 Intergenerational Considerations

Two frameworks fully met this criterion (ASTM and SuRF UK), three partially met (SuRF US, US EPA, and WGSR), and one framework did not meet this criterion (FSCAP). Inherently, remediation projects all contribute positively to future generations by removing harmful contaminants, by reusing and restoring ecological functions. The concept of long term reduction of overall negative impacts and maximizing benefits for communities is reflected explicitly in two of the frameworks, SuRF UK and ASTM. They encourage proponents to think beyond the current generation (Bardos et al., 2011) and ensure the effective management of long-term benefits (ASTM International, 2013). Two frameworks, US EPA and WGSR, focus particular attention on intergenerational considerations in relation to energy use. Long-term stewardship, for example, plays an important role in the US EPA framework, which influences a proponent to use alternative energy options (US EPA, 2009). Energy alternatives, alongside community longevity and long-term stewardship, are identified as contributing to big picture sustainability concepts in US EPA. Specifically, the potential indirect benefits due to long-term viability and potential site reuse makes renewable energy an important aspect in community life cycle, local economy and creating social opportunities. Similar to the US EPA, WGSR also focuses on long-term alternative energy solutions as part of their framework. Other elements such as water consumption, CO_2 emissions, land restoration, and material reuse are also addressed with an inherent long-term focus.

4.7 Cultural Context

Only two frameworks, FCSAP and ASTM, directly mention the importance of cultural context and how it may impact stakeholder engagement, participation and end use design in remediation projects. FCSAP, for example, “seeks to involve aboriginal peoples and addressing psychosocial factors through capacity building and improving stakeholder relationships” (Government of Canada, 2013, p. 10). However, FCSAP provides no specific direction or methods for ensuring such considerations. The ASTM framework suggests that when determining anticipated future use the inclusion of cultural factors are important for proponents to consider (ASTM International, 2013). ASTM notes the importance of having stakeholder influence in project development, as the “arrangement of human actions that is guided by a vision of desired future” is inherent to sustainability (ASTM International, 2013, p.4). SuRF US does remind the proponent that all communications should be tailored for different sectors of the public and stakeholders, which allows transparency and clear access to information (Holland et al., 2011), but does not explicitly address the importance of cultural contexts.

4.8 Public Participation and Engagement

All frameworks, except US EPA, acknowledge that stakeholder involvement and engagement are important to the success of a remediation project (e.g., ASTM International, 2013, p. 8; Bardos et al., 2011, p. 83; Government of Canada, 2013, p. 29; Holland et al., 2011, p.15; US EPA, 2009, p. 7). Some frameworks reference multiple reasons for public involvement, such as learning key information about the site to helping identify preferred future end use, and reducing unnecessary project delays. For example, the US EPA suggests proponents to “solicit community involvement to increase public acceptance and awareness of long-term activities and restrictions” (US EPA, 2009, p.7) which is tokenistic and reduces the ability of a proponent to meaningfully engaged. However, later in the framework, US EPA suggests seeking “optimal methods that stakeholders can use to influence the direction of remediation, revitalization and to maintain an active voice throughout a project” (US EPA, 2009, p. 43). US EPA provides limited guidance on how or when to incorporate stakeholders in remediation projects, and presents a contradictory purpose for engagement.

WGSR, in contrast, identifies each project phase in which communication and stakeholder involvement should occur (Wisconsin, 2012). WGSR states that there are benefits from "transparency that revolve around community involvement in the remedial process" (Wisconsin, 2012, p. 3-2), and outlines in each project phase the need to conduct outreach, gather input, engage community leaders, and to communicate site impacts (see Wisconsin, 2012, p. 3-7). WGSR explains that "sustainability will have different meanings to different stakeholders, and different stakeholders may place an increased emphasis on a particular issue", so it is important to weight various options with public's input (Wisconsin, 2012, p. 3-9).

The SuRF US framework reports that consultation and collaboration with local communities is a fundamental process to executing a sustainable remediation project (Holland et al., 2011). It recommends that the community be consulted on the design for future land uses associated with a remediation project because the community will be the primary users of the site. This idea reaches beyond the social license to operate in that each stakeholder may provide key information about the site, as well as objectives and parameters to include as part of the remediation and assessment process. Repeatedly, the framework states that stakeholders should be engaged as early as possible and throughout the project (see, Holland et al., 2011, pgs. 8, 10, 11, 12, 15, 18, 20, 31-33). This is for fulfilling engagement and so stakeholders can identify the end use at the beginning of the project to avoid unnecessary processes and activities (Holland et al., 2011).

A major component of the SuRF UK framework is a sustainability assessment, described as a "consultative process that seeks to find consensus between the different project stakeholders" (Bardos et al., 2011, p.88). Consequently, SuRF UK "strongly endorses early engagement with stakeholders from the inception of the assessment procedure when its objectives are agreed upon" (Bardos et al., 2011, p.88). "As a rule of thumb", SuRF UK states, "where the findings are used to influence a stakeholder, that stakeholder should also have an opportunity for involvement, to comment, and to ensure the approach taken is acceptable to the stakeholder" (Bardos et al., 2011, p.89). This emphasizes the notion that when stakeholders are involved throughout the process, it may result in a more fluid and collaborative project. This also supports SuRF UK's definition that sustainable remediation is "in terms of balanced decision making" (Bardos et al., 2011, p.80).

The key objective to ASTM's framework is encouraging collaborative participation with stakeholders to ensure their views are considered in the final decision (ASTM International, 2013). ATSM emphasizes that stakeholder involvement be done as early as possible in the cleanup process, during the scoping and planning phase. ASTM acknowledges that stakeholders, with differing perceptions and values, will influence decision-making (ASTM International, 2013). A tool called community engagement charettes is suggested to foster community involvement (ASTM International, 2013). Charettes can be series of meetings and workshops where the objective is to find stakeholder consensus on various issues surrounding the project (ASTM International, 2013). Furthermore, ASTM reports that stakeholders should be able to have input on objectives and BMPs that are used to assess overall project planning (ASTM International, 2013). ASTM also has a stated goal of transparency that translates into having all documentation ready for public disclosure and to demonstrate sustainability processes (ASTM International, 2013). This also includes documentation of stakeholder involvement by specific activities, notices, and information presented (ASTM International, 2013).

FCSAP identify that engaging in consultation is important because "stakeholders can provide key information about the site history and conditions, end of use, exposure pathways, and receptors, contaminants of concern and safe exposure limits" (Government of Canada, 2013, p.29).

Chapter 5
Discussion

This chapter first presents a synthesis and discussion of the performance of the remediation frameworks against the sustainability evaluation criteria. Second, several broader observations that emerged from the analysis are presented to provide insight to the state of practice and understanding of sustainability in the SR industry. The broader themes emerged are the reductionist versus holistic debate in sustainability, sustainability as process or outcome, the variable roles of SR, and attention to the social aspects of SR practice.

5.1. Framework Performance

Three of the frameworks reviewed were specifically labeled with the term ‘sustainability’. Two of the frameworks were labeled as incorporating both ‘sustainability’ and ‘green remediation’. Only one framework included in the review was a general remediation framework, but contained a reference to sustainability as a criterion for decision making. There is no magic number of criteria that needed to be met for a remediation framework to be considered a ‘sustainable’ remediation framework.

However, overall, across the six frameworks not one fully met all of the sustainability criteria, suggesting that there is room for improvement in the remediation industry if frameworks are to help achieve sustainability objectives (see Table 5.1). Similar to White and Noble’s (2013) observation of impact assessment guidance, many frameworks adopt the language of sustainability and use the ‘sustainability’ or ‘sustainable development’ title, but do not fully integrate sustainability into practice.

ASTM was the highest-scoring framework, having fully met nine criteria and partially meeting one criterion[2]. SuRF UK fully met seven criteria and partially met two, but there was insufficient information to allocate one grade – specifically whether the framework encouraged intra-

[2] Criterion 1 consisted of three separate sub-criteria, for a total of 10 evaluation criteria.

generational land use and design. While SuRF USA only fully met four criteria, it partially met six criteria. The US EPA, WGSR, and FSCAP frameworks performed relatively poorly, with FSCAP fully meeting only three criteria and not meeting six criteria. The US EPA and WGSR were similar in only fully meeting two criteria and partially meting five and four criteria, respectively.

Table 5.1: Ranking[1] of framework based on the number of sustainability criteria[2] fully met.

Rank	Framework	# criteria fully met	# criteria partially met	# criteria not met	Insufficient information to make a determination
1	ASTM	9	1	-	-
2	SuRF UK	7	2	-	1
3	SuRF US	4	6	-	-
4	US EPA	2	5	3	-
5	WGSR	2	4	4	-
6	FCSAP	3	-	6	1

[1] Rankings of the frameworks are based on the number of criteria fully met, followed by partially met, then not met. This table does not take in account which criteria are favorable or preferred, if any, in sustainability.
[2] Criterion 1 consists of three individual sub-criteria. They are counted separately in this table, for a total of ten evaluation criteria.

The best performing frameworks were those identified as SR frameworks. These frameworks did better then those labeled as GR frameworks, yet the GR frameworks did better than the standard remediation framework, FCSAP. The premise of the ASTM framework is to focus on interrelationships between the three pillars and to provide strong overall guidance and methodology for sustainability integration, versus only a process to maintain the *status quo* with a 'sustainable calculation' or typical evaluation matrix. Overall, the ASTM performed better based on its integration of a socio-economic focus and its interrelations to the biophysical environment.

SuRF UK performed better then SuRF US, due to its focus on the interrelationships between the three pillars and the provision of a process for integrating sustainability throughout the remediation process, and not just on providing calculations or ratings to evaluate sustainability. However, looking at the principles of sustainability, SuRF US did focus strongly on participation and encouraging equitable development for future end use. This suggests that it may be possible to contribute toward sustainability in SR by fulfilling individual principles, and not necessarily focusing on integrating sustainability, *per se.* The idea of operationalizing principles into practice is known to be a difficult and complicated task (White and Noble, 2013).

Perhaps the difficulties of integrating sustainability depend on institutional culture or understanding of sustainability, such as having a primary focus on biophysical elements, but extending the focus to include the socio-economic components of sustainability. For example, US EPA claims that SR is simply the addition of the two pillars to GR. However, true sustainability is more than considering the three pillars in a single assessment or evaluation process (Bond and Morrison-Saunders, 2011; Pope et al, 2004). Indeed, new SR literature also acknowledges that there is a difference between the shifts from traditional remediation to GR to SR (Hadley and Harclerode, 2015). WGSR, US EPA, and to an extent SuRF US, all focus on biophysical environments, however their approach was assessed in this study as favorable to fostering sustainability.

The label of 'sustainability' may sometimes be used as a label of convenience in WSGR and US EPA; however, the adoption of practices such as alternative energy use, future socio-economic land use considerations, and stakeholder consultation, whether adopted as part of a broader sustainability mandate or not, can make meaningful contributions to the otherwise biophysical-focused frameworks.

5.1.1 Criterion performance

Not all criteria were met equally, and there was considerable variability across criteria (see Table 5.2). Only one criterion, early integration of land use design as part of the project and the remedial treatment selection (criterion 4), was fully met by all six frameworks. This is perhaps not surprising, since remediation is inherently designed to restore previously used, barren, or contaminated lands and ensure some degree of suitability for future use (Bardos, 2014). The focus of early consideration of land use was not surprising, important factors like value of land, location, contamination type and levels would be predetermined factors when prioritizing sites for remediation. Additionally, future land use would be considered important for allocating government or investment funds for cleanup. That said, how future use was considered in the frameworks varied. Four frameworks encouraged the early integration of land use plans in the overall remediation project concept and in the remedial treatment options; two suggested this as a process to reduce unnecessary steps of treatment options to align with site end use and acceptable risk; and one framework considered future use as part of a sustainability metric checklist to be carried throughout the evaluation process for treatment options.

Table 5.1: Criterion performance

#	Criterion	# frameworks fully meeting	# frameworks partially meeting	# frameworks not meeting	Insufficient information to make a determination
1a	Integrative approach: Sustainability is presented as a guiding principle	2	2	2	-
1b	Integrative approach: Relationships between the three pillars are acknowledged	2	1	3	-
1c	Integrative approach: Sustainability is present in the framework beyond the statement of a guiding principle	2	3	1	-
2	Specific tools or indicators are identified for assessing sustainability	2	2	1	1
3	Life cycle principles or tools are identified or encouraged	1	4	1	-
4	Future land use and design is part of the remedy alternative selection process	6	-	-	-
5	Encourages intra-generational land use and design	4	-	1	1
6	Encourages inter-generational land use and design	2	3	1	-
7	Encourages engagement in a culturally appropriate context	2	2	2	-
8	Public participation is integrated throughout the framework's prescribed process	5	-	1	-

The second most satisfied criterion was public participation, fully met by five frameworks. Several frameworks satisfied this criterion, which outlines the importance of collaboration with communities affected by the project to remediation practices regardless of sustainability claims. Indeed, "participation has become something of a holy grail in development literature" (Bell and

Morse, 2008), and Fidler (2010) claims that incorporating local concerns into decision-making around development can improve outcomes. Open dialogue is also considered very important to sustainability and is supported by the Aarhus Convention and other legislative 'rights to participate' (UNECE, 1998; Bond Morrison-Saunders, 2011). Pintér et al. (2012) also link democracy and participation to long-term policy design that can generate public legitimacy and accountability by fostering more equitable outcomes (p. 21).

However, though a much-promoted concept, there are often significant difficulties in achieving participation in projects (Bell and Morse, 2008) and, in some cases, can be less meaningful as US EPA claims to 'solicit public involvement to increase acceptance' (US EPA, 2008, p.7). The US EPA framework focuses more on *managing the public* or consulting the public for the sake of trying to minimize conflict – a well recognized, but poor practice approach to engagement (Arnstein, 1969). Such tokenistic participation (Arnstien, 1969; Collier and Scott, 2009; Escobar, 2014), as opposed to genuine involvement, ultimately poses a significant barrier to the long-term legitimacy of any development and often results is a lack of public trust in the project. Arnstein (1969) discusses the various levels of public engagement that range from nonparticipation to citizen power; overwhelmingly in the sustainability literature citizen power and collaboration are identified as key to sustainability and also key to meaningful engagement in any forum (Bond et al., 2013; Gibson et al., 2005; Pintér et al., 2012). Consultative and collaborative learning processes– all of which are key characteristics of meaningful participation (Collier and Scott, 2009; Sinclair and Diduck, 2009) and imperatives to sustainability (Bond et al., 2013; Gibson et al., 2005). As Mascarenhas et al. (2015) confirm, involving many stakeholders in the process and empowering them with choice will result in higher project success. Cundy et al. (2013) similarly suggests that stakeholder involvement is increasingly becoming a "key requirement for the optimal application of [SR] strategies" (p. 285).

Two criteria were tied in terms of being the least met criteria across the six frameworks: sustainability as a guiding principle; and integrating the three pillars of sustainability. White and Noble (2013) found that the sustainability concept is often introduced as a guiding principle in many impact assessment frameworks, but not integrated beyond that initial statement. In this study, it was found that those frameworks that do adopt sustainability as a guiding principle tended to provide better guidance for greater integration of sustainability throughout the remediation process than the frameworks that failed to adopt sustainability as an overarching principle.

The concept of sustainable development is clearly the basis for sustainability assessment and the diverse interpretation of this is a three-pillar concept or triple bottom line (TBL) (Pope et al., 2004). The TBL approach to sustainability represents the traditional approach to sustainability, and it is often difficult to articulate sustainability beyond this known concept. Originally, environment and development issues were the only two concepts Brundtland focused on as the primary concern (Pope et al., 2004). Since then, the separation of development issues into separate 'social' and 'economic' pillars has slightly changed the conceptual framework into measurable gains. Gibson emphasizes, "material gains are not sufficient measures or preserves of human well-being" (Gibson in, Pope et al. 2004, p. 597). Development issues like well-being should be the measure of sustainability, not solely economic gains.

Merely measuring the TBL is not good enough, and it does not move the user away from 'unsustainable thinking'. This relates to the idea of the "tendency to grow socioeconomic capital through new development while at the same time nibbling away at natural capital" (Bond and Morrison-Saunders, 2009, p. 327). Furthermore, defining a SR framework, or any sustainability process, as simply including the TBL, risks that its users can loose sight of the ultimate goal, to reduce unsustainable decision-making. Pintér et al. defines "the progress toward sustainable development will be guided by the goal of delivering well-being within the capacity of the bio-sphere to sustain in for future generations" (2012, p. 22), which can easily be lost in absence of a guiding principle. The shortcomings of the TBL approach can, however, be mitigated with the use of indicators and objectives, such like the Bellagio Principles (see Pintér et al., 2012), broad sustainability principles reported by Gibson et al. (2005) (see also Gibson 2006a; Gibson 2006b), or the SA imperatives proposed by Bond et al. (2013), which can help bridge the gap in remediation practices between traditional biophysical site remediation actions and considerations of broader socio-economic dependencies on the environment – including human health and well-being.

Three criteria, typically cited in the literature as essential elements of sustainability, were not well addressed by the frameworks, namely: inter-generational equity, intra-generation equity, and recognizing cultural sensitivities. Granted, such aspects are difficult to address if sustainability itself is not well defined or represented beyond the three individual pillars (see United Nations, 1987). The fact that so few criteria were met across all six frameworks, overall, may be because sustainability is a concept that is difficult to operationalize (Brunner and Starkl, 2004) or perhaps, it is a concept that is not seen as having practical application beyond basic principles (White and Noble 2013).

Achieving sustainable development "depends on a myriad of interconnected factors and the entire socio-ecological system needs to be considered as a whole…but the most significant problems that jeopardize [it] are wicked" (Pintér et al., 2012, p. 22). These problems are very complicated and may be impossible to solve, and the pursuit of sustainability may never be attained by an end-state (Gibson, 2006b). Nobody is likely to disagree that sustainability is a good guiding principle for remediation; and scholars have argued sustainability serves little merit in the absence of criteria that can be operationalized and practical guidance on how to do so (see White and Noble, 2013). However, this research suggests that there is a need for greater awareness and integration of the broad goals of sustainability - particularly in the absence of the consensus on indicators, a universal framework, or metrics for a sustainability framework (Fortuna et al., 2011). In this regard, Favara et al. (2011) argues the need for further guidance to help practitioners in understanding and implementing 'sustainable' remediation.

5.2 Observations

The sections below outline several key observations emerging from this research, beyond the performance assessment of the remediation frameworks. These observations are not presented in any order of importance. The observations relate to the debate around sustainability being *holistic* or *reductionis*t in approach; understanding the context for SR; whether the structure of SR should be *processes-based* or focused on *outcomes*; and, the nature of social methods and indicators in SR.

5.2.1 Holistic versus reductionist approach to sustainability

Based on the analysis of the remediation frameworks, there is evidence to suggest that the remediation industry is struggling with the symptoms of a critical debate in applied sustainability assessment and evaluation. Much literature discusses the struggle of sustainable decision-making given the lack of a prescribed approach for the structure and assessment or evaluation process (Bell and Morse, 2008; Bond and Morrison-Saunders, 2011; Bond et al., 2013; Pope et al., 2004; Ritcher et al., 2015; White and Noble, 2013). Half of the frameworks examined in this study tended to approach sustainability as a holistic concept (ASTM, SuRF UK, and SuRF US). Bond et al. (2013, p.43), suggesting that a holistic approach is one that facilitates "moving away from analyses of isolated risks and towards a broader understanding". The benefit of the holistic approach, in principle, is that it can deal with complex systems without loosing focus of the 'whole' (Bell and Morse, 2008). This idea is consistent with the Bellagio Principles that claim, "sustainability should be considered in a holistic sense" (Hodge and Hadi, 1997 in Bell and Morse, 2008, p. 22). This does not mean that sustainability must be a broad and fuzzy concept. In a review of sustainability integration in impact assessment, for example, White and Noble (2013) argue that a "structured framework, can readily support sustainable development goals and objectives by… incorporating sustainability considerations directly into impact assessment tool" (p. 61). While flexibility is important to holistic thinking, it need not exclude the use of a clearly structured approach to sustainability integration throughout a remediation process.

The remaining frameworks tended to reflect a reductionist approach to sustainability (FCSAP, US EPA, and WGSR). Bond et al. (2013, p. 42) define reductionism as "breaking down complex process to simple terms or components". In this regard, a selection of sample indicators is often used to represent the state of whole and complex sustainability systems. Such an approach facilitates the separation of environment into the three pillars of sustainability. This method is sometimes criticized by scholars for selecting the wrong indicator, too few indicators, or too many indicators (Bond and Morrison-Saunders, 2010; Rinne et al., 2013). A benefit of its use in a large-scale remediation projects however is the ability to quantify various impacts, and then to compare complex remedial alternatives using standard metrics. Arguably, however, the compartmentalizing or over simplification of project components into separate quantifiable packages may be seen as ‘bad science’ or the distillation of impacts into separate, disconnected units that do not reflect the complexity of real environmental systems (Bell and Morse, 2008, p. 41).

Specifically in the SR context, the ‘reductionist’ approach is necessary to calculate and assess remedial options. However, before those calculations are truly considered in decision-making, they must conceptualized in a holistic manner, considering the potential interrelationships between biophysical and socioeconomic components and the complexities of real world socio-ecological systems, thus ensuring their proper use and appropriateness for the specific context of the site. Once appropriate options are considered (e.g., congruent with future end use), those options can be comparatively analyzed in detail for the most appropriate action.

Often, reductionism and holism are pitted against each other, where a user will use one but not the other, or the ideologies are comprised of irreconcilable differences. In practice, there should be plenty room for both sets of processes, and indeed in particular contexts one choice may be preferred over the other. For example, if there is an emergency response to a toxic spill, using a three pillared-approach (or even single-pillar, i.e. biophysical focused) to reduce impacts within a timely manner may be the appropriate solution. The risk associated with this may warrant very little holistic thinking or stakeholder consultation, as an immediate response to control or prevent a catastrophic event is needed. In regards to larger sites or other types of problem, however, without holistic oversight the project may result in redundant steps through inappropriate remedial option selection, and failure in achieving a meaningful end-use. Generally speaking, a balance of both holistic and reductionist approach is necessary in a continuous and fluid motion.

5.2.2 Understanding the context for sustainable remediation

Remediation has slowly evolved from simple ‘dig and dump’ methods to using complex biological and chemical processes. Conventional approaches to remediation and contaminated land management had traditionally focused on containment, cover, or removal to landfill (Cundy et al., 2013). Since the late 1990s, the shift from ‘dig and dump’ methods has resulted in a range of new technologies both, *in situ* and *ex situ* treatment options (Camenzuli et al., 2014; Cundy et al., 2013; Fortuna et al., 2011). In the last decade, there has been a tremendous shift to SR and as a result a series of tools and technologies have been developed to make remediation *more sustainable*.

There is general agreement that SR reduces the overall negative impacts associated with remediation projects (Bardos, 2014; Cundy et al., 2013; Ellis and Hadley, 2009; Hadley and Harclerode, 2015); however, remediation frameworks are often designed for different applications and within different contexts. The concept of sustainability often reflects individual and institutional values, and SR itself is also quite varied – presented as a process to optimize biotechnology, to integrating stakeholder cultural values, for land renewal through brownfield revitalization (see CABERNET.org), to optimize project performance with matrixes, or to ask the question about whether to remediate at all (Beames, 2014; Cundy et al., 2013; Döberl et al., 2013; Fortuna et al, 2011). SR must focus on using the most sensible and appropriate methods of contaminate removal or containment and, if applicable, maximize benefits from land reuse (Fortuna et al., 2011; Cundy et al., 2013).

The variety of SR functions should be considered a strength and provide more rationale for its need as a tool in contaminated land management in remote, rural, and urban settings. There is literature that speaks to the importance of understanding and determining the nature and context of a project, which can dictate the effectiveness of an assessment or framework (Bond et al., 2013). Of course, it is necessary to employ proper technologies for the natural characteristic of the site (Döberl et al., 2013). However, the general argument about context is that what is useful, important or effective in one context, regulatory system or resource sector may not be considered under another (Hanna and Noble 2015; Mascarenhas et al., 2015). Hanna and Noble (2015) caution, however, that whilst context is important for understanding, among other things, why an assessment process may or may not advance sustainability, it is not an excuse for a less than effective system and "nor does it preclude the evaluation or audit of…processes for effectiveness using generally accepted evaluation criteria" (p. 122)

Indeed, different remediation frameworks are designed for different purposes, but that does not diminish the importance of whether such frameworks should deliver on sustainability principles.

If a remediation framework claims to address sustainability, then there should be clear guidance for how to do this throughout the framework and an expectation that the basic principles of sustainability (identified in this research and criteria for framework evaluation) are evident. Regardless of context, there are common qualities that remediation frameworks must possess if they are to contribute to sustainability: a focus on end-use throughout the entire process; an attempt to achieve a fair and equitable future end use; encouragement multi-scale jobs for communities; stakeholder empowerment; reduction of emissions; and, optimal remedial selection (including development of bio- and phyto-remediation, where applicable).

5.2.3 Sustainability: process versus outcomes

A third issue that surfaced from this research, and also an ideological debate around sustainability, is whether tools or concepts will direct the industry to achieving sustainable remediation outcomes. Current sustainability literature addresses the disagreement on how an assessment should function. Mascarenhas et al. (2015) mention that considering specific targets and goals is an obvious choice to achieve desired outcomes, but then presents a counter argument that planning should be 'process-based' rather than 'fixed-goal' oriented. Such is the contested nature of sustainability, it has no starting point, nor an end point; therefore, what the 'outcome' or goal should be, is often a source of disagreement, if not outright conflict (Bell and Morse, 2008; Bond and Morrison-Saunders, 2011). Arguably, if sustainability approached *only* as a process-based function, there would be much distillation of complex issues into quantifiable jargon, similar to the reductionist debate (Bond and Morrison-Saunders, 2011). "Rather than viewing intervention as the implementation of a planned action, it should be visualized as an ongoing transformational process" (Long and Long 1992, in Bell and Morse, 2008). Hou, Al-Tabbaa, and Guthrie, (2014) similarly assert that without relevant goals or policies from within the corporate structure, there would be no performance, or project-based goals to achieve a difference, and might result in greenwashing.

A balanced approach is needed to ensure that processes are broad and encompassing of the complex societal and ecological aspects of sustainability (Bell and Morse, 2008). Complex projects will need quantifiable and detailed data to support transparent decision-making, and for any project to have meaningful benefits and minimize impacts, goals must be set to achieve a 'sustainable' outcome, whatever 'sustainable' may mean. The frameworks examined in this research that included holistic references to sustainability were more concerned in achieving positive outcomes. For example, SuRF US aims to "provide a systematic, process-based holistic approach" (Holland et al, 2011, p. 34). ASTM and SuRF US also includes a concept-based outcome versus, the more tool-based process approach from WGSR and US EPA.

5.2.4 Social indicators and methods

In most frameworks, socio-economic aspects were not clearly defined and social-specific methodologies were not included. Most of the frameworks (ASTM, SuRF UK, SuRF US, US EPA, WGSR) acknowledged the benefits of including socio-economic aspects to the sustainability of a remediation project, and commonly referred to including a social or community focus in the framework's goal or focus; however, some fell short of meaningful inclusion of social components (e.g. US EPA and WGSR).

There are six social indicators identified in SuRF US and SuRF UK: impacts on human health and safety; ethical and equity considerations; impacts on neighborhoods or regions; community involvement and satisfaction; compliance with policy objective and strategies; and, uncertainty and evidence (Bardos et al., 2011; Holland et al., 2011). SuRF US suggested using social indicators late in an assessment, once the key decisions about remediation have been made, and also notes that this late stage of assessment, in which social indicators are addressed, may not always be necessary to complete (see, Holland et al., 2011, p. 19-22). ASTM did not have a list of indicators, but their BMPs did include items such as local training, using local labour, ensuring contractors and suppliers have social responsibility policies, and specifying a minimum number of local workers for higher qualified jobs or training local residence for those positions (ASTM International, 2013, p.14). US EPA's strong biophysical focus significantly reduced its ability to carve out a proper space for socio-economic considerations along side its 'sustainable goals', and gives no attention to social aspects or the integration of social dimensions in the framework. WGSR defines social and community metrics (e.g., safety, traffic, fugitive dust, vapors, noise, land reuse, engagement, jobs, transparency, and building community assets like parks or green space) (Wisconsin, 2012, p. 3-2), but with limited direction for integration or guidance on when to consider such indicators in project assessment.

Hou and Al-Tabbaa (2014, p. 29) argue that "the lack of social sustainability consideration may be attributed to an institutional barrier: people working in the remediation industry have focused too much on technology, with little attention and knowledge on the social aspects of the issues [but…] inclusion of such considerations may also help increase the environmental restoration process". In 2014, a study of remediation practitioners showed that social sustainability was ranked as one of the lowest adopted methods; and attributed this, in large part, to the lack of knowledge and consensus on how to achieve 'social sustainability' (Hou, Al-Tabbaa, and Guthrie, 2014, p. 908). Reddy et al. (2014) suggest as an urgent priority the need to develop social tools by SR practitioners. Selecting social indicators, however, requires making a value judgment about which indicators to include, exclude, and/ or the project's primary goals (Sala et al., 2012b). Unlike biophysical components, which can operate like a binary platform of: present- not present; applicable- not applicable, social impacts may not be readily present and are often difficult to measure, such as individual or community well being. Unfortunately, choosing applicable indicators, particularly within the context of end-land use, and examining the potential social impacts or benefits is often outside the scope, and training, of remediation practitioners. Mascarenhas et al. (2015) suggest that experts select such indicators through participatory approaches- and through a participatory approach stakeholders are likely to feel empowered and likely to take ownership of the project. Even if not all indicators are used or deemed relevant, the better inclusion of social consideration in remediation can help change some of the discourse of current remediation practice (see Reddy et al., 2014).

5.3 Recommendations

Through this research, it is clear that operationalizing sustainability in a meaningful way is difficult. However, by promoting sustainability through objectives, principles and goals it is much easier to attain a healthy outcome, which is the most important concept in sustainability

(Bond et al., 2013; Gibson, 2005). Arguably, making sustainability operational in remediation frameworks in an effective and meaningful way requires, at a minimum:

1) *Institutional understanding, training, and support for sustainability, both in public policy and specifically at the corporate level;*
    a. Training individuals and community members involved in the project on what sustainability means in broad terms, and how sustainability should be approached based on the context of the specific project.
    b. Encouraging the use of both holistic and reductionist thinking.
    c. Challenging the status quo to achieve *better* outcomes, and not just less-adverse ones

2) *The development of overarching guiding principles and goals that are founded on basic sustainability principles;*
    a. The development of principles that are outcome focused, equitable, and that aim to preserve ecological functions as a priority.
    b. The use of collaborative approaches, involving stakeholders and proponents, to identify goals with respect to the context of the project.

3) *The development of basic indicators and tools for practitioners to adopt in evaluating contributions to or detractions from sustainability, including supporting tools such as LCA or GOST;*
    a. Populating matrix, checklists, or high complex crosswise methods (like LCA) for comparison of data will help give real insight to projects.
    b. Stakeholders have input on the selection of indicators with regard to context.
    c. Ensure data compared is relevant to the project and its context. Avoid redundant and unnecessary steps by holistically planning prior to detailed calculations.
    d. Balance appropriate methods and indicators with broad principles and goals, should result in more meaningful results.

4) *Meaningful engagement in remediation practices;*
    a. Emphasis is placed on partnership building and , collaboration.
    b. Innovative tools are processes (e.g. Expert Choice, iTracks) are encouraged to ensure efficient and informed participation, whilst avoiding stakeholder fatigue caused by over-participation.

5) *Multidisciplinary remediation teams to tackle the social context of the project and its interrelationships with the biophysical environment.*
    a. The use of skilled remediation teams with balance of social science, humanities, and hard science knowledge, skill sets and understanding.
    b. A willingness to work outside disciplinary silos to create new and innovative interdisciplinary and trans disciplinary solutions.

These five elements could help implement sustainability in practical and in meaningful terms in SR. However, as each project is different, it is important to understand the context of the land and contaminants, and the specific nature and interests of the local publics. The benefits of common guiding principles, tools, and indictors are to ensure that all players engaged in the SR process understand what it is that is to be achieved. In doing so, SR projects could result in real tangible benefits, which may result in more users of SR frameworks, which may ultimately sharpen and refine future SR contributions to sustainability.

Chapter 6
Conclusion

International consensus is starting to emerge internationally on the value of SR in reducing the impacts and maximizing the long-term benefits of remediation projects, thus ensuring an overall net benefit to social, economic, and biophysical environment – the foundations of sustainability (Bardos, 2014; Cundy et al., 2013; Hadley and Harclerode, 2015). However, there is no universal framework or guidance for incorporating sustainability considerations in remediation projects (Bardos, 2014; Bardos et al., 2009; Ellis and Hadley, 2009; Fortuna et al., 2011; Hadley and Harclerode, 2015; Hou and Al-Tabbaa, 2014), and no specific directive has been finalized for ensuring sustainability integration in SR. This research was based on the premise that the lack of a consistent framework, and set of principles for sustainability integration in remediation frameworks was, and continues to be a barrier in accomplishing sustainability in remediation practice (Bardos, 2014; Ellis and Hadley, 2009). Indeed, these barriers are recognized broadly in the international sustainability literature (see Dimitrov, 2010; Pintér et al., 2012). This research thus filled a gap in current understanding of how sustainability is best integrated in SR frameworks, with a focus on social and economic elements. This research further proposed a set of principles for examining the integration and operations of sustainability within remediation frameworks.

This research compiled and applied normative principles of sustainability, then adapted them as a set of criteria to evaluate six international remediation frameworks. The sustainability principles reflected the major values from sustainability literature and some remediation specific aspects found in literature. Out of the six frameworks reviewed, three were identified as sustainable remediation, two were labeled as green remediation, and one carried neither label. This selection of frameworks provided insight to the difference between a traditional remediation framework and a SR framework. None of the frameworks fully met the set of eight criteria, suggesting there is room for improvement in the remediation industry. The best performing frameworks were

those identified as SR frameworks. These frameworks did better than those labeled as GR frameworks, yet the GR frameworks did better than the regular remediation framework.
Not surprisingly, the consideration of future land use was a major component of all six frameworks. Public participation was acknowledged in all six frameworks, however it was not always in the form of meaningful engagement but rather focused on ensuring public buy-in of the remediation project.

Several underlying debates in current sustainability literature were also evident based on the frameworks' approach to sustainability: the competing use of holistic versus reductionist approach to sustainability; SR structure should be outcome-based or procedural; the influence of context of SR itself; and, the complex challenge to integrating social considerations and indicators alongside biophysical, especially, in a field traditionally dominated by the biophysical sciences.

Further research into case studies comparing the different frameworks would be advantageous to the SR industry, with the end goal to develop a universal framework for SR or, at a minimum, agreed-upon principles for sustainability integration. Those suggested in this research are perhaps a starting point. In urban settings understanding the relationship between SR and urban regeneration of post-industrial landscapes could foster urban sustainability and revitalization of many cities. The role of SR in urban settings will be a key player for municipal level policies,, planning, and future development. Additional research into the role of *in situ* technologies (such as bio-remediation, phyto-rememdiation, and so on) may facilitate an increased focus of contaminated sites in difficult and remote areas. Social indicators and supporting methodology for integration in remediation is also in need of additional research and focus. Future research could provide practical guidance to practitioners on how to address social issues, how to quantify social phenomenon, and social methodologies in remediation projects. This increased comfort level may result in greater overall inclusion and efficacy of social aspects in SR. Additionally, increased inclusion and efficacy, could help address the larger picture of sustainability, reducing poverty and restoring equality.

Increased SR discourse may bring more regulator drivers for various levels of government, regulatory bodies and legislation, which in turn, would act as a symbiotic relationship of more SR (Hou, Al-Tabbaa, and Guthrie, 2014). SR industry has largely grown as a result private corporate business and public pressure to do better. Until recently, there as been limited scholarly attention on SR, with increased focus on SR may result in more research to develop, test, and advance sustainability principles in SR.

As the context of each remediation project is vastly different, each framework should reflect an inherent adaptability. However, as more frameworks are created, and more projects are completes, the knowledge of the industry will grow and agree upon a working framework or process. With increased project experience, teams and communities will embrace SR as can achieve tangible outcomes and trust.

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