Risk Management in the Extractive Industries: Environmental Analysis and Mitigation

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Abstract

Risk management has been used regularly in the mining industry over the last few decades. The majority of those instances have focused on health and safety issues. Health and safety has improved in the United States, Australia, and other major mining districts because of the successful use of risk management and mitigation practices. Risk management has been used to a lesser extent to reduce or avoid environmental issues as well. There are a number of factors that make utilization of risk management analysis more applicable to health and safety than to environmental issues.

This thesis explores the use of risk management in the context of environmental issues associated with mining. Specifically, two case studies are developed in two self-contained manuscripts: the first focuses on sequestering CO2 while the second focuses on wild rice in Minnesota with regards to the sulfate standard. Through the lens of risk management, an attempt is made to align project goals and efforts with mitigation potential to reduce the likelihood or result of particular risks.

The end result is a reduction in risks due to mitigation. The first manuscript shows how risks disappear over time because they have been categorized and addressed. The project goals are keep on track by eliminating or reducing these risks. The second manuscript can be used by stakeholders to review their potential risks and mitigate those risks if possible/necessary. In contrast to the first manuscript that contains risks that are known and measurable, the second manuscript examines different risks based on four potential outcomes.

Preface

Risk management is a set of techniques to minimize the effects of a particular incident or scenario. These incidents and scenarios are known as risks. The process of identifying, qualifying or categorizing, analyzing, and ultimately mitigating these risks is the process known as risk management. The uses and applications of risk management are vast and varied. There are situations where its use may be less effective than others, but almost all situations can benefit from a degree of risk management. These following two manuscripts detail efforts to use risk management to improve the likelihood of a successful project and the fulfillment of stakeholder needs. The latter is not always universally achievable as will become apparent when different stakeholder needs overlap. The methods provide mitigation options for each group, even if the outcome is not ideal for one or the other.

The first manuscript examines leakage potential for CO2 when stored in two different geologic formations: Pennsylvanian-aged unminable coal seams and the Devonian-aged Chattanooga Shale. The goal is to determine potential risk points and develop a method to lower that risk. The manuscript was developed for the 23rd World Mining Congress. It was presented on August 13th, 2013 during the Carbon Management session. It has been modified from its original version to reflect changes to the risk registry and includes a review of developments since it was originally prepared in Spring 2013.

The second manuscript focuses on stakeholder groups and their relative risk. Four risk profiles are created which reflect possible levels of a new Minnesota sulfate standard. The debate regarding the sulfate standard and its effect on wild rice growth is examined with risks for each of the stakeholder groups analyzed. Mitigation options are recommended and patterns explained based on the results.

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Finally, I would like to thank the Virginia Center for Coal and Energy Research and the Virginia Tech Mining and Minerals Engineering Department for allowing me this opportunity.

Attributions

Dr. Nino Ripepi works for the Virginia Center for Coal and Energy Research and the Virginia Tech Mining Department. He was instrumental in developing the risk registry used in *Risk Management in Carbon Sequestration: Case Studies from Unconventional Reservoirs in the Appalachian Basin***.**

Ellen Gilliland works for the Virginia Center for Coal and Energy Research. She provided valuable insight to both the risk registry and technical elements used to develop the *Risk Management in Carbon Sequestration: Case Studies from Unconventional Reservoirs in the Appalachian Basin*.

Dr. Gerald Hill works for GERALD HILL PHD, Inc. He played a pivotal role in developing the risk registry used in *Risk Management in Carbon Sequestration: Case Studies from Unconventional Reservoirs in the Appalachian Basin*.

Dr. Michael Karmis is the director of the Virginia Center for Coal and Energy Research. He provided insight to the risk registry, as well as the development of the *Risk Management in Carbon Sequestration: Case Studies from Unconventional Reservoirs in the Appalachian Basin.*

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RISK MANAGEMENT IN CARBON SEQUESTRATION: CASE STUDIES FROM UNCONVENTIONAL RESERVOIRS IN THE APPALACHIAN BASIN

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ABSTRACT

Risk management has taken on renewed vigor since the economic crisis of the late 2000s. The resources of governments, individuals, and corporations are being stretched to a point where only the most promising projects move forward. Risk management is a crucial part of the decision making process, yet it remains a broad term that includes disciplines from engineering to finance. A collaborative effort will be necessary to ensure that the most auspicious and appropriate projects are the ones that progress. Risk management can be quantified to an extent by comparing the likelihood of an instance with the result of consequence of the instance occurring. In this manner it is possible to assign risk factors to instances and ultimately, begin to associate monetary value to the instance.

Carbon sequestration is an emerging field that has a number of unique challenges. Risk management and mitigation must be an integral part of the overall picture. This begins with the planning and design phase, continues through implementation and production, site closure, and does not cease until termination of liability. The ability of carbon sequestration projects to successfully assess, mitigate, and recover from leaks will be a decisive characteristic of overall success. The costs of mitigation and failure will need to be analyzed on a test level, but will still need to be reliable enough to extrapolate to a commercial level operation.

This paper will build a risk management profile based on case studies and field tests in Tennessee and Virginia. These tests are scheduled to commence in early 2014 and consist of small-scale injection tests in unconventional storage reservoirs with an emphasis on enhanced coalbed methane (ECBM) recovery and enhanced gas recovery. The ultimate goal will be to provide a clear and concise direction to move carbon sequestration from the test phase to commercial scale. While it is necessary from a risk management perspective to analyze all risk points, the scope of this paper will focus on pre-injection risk assessment for carbon dioxide (CO2) leakage potential. Despite the differences between the two tests, coalbed methane compared to shale among other differences, a framework for analysis and mitigation can be developed pertaining to

leakage risk. The probability of each type of failure will be assessed and analyzed, and plans to mitigate or reduce these risks will be reviewed. Furthermore, risks were analyzed in five categories; environment, health and safety, cost, reputation, and schedule.

Case Studies: Project Overview

The case studies used in this risk assessment are both injection tests assessing the potential for carbon sequestration. The Central Appalachian CBM test will inject up to 20,000 metric tons into multiple coal seams including several of the Pocahontas seams. The net seam thickness is 15-20 feet (Vasilikou, 2013). The CBM test will occur in Buchanan County, Virginia. A nearby site has already been used to inject 1,000 tons of CO_2 in 2009 (Ripepi, 2009). The geological characteristics of the site are stable and suitable. The operator wells are considered to be depleted making this a promising test of Enhanced Coalbed Methane (ECBM) extraction. Furthermore, there is a single mineral owner, with the majority of surface ownership who is supporting the injection test.

The second case study will examine the ability of the Chattanooga shale to sequester carbon dioxide. Shale formations have taken on greater importance in the last decade, as they have experienced extensive drilling to recover natural gas. The extent of shale formations and the projected amount of natural gas to be produced from them means that large quantities of CO_2 can likely be sequestered if the shale formations are found to be geologically suitable. The test will utilize a "huff and puff" injection method. This means the injections will occur for a short period of time, followed by a soaking period where the well will be shut-in and the formation will be allowed to adsorb CO_2, and then followed by a flowback of the well where production rates and gas quality will be monitored. This study will inject between 300-1000 tons of CO_2 into the Chattanooga shale. The test site is in Morgan County, Tennessee. The site is close to several state parks which is a potential risk from the public acceptance viewpoint as the project may face greater scrutiny and resistance from government and citizens who believe there is a risk of contamination.

Risk Management Overview

An understanding of risk is necessary to successfully evaluate and develop a management and mitigation plan for carbon sequestration. Risk can be defined a number of ways, yet is simply expressed as "a threat, real or perceived, to that which we value" (Covello, 1985). A fully developed risk management plan has a number of key components. It must measure the probability, result, and magnitude of an event or instance. The ultimate goal of a risk management exercise is to choose the best possible outcome in a given situation. This often requires the use of qualitative and quantitative measures, which lend themselves to a single, optimized result.

It is important to consider that different scenarios necessitate different frameworks. Elaborating on the basic definition the International Organization of Standards states, "Risk management is the identification, assessment, and prioritization of risks, followed by the coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events" (ISO 31000, 2009). The definition provided by the International Organization of Standards describes risk in a purely negative manner.

John Moteff explains the basis of proper assessment in his report to congress by providing the following bullet points on proper assessment technique (Moteff, 2005):

Assessments

- *Identify assets and identify which are most critical*
- *Identify, characterize, and assess threats*
- *Assess the vulnerability of critical assets to specific threats*
- *Determine the risk (i.e. the expected consequences of specific types*
- *of attacks on specific assets)*

Using Assessments to Identify and Prioritize Risk Reduction Activities

- *Identify and characterize ways to reduce those risks*
- *Prioritize risk reduction activities based on a risk reduction strategy*

These same techniques can be applied to the Tennessee and Virginia injection tests, specifically to analyze leak potential. Each step of the process is necessary to create a balanced and well managed risk mitigation plan. It is often easy to overlook extreme risk incidents because the likelihood of that event is very low. The problem with this is that mitigation plans cannot be developed, even in the most unlikely of events, if the risk is not considered serious enough to garner attention and inclusion.

Leakage Risks Analyzed

There are a number of leakage scenarios related to the shale test in Tennessee and the CBM test in Virginia. From a risk management perspective it is important to analyze each project individually, but also consider the possible similarities between the two projects. A collaboration between the Virginia Center for Coal and Energy Research, Cardno MM&A, DNV, and GERALD R HILL PHD, Inc. developed a risk registry that analyzes all the risks associated with this project. Furthermore, these risks have been reviewed in five different categories consisting of environment, health and safety, cost, reputation, and schedule.

The environment category is directed at the potential damages the project may cause to the surrounding area and the region as a whole. These may include, but are not limited to, destruction of habitats, loss of wildlife including both flora and fauna, contamination of waterways or aquifers, and unintended alterations to the natural habitat. The health and safety category is focused primarily on potential affects to humans. In this instance, health is more closely linked to long term effects, while safety is immediate dangers to an individual or groups well being. The cost category represents the potential costs to remediate if the particular risk being analyzed occurs. The costs are estimates and therefore utilize a range to insure an acceptable level of accuracy. When reviewing costs of remediation it is important to consider that each risk incident is unique to the site and situation making it more difficult to estimate an exact cost beforehand. Additionally, having the costs measured as a range allows more flexibility when conducting mitigation efforts. Reputation deals with the public perception and interaction with different government and non-government agencies. This includes permitting from the various state and federal agencies. The category labeled scheduling examines any possible setbacks to the overall project based on a risk incident.

Table 1 presents the criteria that are being examined for the shale and CBM injection tests. The table categorizes the risks based on the aforementioned areas of influence. Each category is explained based on the severity of the incident. It is important to note that these consequences are situational based, specifically to the shale and CBM tests in this case. The Southeast Regional Carbon Sequestration Partnership (SECARB) uses a similar structure on a much larger scale (Aarnes and Hill, 2012). Measuring the differences between these projects will assist in moving carbon sequestration technology to a commercial scale. The difference in scale between the SECARB project and the shale/CBM injections are the size, which is reflected in the potential damages and is readily assessed when comparing the potential costs.

Table 1: Risk Evaluation (VT Risk Registry, 2013)

		CONSEQUENCE				
		Environment	**Health and Safety**	**Cost**	**Reputation**	**Schedule**
CONSEQUENCE SEVERITY	**High**	Extensive environmental disturbance on well sites or along pipelines that require remediation, or leakage of CO_2 from storage "complex" into USDWs or to surface. Extensive remediation effort required, environment restored to near original condition > 2 years.	On site and off site exposures or injuries.	More than $1000 k	Regional media attention. Regulatory or legal action likely. Reputational impact to project partners. DOE requires project to cease.	Event infers more than 6 months delay relative to Milestone Log
	Medium	Environmental disturbance on well sites or along pipelines that require remediation, or leakage of CO_2 from storage "complex". No leakage to USDWs. Response and remediation managed by responsible entity, environment restored to near original condition < 2 years.	On site injuries or exposures leading to absence from work or negative health effects lasting more than 5 days.	$100 to $1000 k	Local media attention / regulatory or legal action possible. DOE / project partners express concerns. Incident investigation likely, reporting to DOE, review and possible project cessation.	Event infers 3-6 months delay relative to Milestone Log
	Low	Moderate environmental disturbance on well sites or along pipelines, response managed by responsible entity, environment restored to near original condition after response actions completed.	On site injury leading to absence from work or affecting daily life activities up to 5 days.	$10 to $100 k	Public awareness may exist, but no regulatory action. Briefing of public, regulators, project partners and/or DOE as appropriate. Reinforce job safety, HASP review, goal of no lost time accidents.	Event infers 1-3 months delay relative to Milestone Log
	Very Low	Slight environmental disturbance on well sites or along pipelines, but no lasting effect and no remediation effort required.	Slight injury or health effect - Not affecting work performance and not affecting daily life activities.	Less than $10 k	On-site communications, no concern among DOE, public, regulators, or project partners. Review of HASP plan, reinforce goal of safety.	Event infers less than 1 month delay relative to Milestone Log

Once the risk levels have been designated they should be weighed against the risk incidents. There are nine potential leakage scenarios that may occur with both the shale and CBM injection tests, for a total of 18 possible leak risk scenarios. It should be noted that the leaks being analyzed are those underground and along the well. Leaks during transportation or at the surface are not within the scope of this study. The most difficult part of any risk analysis is ensuring the level of accuracy is reasonable.

This risk listed in the risk registry, found in the appendix, can be used to create a graphical diagram of the classification system. This diagram assists the user in visualizing the risk incidents and highlights the most pressing issues. The Risk Assessment Matrix (RAM) is used to group all the risk factors and systematically reduce or eliminate the risks based on their relative severity and likelihood (Aarnes and Hill, 2012). Aarnes and Gerald Hill explain the Risk Assessment Matrix procedure when analyzing the SECARB project:

- *"Risk scenarios in the green band are assumed to reflect a level where risk is commonly agreed to be acceptable, e.g., broadly accepted by the project partners and relevant stakeholders. At this level further risk reduction is generally not regarded as necessary, but risk controls may be implemented to ensure that risk is maintained at this level.*
- *Risk scenarios in the red band are evaluated to be currently unacceptable, i.e., the risk must be reduced to a low or medium level to ensure compliance with project objectives.*
- *Risk scenarios in the yellow band represent risk scenarios that are of concern, but which may be tolerable without further risk reduction. Risk controls should be considered implemented that will enable further risk reduction. However, in some cases the cost or practicability (e.g., in terms and time and effort) required to achieve further risk reduction may be prohibitive or not justifiable relative to the benefits of further risk reduction. In this case it will need to be decided if the risk can be retained at this level, i.e., if it is tolerable"* (Aarnes and Hill, 2012).

Table 2 is a visual representation of the Risk Assessment Matrix. These two tables will be used to survey the leakage risks associated with the Tennessee and Virginia injection tests.

Table 2: Risk Assessment Matrix

LIKELIHOOD				
A: Remote	B: Unlikely	C: Possible	D: Probable	A: Certain
Very unlikely (P<0.05) to occur during life of project	Unlikely to occur during life of project	50/50 chance of occurring during life of project	Likely to occur during life of project	Very likely (P>0.95) to occur during life of project
M	M	H	H	H
L	M	M	H	H
L	L	M	M	H
L	L	L	M	M
L	L	L	L	M

Potential Leak Risk Assessment

The U.S. Department of Energy requires a risk analysis to be conducted for many of its projects, including the two injection tests in Tennessee and Virginia. The Norwegian firm Det Norske Veritas (DNV) was contracted to perform the risk analysis, internally called the risk registry. The registry was created to analyze all the risks associated with the project. The scope of this paper is limited to those risks associated with leaks, specifically leaks underground. The risk analysis conducted by DNV found 18 possible leak scenarios, with nine of those occurring exclusively underground. The nine underground leakage possibilities will be examined by examining their causes, consequences, mitigation actions, and likelihood. Furthermore, they will then be compared to the risk evaluation table and given a risk rating. The risk evaluation will measure the potential incidents affect on the environment, human health and safety, potential costs, public perception (reputation), and potential setbacks to the scheduling of the project.

The first two examples will be analyzed in depth. All the leakage risks will then be examined as a group. The example is adapted from the Virginia Polytechnic Institute and State University (Virginia Tech) Risk Registry prepared for the project. The Risk Registry was prepared using a classification system designed to separate the coalbed methane test risks from the shale test risks. The risk identification number is R-0055 is part of the shale injection test. This will allow for a detailed discussion of the risk management process. Furthermore, it will allow the potential incidents with the highest risk ratings to be compared and mitigation plans developed.

Table 3: R-0055 (VT Risk Registry, 2013)

Risk description	Causes	Consequences	Risk treatment actions	Likelihood
Shale test - Plume breakthrough at 3rd party production wells.	Geologic high permeable streaks, hydro fracture connectivity	Gas quality may be affected, production rate may increase in 3rd party wells. Cease Injection or stop production on off-set well(s). Potential liabilities associated with impact on production at wells not owned by operator . Expand area of monitoring.	Start injection with slow rates. Lower injection pressure. Detect CO2 breakthrough in monitoring wells. Image CO2 plume. Employ best management practices for CO2 injection and monitoring. Stop injection if third party objects.	A: Low permeability in tight shale formation and small volume of CO2 injected should prevent CO2 from reaching 3rd party offset wells.

The first possible leak scenario results in the plume leaking into an adjacent well not under the control of the project. All the wells for the injection test are owned and operated by a single company, however, there are numerous 3rd party wells in the vicinity that are still in operation. Since the low permeability of the shale formation is well known the most likely cause is the extent of hydraulic fracturing. The example provided by DNV reaffirms this notion stating that the permeability is low and the low volume of CO2 injected are unlikely to cause the scenario to realize. The extent of hydraulic fracturing by the operator at its various wells can be estimated, however, the other operators in the area may not be willing to share their hydraulic fracturing information. For this reason it is possible that hydraulic fractures may exist within the final extent of the CO2 plume. Once the risk is understood it is necessary to analyze the impacts on the environment, health and safety, cost, reputation, and scheduling.

Table 4: R-0055 Continued (VT Risk Registry, 2013)

Environment	Health and Safety	Cost	Reputation	Schedule
A: None	A: None	B: Associated liabilities. Loss production for a short period of time, less than $100K. Some lost production recovered after shut in.	C: Limited impact unless 3rd party files lawsuit. Regulatory or legal action possible, DOE would express concerns.	D: Injection would cease if 3rd party objects.

In this example the potential damages to the environment and health and safety are non-existent. For either to be affected there would need to be additional failures in the system. Table 1 was used to determine the severity of each occurrence when compared to the likelihood of the incident occurring. The most severe consequences reflect the actions of the 3rd party in response to the CO2 plume breaking into their production zone.

To provide contrast another risk scenario will be evaluated, R-0015. The potential for leakage through faults or fractures in seals presents a broader perspective of the damages that can be caused by leaks. Table 5 and 6 use the same criteria to evaluate R-0015 as was previously used with R-0055. The likelihood is very low as in the previous example. The consequence of a leak along a fault, with the potential to reach an underground source of drinking water (USDW), carries very severe consequences. A Duke University study showed that any CO2 leakage into an USDW would contaminate the water to a level that was unacceptable for drinking (Little and Jackson, 2010). For this reason, it is necessary to pursue all methods of mitigations to further reduce the likelihood of a leak into an USDW. There are various causes that can lead to a leak of this type as well as risk treatment actions. To fully understand the implications of such a leak it is necessary to evaluate the leak's effect of the environment, health and safety, cost, reputation, and scheduling. Table 5 and 6 are taken form the Virginia Tech Risk Registry.

Table 5: R-0015 (VT Risk Registry, 2013)

Risk description	Causes	Consequences	Risk treatment actions	Likelihood
CBM test - Leakage through faults or fractures in seals	Previous hydraulic fracture treatment potentially caused fractures out of zone. Earthquake events. Unmapped (sub-seismic) faults.	Potential migration to USDWs. Possible risk of not being able to inject full volume in target area of review. Possible cessation of injection in one or more wells.	Appropriate site selection. Lower injection pressure. Microseismic monitoring. Stop injection in one (or more - CBM) well(s). CBM test - Redistribute injection among wells. Diagnose extent of leakage.	A: 0-1%: Injection below permitted pressure based on 90% of estimated fracture pressure.

Table 6: R-0015 Continued (VT Risk Registry, 2013)

Environment	Health and Safety	Cost	Reputation	Schedule
C: Leakage of CO2 may cause concern and risk to USDWs.	B: Slight health impacts may result if CO2 or displaced fluids migrate to USDWs or surface.	C: Implied costs associated with the need to stop injection prematurely in one or more wells.	C: DOE / project partners express concerns.	C: Injection period may be extended by 3-6 months if injection is limited to 1-2 wells.

The most prominent contrasts between the first example (R-0055) and this example (R-0015) are the detrimental effects on the environment and human health and safety. Table 5 and Table 6 can be compared, as there are similarities between the two. While R-0055 had negligible effects on the environment and health and safety, R-0015 is of serious concern. Using the rating scale (A through D, with D reflecting the most severe consequence) it becomes clear that R-0015 is of greater concern. The evaluation yields four Cs, and one B. If possible, these should be reduced. If such action is not possible then plans will need to be designed to deal with that type of leak. Furthermore, strict monitoring will be necessary to be able to detect a leak. It may be prudent to consider utilizing a different injection site if the risks cannot be mitigated to an acceptable level. In this case, the faults are well known, however, the potential exists for undiscovered faults to be present or new faults to be created through earthquakes or sufficient pressure.

Risk Incidents: Charting and Classification

Once a thorough understanding of how to analyze each risk factor has been developed it becomes possible to look at the risk incidents as a whole. It is still necessary to analyze each risk scenario first before grouping them. The following are two lists, adapted from the Risk Registry, compromise all the risk incidents related to underground leaks(VT Risk Registry, 2013, Appendix A – Table 1). The lists are broken up between the CBM and shale injection tests. Furthermore, a RAM has been developed which shows each risk factor plotted enabling the user to visualize the data.

CBM Injection Test – Risk Identification Number and Risk Description

- R-0010 - Internal or external corrosion of pipeline requiring corrective action.
- R-0013 - Leakage along existing or new wellbores due to inadequate well integrity.
- R-0014 - CO2 migration outside area of review along transmissive faults or natural fractures.
- R-0015 - Leakage through faults or fractures in seals.
- R-0019 - Size/direction of plume expansion not consistent with baseline monitoring and predictions.
- R-0021 - Baseline insufficient to differentiate indicators of CO2/formation fluid/gas migration.
- R-0023 - Leaky Packer.
- R-0024 - Leaking tubing.
- R-0025 - Casing leak.

Shale Injection Test – Risk Identification Number and Risk Description

- R-0055 - Plume breakthrough at 3rd party wells (Used for example 1).
- R-0064 - Leakage along existing or new wellbores due to inadequate well integrity

- R-0065 - CO2 migration outside area of review along transmissive faults or natural fractures.
- R-0066 - Leakage through faults or fractures in seals.
- R-0068 - Monitoring program unable to detect lateral extent of injected CO2 and demonstrate containment.
- R-0070 - Baseline insufficient to differentiate indicators of CO2/formation fluid/gas migration.
- R-0071 - Leaky packer.
- R-0072 - Leaking tubing.
- R-0073 - Casing leak.

Figure 1: Plotting the Potential Risks Using the Risk Assessment Matrix

		LIKELIHOOD/FREQUENCY			
		A	**B**	**C**	**D**
		Very unlikely	**Unlikely**	**Possible**	**Probable**
		0-1% chance during life of project	1-10% chance during life of project	10-25% chance during life of project	More than 25% chance during life of project
CONSEQUENCE SEVERITY	**High**	55 - 65 - 66 68 - 73			
	Medium	13 - 14 - 15 21 – 25 - 64 - 70		19	
	Low	10 - 24 - 72	23 - 71		
	Very Low				

The Risk Assessment Matrix allows a user to visualize the risks and determine which risks require attention. By placing all the risks related to leakage on the RAM it is possible to look for patterns, which may aid in corrective action or mitigation. In this exercise the CBM injection test uses a black font and the shale injection test uses a red font. The pattern that emerges shows the importance of controlling the leaks in the shale formation. The CBM leaks can still have undesirable effects, but as a whole the shale test has much more severe consequences. Ideally, the process would allow for movement of these risks identification numbers to reflect the mitigation efforts. The goal is to move to the bottom left corner, representing the lowest risk in terms of likelihood and severity.

Shale test risk numbers 55, 65, 66, 68, and 73 are very unlikely yet carry severe consequences. Using the example from before, it is possible to understand why the risk of a plume breaking into a 3rd party production area is considered so severe. There is the possibility that the whole project is shutdown due to such a leak. To lower the relative consequence it is necessary to mitigate the risk incident. In this case it may be possible to reach an agreement with companies operating nearby production wells. The goal of such an agreement would be to move these risk incidents to a lower severity category. Hypothetically, if such an agreement is reached, then R-0055 can be moved from high severity to medium or low severity, greatly reducing its risk factor.

An additional benefit of the RAM is that the user can immediately see any outliers in a way that did not stand out before. Risk incident R-0019 is considered to be of medium severity but with a possible likelihood. This is the most pressing issue for the project at the current time and it will need to be mitigated to reduce either the consequence or likelihood before the project can move forward.

Conclusion

The success of carbon sequestration projects will be determined by whether these projects can meet the standards set forth in the categories of environment, health and safety, cost, reputation, and project scheduling. A thorough understanding of risk analysis is necessary to properly develop a risk portfolio for carbon sequestration projects. The potential for leaks is one of the greatest challenges to sequestration projects now, as researchers attempt to demonstrate the feasibility of carbon sequestration projects over a long-term period. The potential for leaks can be examined on a individual risk incident level, but should also be evaluated as a group. If groupings yield patterns within the risk assessment matrix (RAM) it may be possible to systematically lower the likelihood or severity of these risks in unison. Furthermore, it allows researchers and operators to visualize the more severe aspects of injection tests, and mitigate those risks accordingly. Carbon sequestration will rely on risk management approaches such as the ones explained above to move from test to commercial scale injections.

Review

A benefit of risk management is the ability to see progress, especially if the risk profiles are created at the beginning of the project. The following has been added after allowing an extended period of time for project progression and mitigation efforts to commence. The results show the changes over time. The major takeaways are those risks that are no longer present and the risks that remain. Both cases offer insight into the risk management process for this project. Those risks that have been removed were successfully mitigated. This is either in the form of reducing the severity of the incident or by reducing the likelihood. The majority of those no longer present have been removed because they are no longer likely to occur because of mitigation efforts.

The following figures (Figures 2-5) show the breakdown of the coalbed methane test and the shale test based on the five categories; cost, reputation, health and safety, environment, schedule. Figure 1 shows the results for the CBM test as of October, 2013. Figure 2 shows the results for the shale test as of October, 2013. The figures show the breakdown based on each category, and what risks remain and the likelihood of them occuring. These are useful when comparing to the initial risk registry as change over time can be tracked. From this, decisions can be made regarding where to focus mitigation efforts. For example, in Figure 2 the total number of risk scenarios for the health and safety and environmental categories is much lower than those for cost, reputation, and schedule. It is important to note these figures encompass all risks, not just those related to leakage risk. Figures 4 and 5 show the original risk distributions from January 2013. The figures show the difference over time as mitigation efforts have lowered the total number of risk measured. The CBM test decreased by five risks and the shale test by six risks. These risks were completely mitigated and no longer pose a threat to the project. If the risk were not completely mitigated then the next best option would be for them to move towards the bottom left corner, as this represents a drop in either likelihood or severity.

What is immediately apparent is that both the CBM injection test and the shale injection test were able to mitigate many of the potential risks. The stakeholders who took ownership of each risk showed initiative and creativity in reducing the likelihood, severity, or both.

Future work should continue to review the risks and mitigation options. Mitigation includes reduction of likelihood, severity, or both by following the plans laid out in the risk registry and developed during risk workshops. The process of risk management is constant and continuous and therefore should be evaluated on a regular basis.

Figure 2: CBM Categories, October 2013

CBM

CBM Cost	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	5	7	2	0	14
Low	12	2	1	3	18
Very Low	2	1	0	0	3
Sum	22	10	3	3	38

CBM Reputation	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	5	6	2	0	13
Low	11	1	1	0	13
Very Low	1	2	0	3	6
Sum	20	9	3	3	35

CBM H&S	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	1	0	0	0	1
Medium	1	0	0	0	1
Low	10	1	0	1	12
Very Low	1	3	0	0	4
Sum	13	4	0	1	18

CBM Environmental	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	2	1	0	0	3
Low	7	1	0	0	8
Very Low	1	2	0	2	5
Sum	13	4	0	2	19

CBM Schedule	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	3	0	0	6
Medium	5	3	2	0	10
Low	11	0	1	1	13
Very Low	2	4	0	2	8
Sum	21	10	3	3	37

Figure 3: Shale Categories, October 2013

Shale

Shale Cost	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	2	1	0	0	3
Medium	1	2	1	0	4
Low	16	2	0	3	21
Very Low	0	0	0	0	0
Sum	19	5	1	3	28

Shale Reputation	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	5	0	0	0	5
Medium	5	3	1	0	9
Low	9	1	0	0	10
Very Low	0	1	0	3	4
Sum	19	5	1	3	28

Shale H&S	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	1	0	0	0	1
Medium	1	0	0	0	1
Low	7	1	0	1	9
Very Low	0	1	0	2	3
Sum	9	2	0	3	14

Shale Environment	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	1	0	0	0	1
Low	5	1	0	0	6
Very Low	0	1	0	3	4
Sum	9	2	0	3	14

Shale Schedule	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	5	2	0	0	7
Medium	1	1	1	0	3
Low	13	0	0	1	14
Very Low	0	2	0	2	4
Sum	19	5	1	3	28

Figure 4: Original CBM Categorical Distribution, January 2013

CBM

CBM Cost	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	5	1	0	0	6
Medium	3	10	2	0	15
Low	13	1	1	3	18
Very Low	2	1	0	0	3
Sum	23	13	3	3	42

CBM Reputation	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	6	2	0	0	8
Medium	3	7	2	0	12
Low	11	1	1	0	13
Very Low	2	2	0	3	7
Sum	22	12	3	3	40

CBM H&S	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	0	0	0	0	0
Medium	2	1	0	0	3
Low	10	1	0	1	12
Very Low	2	1	0	0	3
Sum	14	3	0	1	18

CBM Environmental	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	4	0	0	0	4
Low	6	1	0	0	7
Very Low	1	2	0	2	5
Sum	14	3	0	2	19

CBM Schedule	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	5	6	0	0	11
Medium	4	5	2	0	11
Low	12	0	1	1	14
Very Low	2	2	0	2	6
Sum	23	13	3	3	42

Figure 5: Original Shale Categorical Distribution, January 2013

Shale

Shale Cost	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	5	1	0	0	6
Medium	1	5	1	0	7
Low	15	1	0	3	19
Very Low	0	1	0	0	1
Sum	21	8	1	3	33

Shale Reputation	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	6	1	0	0	7
Medium	5	5	1	0	11
Low	10	2	0	0	12
Very Low	0	0	0	3	3
Sum	21	8	1	3	33

Shale H&S	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	1	0	0	0	1
Medium	1	0	0	0	1
Low	9	1	0	1	11
Very Low	0	0	0	3	3
Sum	11	1	0	4	16

Shale Environment	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	3	0	0	0	3
Medium	2	0	0	0	2
Low	6	1	0	0	7
Very Low	0	1	0	3	4
Sum	11	2	0	3	16

Shale Schedule	Likelihood				
Consequence	Very Unlikely	Unlikely	Possible	Probable	
High	7	4	0	0	11
Medium	2	2	1	0	5
Low	13	0	0	1	14
Very Low	0	2	0	2	4
Sum	22	8	1	3	34

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UTILIZING RISK MANAGEMENT TO PROMOTE SUSTAINABLE DEVELOPMENT IN THE MINING INDUSTRY: WILD RICE AND STAKEHOLDER GROUPS IN MINNESOTA

Abstract

Risk management is a powerful set of tools and methods that can be utilized in the sustainable development process. Minnesota is in a unique position as it has six large mines in operation, a number of companies attempting greenfield and brownfield projects, and a large regional population. The area is popular with fishing, hiking, and contains the Boundary Waters Canoe Area Wilderness. Tourism is a major industry alongside the mining industry. Sustainable development must look at all stakeholder groups and assess the risks and results of a particular action or regulation. All of these stakeholder groups are connected by a regulation governing the level of sulfate discharged into waters that contain wild rice.

Minnesota is currently reevaluating their effluent discharge limit for sulfates, specifically how it affects wild rice growth. This presents a number of issues for sustainable development, all of which can benefit from a risk management approach to mitigation. By developing a risk analysis table it is possible to view the risks to all stakeholders and examine patterns. These patterns allow for more focused and successful mitigation, as well as identifying areas that require greater attention.

The following paper describes various issues surrounding wild rice in Minnesota and the current state of the sulfate standard. It then proceeds to identify prominent stakeholder groups and ultimately develops a risk analysis for four potential sulfate standard levels. Finally, mitigation potential is examined alongside pattern analysis in order to reduce the likelihood or magnitude of a particular risk.

Wild Rice Study Background

The Wild Rice Standard Study began in 2011 when the Minnesota Legislature provided the necessary funds to undertake a multi-year study. The Clean Water Land and Legacy Amendment Bill allows, "a $1.5 million appropriation to implement a wild rice research plan and contract with scientific experts to conduct the study. The Minnesota Pollution Control Agency (MPCA) was also directed to produce a report on the status of wild rice rulemaking and research implementation by December 2011." [1]. The MPCA website outlines the key stakeholder groups including the EPA, Minnesota Department of Natural Resources, as well as local and regional Native American Tribes. Additional stakeholder groups include mine operators, mine employees, wild rice growers (both recreational and commercial), and other users of the waters of the state.

Figure 1 is modified from a map showing the wild rice sampling sites for 2011. The highlighted area represents the overall extent of mining. The study focuses heavily on counties that are traditionally wild rice producing and counties that contain taconite mining operations. The counties of Itasca, St. Louis, and Lake contain 19 of the 50 planned sites (38%)[2] These three counties account for all the taconite production in the state, nearly 39 million tons of pellets in 2011[21].

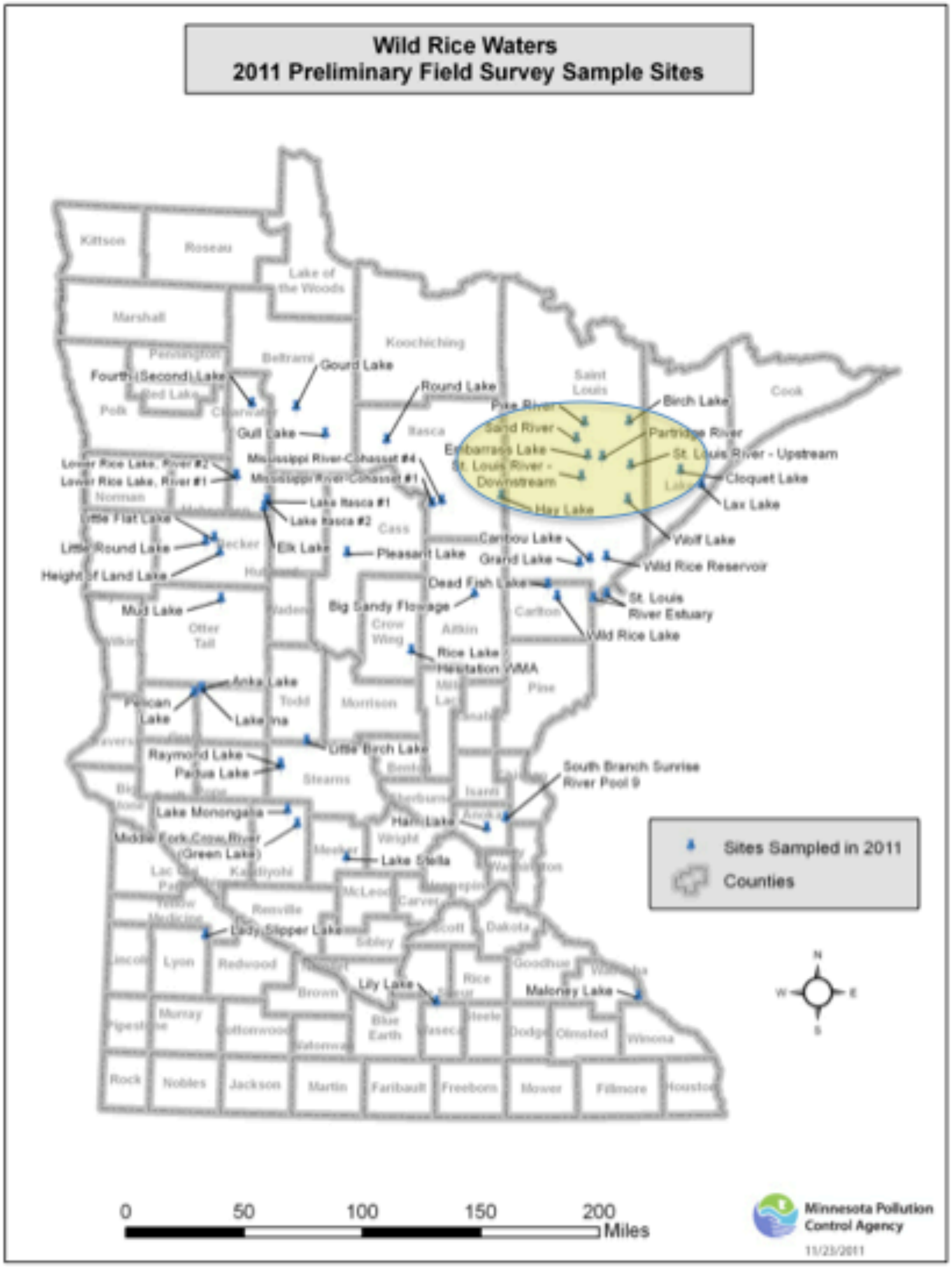

Figure 1: Minnesota Wild Rice Survey Sites and Mining Locations [2]

The Minnesota Pollution Control Agency (MPCA) regulates water in the State of Minnesota. The MPCA has primacy as granted by the United States' Environmental Protection Agency (EPA) by meeting all primacy criteria as listed in 40CFR142, Subp. B [3]. Part of the criteria dictates that the MPCA must adhere to and regulate based on the provision of the Clean Water Act. While the Clean Water Act is extensive, Section 101 (a) summarizes the overriding goal of the piece of legislation, "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Act proceeds to detail measures, criteria, and systems to ensure these goals are met in an effective and timely manner [4]. To this end, the MPCA is in charge of issuing National Pollution Discharge Elimination System permit. Specifically, the EPA website states, "The federal Clean Water Act requires that all municipal, industrial and commercial facilities that discharge wastewater or stormwater directly from a point source (a discrete conveyance such as a pipe, ditch or channel) into a water of the United States (such as a lake, river, or ocean) must obtain a *National Pollutant Discharge Elimination System (NPDES)* permit [5]. All of the mines currently operating on the Mesabi Iron Range require this permit, as well as those that intend to begin production in the state of Minnesota.

The directives established in the Clean Water Act allow the State of Minnesota, through the MPCA, to regulate sulfate levels in water. The ruling regarding wild rice in the state of Minnesota can be found in the Minnesota Administrative Rules, specifically 7050.0224 subpart 2 [6]. The rule states,

Sulfates (SO_4)	10 mg/L, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.

The definition is ambiguous throughout and leads to two main issues, in addition to the current limit of 10 mg/L. The two major issues that arise from this are how to define "water used for the production of wild rice" and "during periods when the rice may be susceptible to damage by high sulfate levels." The issues with this definition have allowed interpretations to be made in favor of particular opinions without providing a sound legislative backing.

As part of the standards review the state of Minnesota will also clarify the meaning of “water used for the production of wild rice.” There are several options that will be examined more thoroughly during the risk analysis, but it is important to mention them here. The bullet points below examine a number of possible interpretations:

- How far downstream does the standard apply?
- Does the volume of water passing a particular point affect the standard (dilution)?
- Is the whole lake/stream considered wild rice bearing, or is it only upstream/downstream of a wild rice patch?
- How much wild rice must be present for it to qualify for the standard? Alternatively, does the waterbody only need to be suitable for wild rice growth to qualify?
- If the study determines that sulfate discharges do not affect wild rice above the 250 mg/L or 1000 mg/L limits, is a wild rice based standard necessary?

The second part of the definition that requires clarification is the time frame that is represented by, “periods when the rice is susceptible to damage by high sulfate levels. This definition will be easier to quantify once the wild rice study has been completed. There will be less ambiguity surrounding the growing season. Ideally, the study will also be able to identify if wild rice is only susceptible to damage during different stages of growth, or if exposure to sulfate at the prescribed level during any time is unfavorable.

State of Iowa Survey

The state of Iowa conducted a study in 2009 to reevaluate their current standards for chlorine, sulfates, and total dissolved solids (TDS). The study reviewed the standards and rules established by nearby states, including Minnesota. The document details the Minnesota standard by saying, “Minnesota has a standard of 250 mg/L sulfate that applies to public water supply intakes and trout waters. For other waters, MN uses a site-specific guideline value of 1,000 mg/L which is said to come from the Canadian Water Quality guidelines manual. [7]" The survey continues to explain one of the main issues surrounding the wild rice specific limits by saying, "MN also has a sulfate standard of 10 mg/L to protect wild rice. In their reply to our survey, they relate however, that MN staff believes there is little scientific justification for this low value and they seek to change the standard as part of their next Triennial Review of standards" [7].

The opinions of the Minnesota staff have become a central aspect of the discussion. The basis for the current wild rice standard is the result of research conducted in the 1940s by Dr. Moyle. Dr. John Moyle was a researcher for the Minnesota State Department of Conservation, which evolved into the current Department of Natural Resources. Dr. Moyle received a number of degrees from the University of Minnesota before beginning his work with the Department of Conservancy (DOC) in 1938. He worked in various roles with the DOC until his death in 1977. Among his notable accomplishments is a single line in the July 1944 issue of the Journal for Wildlife Management that pertains to wild rice research, "No large stands of rice occur in waters having a SO4 content greater than 10 p.p.m., and rice generally is absent from water with more than 5 p.p.m" (Moyle, Journal of Wildlife Management, Vol. 8, No. 3, July 1944). It is important to note that 1 part per million (p.p.m.) is equivalent to 1milligram per litre (mg/L). The Minnesota Legislature then established Minnesota Administrative Rules 7050.0224 (subpart 2 in particular) based on these findings. The new standard was passed into law in 1973, but has only become more prominent as new permits are processed, and older permits are getting closer to renewal. The sulfate standard will be added to these new permits.

Anti Backsliding Rule

The anti backsliding rule has exacerbated the issue by encouraging companies to meet a higher limit for effluent discharges. The Clean Water Act states,

"In the case of effluent limitations established on the basis of subsection (a)(1)(B) of this section, a permit may not be renewed, reissued, or modified on the basis of effluent guidelines promulgated under section 1314(b) of this title subsequent to the original issuance of such permit, to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit. In the case of effluent limitations established on the basis of section 1311(b)(1)(C) or section 1313(d) or (e) of this title, a permit may not be renewed, reissued, or modified to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit except in compliance with section 1313(d)(4) of this title" [8].

When an industrial or municipal entity applies for a permit to regulate an effluent limit, it is in their best interest to choose the highest allowable limit, as opposed to what is achievable. There is no incentive to pursue an effluent level that is lower/more favorable for the environment. If an entity agrees to an effluent discharge limit, and does not meet that limit, there are strict penalties and the entity cannot ever reapply for a limit that is more realistic than previously thought.

Wild Rice – Location and Abundance

One of the prominent responsibilities of all stakeholders will be to identify waters containing wild rice. Not all waters in the state of Minnesota will be required to meet the effluent limits set forth in the revised sulfate standard ruling. The location of wild rice beds will be crucial in insuring the successful implementation of sustainable development practices. Simply put, it is difficult to protect what one does not know exists. When a wild rice bed is located it allows that water body to be protected. It will also be necessary to identify waters that traditionally contained wild rice. Unfortunately, there is not a great deal of historic information on which water bodies contained wild rice. Specific information is needed as opposed to general mappings that show the traditional range. Figure 2 provides an example created using John Moyle's field notes regarding the location of wild rice paddies.

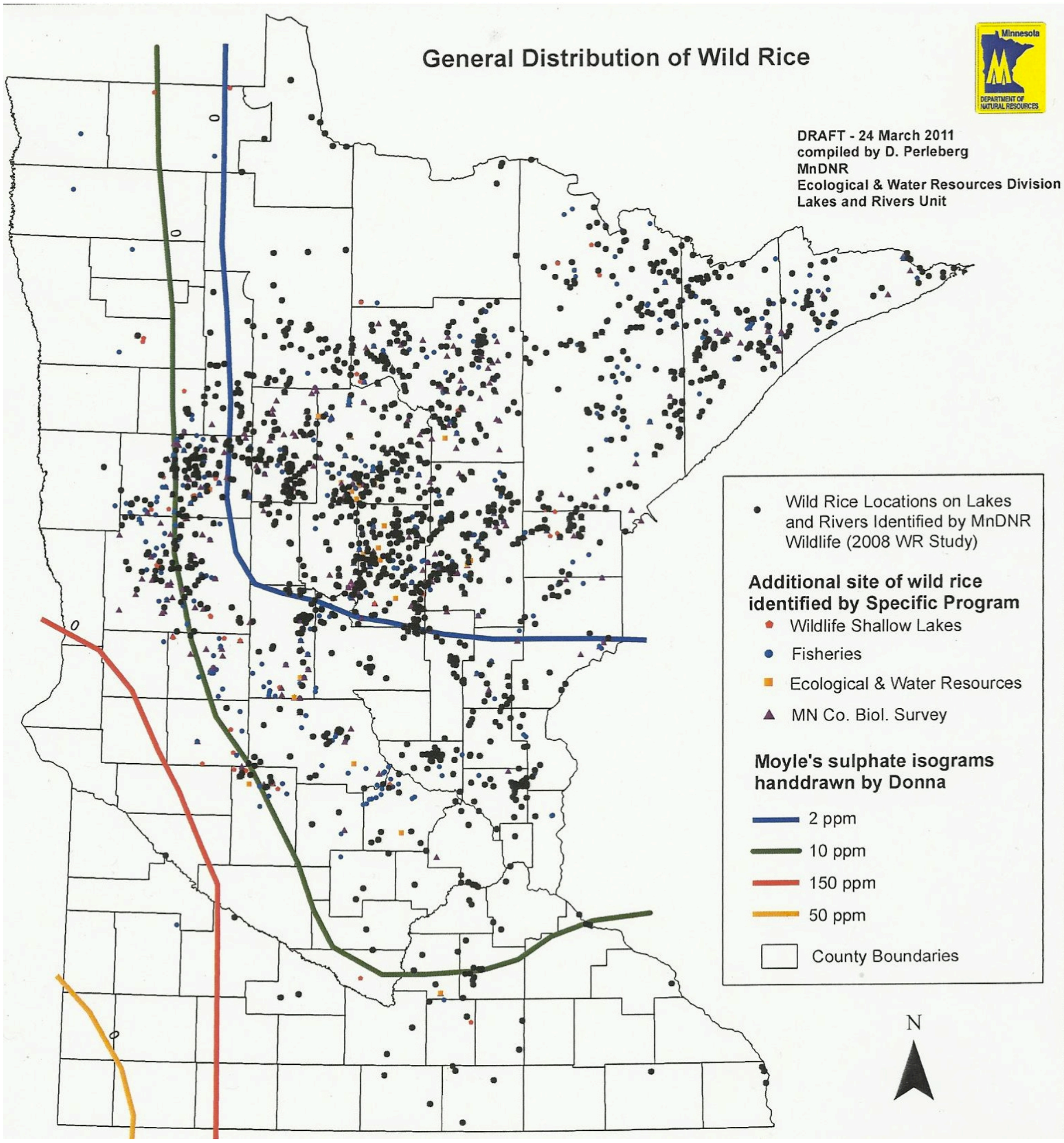

Figure 2: 2008 Survey Locations [9]

According to the Minnesota Administrative Rules there are 23 lakes and one river that are classified as a wild rice habitat. The 23 lakes are listed in Table 1. All of the lakes are located in the three counties of St. Louis, Cook, and Lake. These three counties are located in the northeast portion of the state, with St. Louis County being the largest by area. These lakes account for approximately 6,282 acres with the potential to produce wild rice. The only river classified as containing wild rice is the St. Louis River.

Lake	County	Size (Acres)
Artichoke Lake	St. Louis	285
Bluebill Lake	Lake	42
Breda Lake	St. Louis	137
Cabin Lake	Lake	67
Caribou Lake	Cook	720
Christine Lake	Cook	195
Fourmile Lake	Cook	593
Hay Lake	St. Louis	N/A
Lieung (Lieua) Lake	St. Louis	358
Long Lake	St. Louis	442
Marsh Lake	Cook	66
Moore Lake	Cook	61
Northern Light Lake	Cook	453
Papoose Lake	Lake	N/A
Rice Lake	Cook	223
Round Island Lake	Lake	54
Round Lake	St. Louis	311
Seven Beaver Lake	St. Louis	1410
Stone Lake	St. Louis	143
Stone Lake (Skibo Lake)	St. Louis	N/A
Stone Lake (Murphy Lake or Tommila Lake)	St. Louis	71
Swamp River (Reservoir)	Cook	305
White Pine Lake	Cook	346

Table 1: Wild Rice Lakes [11]

The St. Louis River Watershed drains 3,634 square miles and flows for approximately 179 miles in Minnesota and Wisconsin before draining into Lake Superior [10]**.** The St. Louis River runs along the Mesabi Iron Range, which forms most of the northern border of the watershed. Of the major waterways that feed the St. Louis River, over half originate of pass near the Mesabi Iron Range. The Floodwood, West Swan, East Swan, West Two, East Two, and Embarrass waterways all drain into the St. Louis River and have the potential to receive water from the Mesabi Iron Range. The Minnesota Administrative Rules do not list or classify these tributaries as containing wild rice [11].

In addition to work done by the state and individuals, the 1854 Treaty Authority has conducted a thorough evaluation of wild rice location within its territory. The 1854 Treaty is an agreement between the Chippewa of Lake Superior ceded land to the United States. The 1854 Treaty Authority was then established to promote and protect Native America interests within the ceded area, wild rice in this case. The three counties it encompasses from east to west are Cook County, Lake County, and St. Louis County

[13]. Additionally, Carlton County, Pine County, and Aitkin County make up the southwest corner of the ceded area.

The 1854 Treaty Authority also prepared a survey in 2012 to document the variability in growth patterns of wild rice at select locations. The sites were surveyed for water depth, temperature, and quality, wild rice density and acreage. This information was then used to calculate the abundance index, which is defined as, “An abundance index was developed for each water body monitored. This index is determined from the acreage and density of wild rice. The abundance index was calculated for each lake or river by multiplying the acreage of wild rice by the average number of stalks per 0.5 m^2 found in the rice beds” [12]. Information from *Wild Rice Monitoring and Abundance in the 1854 Ceded Territory (1998-2012)* was used to develop the locations of wild rice beds on the preceding map [14].

Figure 3 provides trend lines for both Average Abundance Index and Average Acreage. These trend lines are crucial in examining any changes over time. In particular, the Average Acreage trend line shows that there is very little change year to year. The Average Abundance trend line shows a consistent decline in wild rice abundance. Essentially, the density of wild rice is declining but the total acreage that wild rice covers has not decreased noticeably. Significance can also be found when comparing the declining Average Abundance to the sulfate readings taken at the same lakes and rivers. The readings were often taken at different sampling times, but all were taken within the wild rice growing season. The water sample analysis was carried out for each lake or river, and includes a sample in 2007, three in 2011, and one more in 2012 for a total of five samples at each site. The information provided by the water sample analysis suggests that sulfate does not have a significant impact on the wild rice, and is not correlated to the decline in wild rice abundance as measured by the study. Only one time do the water quality analysis return a value greater than the 10 mg/L limit (11.8 mg/L in Vermillion River, 7/27/2007). The data provided by the 1854 Treaty Authority reflects the sentiment that has been expressed by environmental group and Native American rights groups, however it does not provide a link between wild rice and sulfate levels. In the summary of the survey explains one potential cause for declining rice (discussing the 2012 harvest in particular), " High water events at the end of May and again at the end of June impacted wild rice success, and in some areas caused complete crop failure" [12]. Discussing the overall survey, "Across the group of waters monitored since 1998, the total wild rice acreage in 2012 was near the average over this period. However, the total abundance index was the lowest recorded, indicating poor density rice beds" [12].

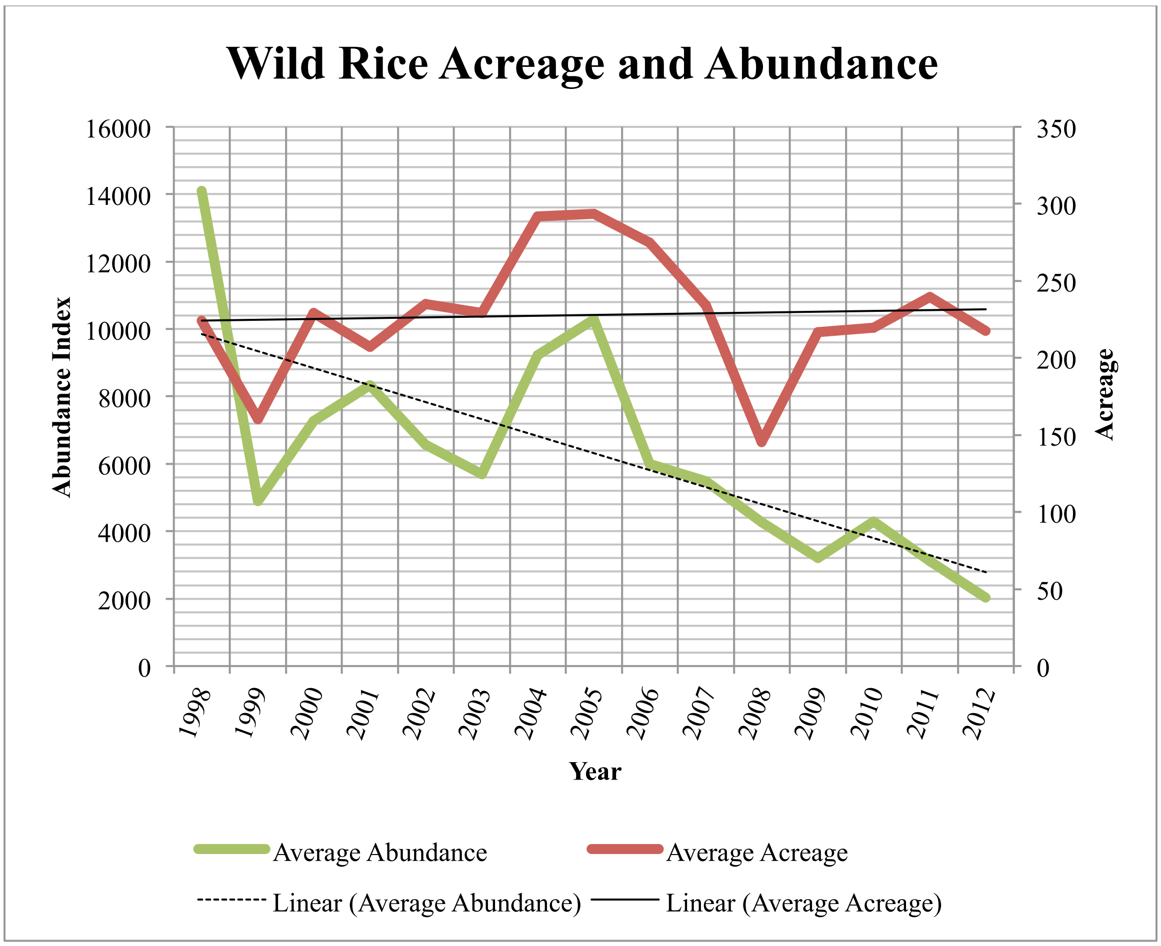

Figure 3: Wild Rice Acreage and Abundance [12]

Historic Sulfate Data

Over the years the state of Minnesota has gathered data containing sulfate information from numerous sources. It has compiled this data which consists of over 10,000 sampling instances in the last ten years. This data was used to develop the following maps. The first map, Figure 4, shows the state of Minnesota with all the sampling sites. The color of the dot represents the category for which the sample falls. Red indicated above 1000 mg/L, orange indicates between 250 mg/L and 1000 mg/L, yellow indicates between 100 mg/L and 250 mg/L, green indicates between 10 mg/L and 100 mg/L, and blue indicates below 10 mg/L. These results were also sorted to ensure they only covered samples taken during wild rice growing season (April through August). The trends to notice within the map are that there is higher sulfate content in the south and western parts of the state. The twin cities of Minneapolis-St. Paul and their suburbs have values that regularly exceed 10 mg/L, however there is little wild rice growth in that area of the state. Finally, there is a clear spike in both number of samples and sulfate content within those samples in the area surrounding the taconite mines.

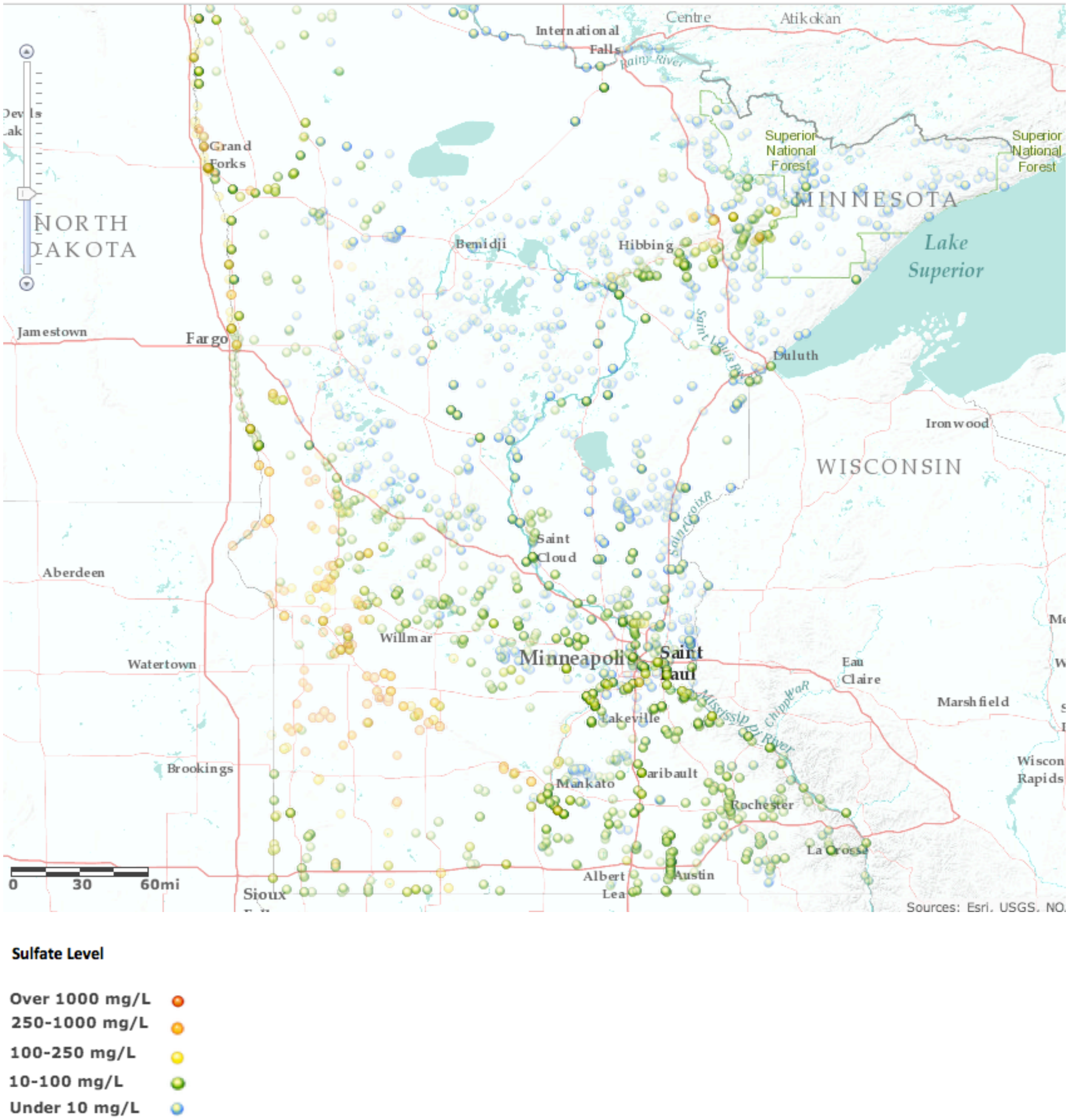

Figure 4: Sulfate Survey Results

The second map (Figure 6) focuses specifically on the current taconite operations. The major operations are colored in light green. The sulfate readings in the area are generally between 10 mg/L and 100 mg/L with a few samples moving into the 100 mg/L to 250 mg/L category.

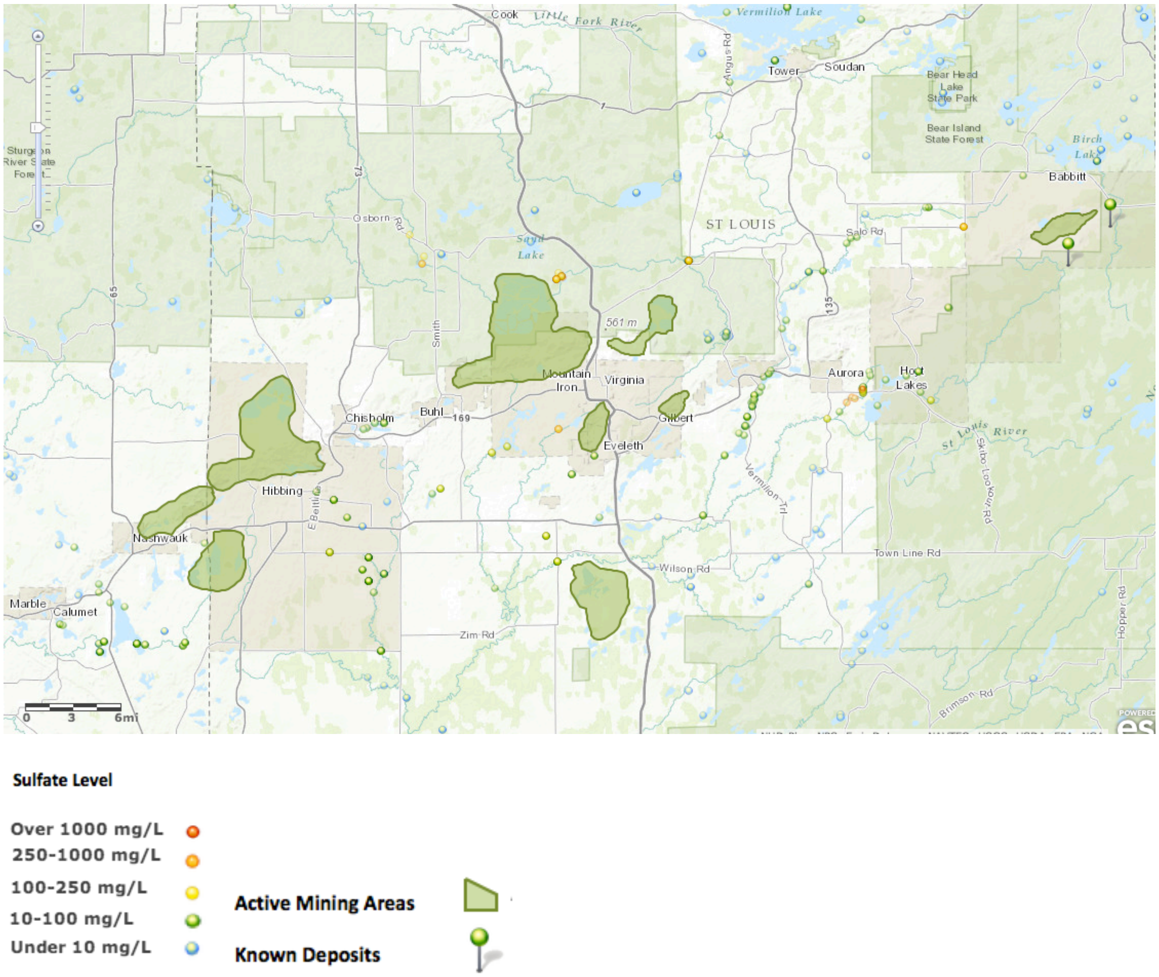

Figure 5: Iron Range Mines and Sulfate Results

The final map (Figure 6) shows the whole mining district, with current mines shaded and potential mines shown as points. The important takeaways are the current levels being discharged by mining operations, and the much lower levels of the surrounding wildlife areas.

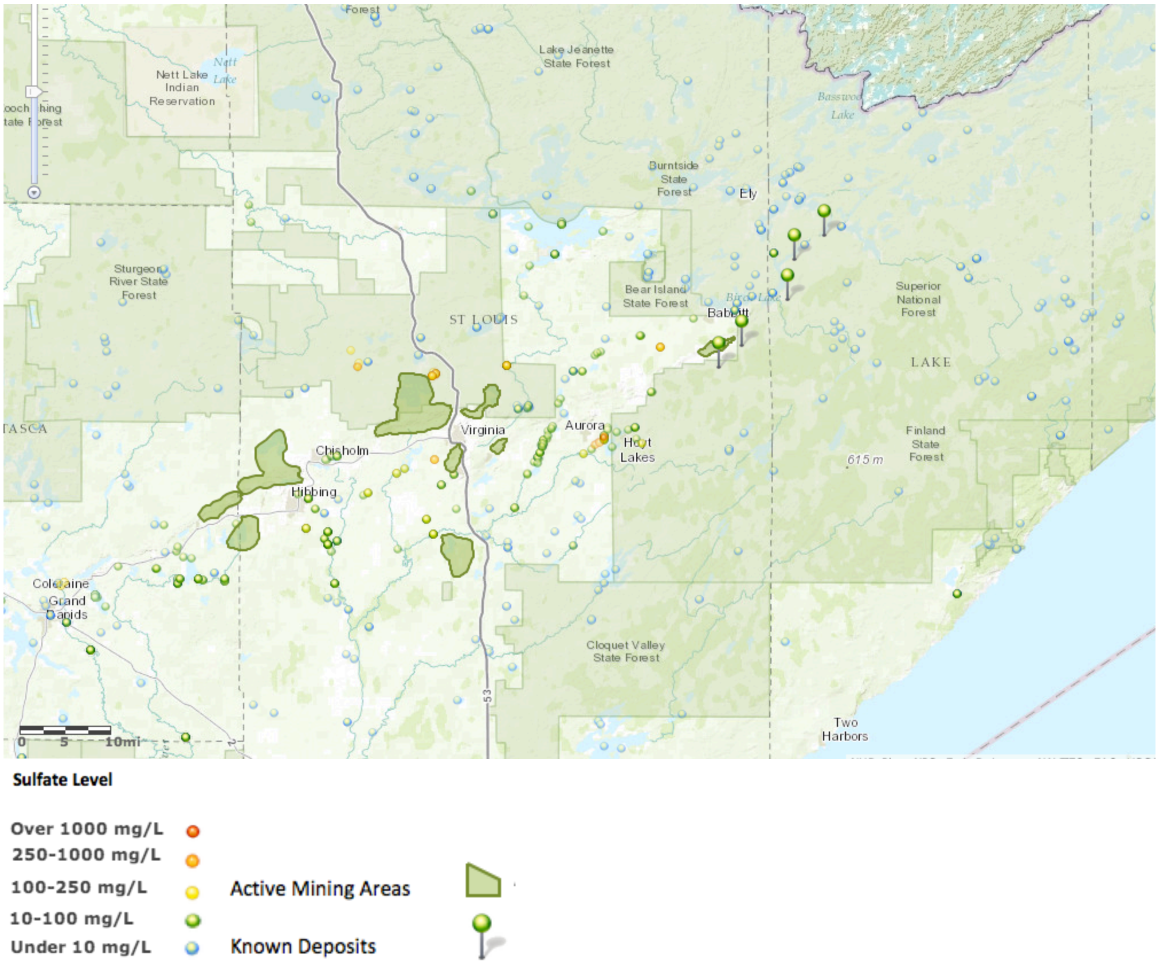

Figure 6: Operating and Potential Mines

Stakeholder Groups

Minnesota Tourism Industry

Minnesota is a prominent tourist destination because of the unique features of the state. The cities of Minneapolis and St. Paul, and surrounding suburbs, are known as the twin cities. The population for the Minneapolis-St. Paul metropolitan area is over three million, and is also a major cultural center in the Midwest. As a state, Minnesota attracted $11.9 billion in gross sales directly related to the leisure and hospitality industry [19]. This comes out to nearly $32 million per day and accounts for nearly 240,000 full and part time jobs, as defined by the *2011 Tourism and Minnesota's Economy,* which is prepared by the Explore Minnesota Campaign, a marketing tool of the Minnesota Department of Tourism. The report details the tax revenue from tourist activities, which total $769 million, or approximately 17% of all state sales tax revenue (document). The report also details the tourist industry impact when by subdivided the state into different regions. The "Northeast Minnesota" region as defined by the report encompasses the primary area of concern in the wild rice debate, although the whole state will be impacted to an extent. Figure 8 is taken directly from the 2011 Tourism and Minnesota's Economy report. The counties included in the "Northeast Minnesota" region contain all operating taconite mines in the state, as well as the major mines in development. Additionally, a large wild rice presence exists in these counties [19].

Employment statistics for the region are crucial to understanding the importance of the leisure and hospitality industry. The total population of the counties included in the "Northeast Minnesota" region is 355,322. The report explains how these sales are incurred by trip stating, "Spending during Minnesota's 71 million annual person-trips (including overnight and day trips)" (tourism brochure). Using this number, an estimate was calculated assuming person-trip spending was even across each region. Figure 8 uses data from both the Minnesota Department of Tourism (Explore Minnesota) and the Minnesota Department of Employment and Economic Development. The figure illustrates the impact of the leisure and hospitality industry on the "Northeast Minnesota" region, and each county's impact. In particular, the number of person-trip was calculated by using the total gross sales for the region, and applied to the percentage each county adds to that total.

County	Gross Sales	Sales Tax	Private Sector Employment (Tourism)	Population (2012 Estimate)	Percentage Employed by Tourism	County Percent of Total Sales
Carlton	$56,754,339	$3,785,229	996	35,348	2.8%	7.4%
Cook	$51,475,292	$3,426,587	876	5,185	16.9%	6.7%
Itasca	$65,559,174	$4,320,962	1,482	45,221	3.3%	8.6%
Kanabec	$12,404,529	$798,380	301	16,005	1.9%	1.6%
Koochiching	$28,171,147	$1,855,841	566	13,208	4.3%	3.7%
Lake	$30,392,095	$2,060,150	872	10,818	8.1%	4.0%
Pine	$61,139,170	$3,395,227	999	29,218	3.4%	8.0%
St. Louis	$458,947,071	$30,897,156	10,070	200,319	5.0%	60.0%
Total	$764,842,817	$50,539,532	16,162	355,322	4.5%	
Minnesota	$11,873,601,322	$768,815,193	239,855	5,379,139	4.5%	

Table 2: Tourist Statistics [19]

By examining the table it becomes apparent that the vast majority of tourism is in St. Louis County, which also contains the taconite mines. The percent employed by tourism mirrors the population breakdown between counties as a percentage of the total, with an r-squared value of .974. For this reason, St. Louis County is a vital part of the sulfate standard debate. It contains the major mining operations, is the center of tourism in Northeast Minnesota, contains the largest population in the region, and is within the traditional range of wild rice.

Mine Operators (current - Taconite)

There are currently six taconite mines operating on the Mesabi Iron Range. The location of the Mesabi Iron Range is completely encompassed by the traditional breeding ground for wild rice [20]. Table 3 shows the six mines, their production, owners, operating company, and the nearest town or city. These mines are well developed, and have been in operation since at least 1890 [21]. Total taconite production is estimated at 1.8 billion to tons, which account for pellets, concentrate, and direct ship iron ore.

Mine	Pellet Production (2011)	Owner	Operator	Nearest Town/City
Minntac	13,047,915	U. S. Steel	U. S. Steel	Mt. Iron, MN
Hibbing Taconite	7,604,595	ArcelorMittal, Cliffs Natural Resources, U.S. Steel	Cliffs Natural Resources	Hibbing, MN
Northshore Mining	5,591,721	Cliffs Natural Resources	Cliffs Natural Resources	Babbitt, MN
United Taconite	5,095,221	Cliffs Natural Resources	Cliffs Natural Resources	Forbes, MN
Keewatin Taconite	4,969,039	U. S. Steel	U. S. Steel	Keewatin, MN
Minorca	2,625,659	ArcelorMittal	ArcelorMittal	Virginia, MN
Total	38,934,150			

Table 3: Mine Operating Information [22]

The total tax obligation of these six mining operations was $127,972,529 for the year 2011 [22]. These taxes provide funding for state, regional, and local entities, as well as assistance to individuals or families that demonstrate a particular need. Additional revenue is set aside in different funds to assist future development projects.

Figure 7 explains the distribution of tax revenue that goes to different entities in the state. The tax structure is well developed to ensure that parties affected by taconite mining, both directly and indirectly, receive compensation or another benefit. The additional, non-compensatory benefits include a better-educated populous, economic and environmental relief funds, improvements to bridges and roadways, and development of recreation areas. Additionally, the taxes have provided nearly $10,000,000 for a Biomass Energy Project Loan and Renewable Energy Initiative in the last five years [22].

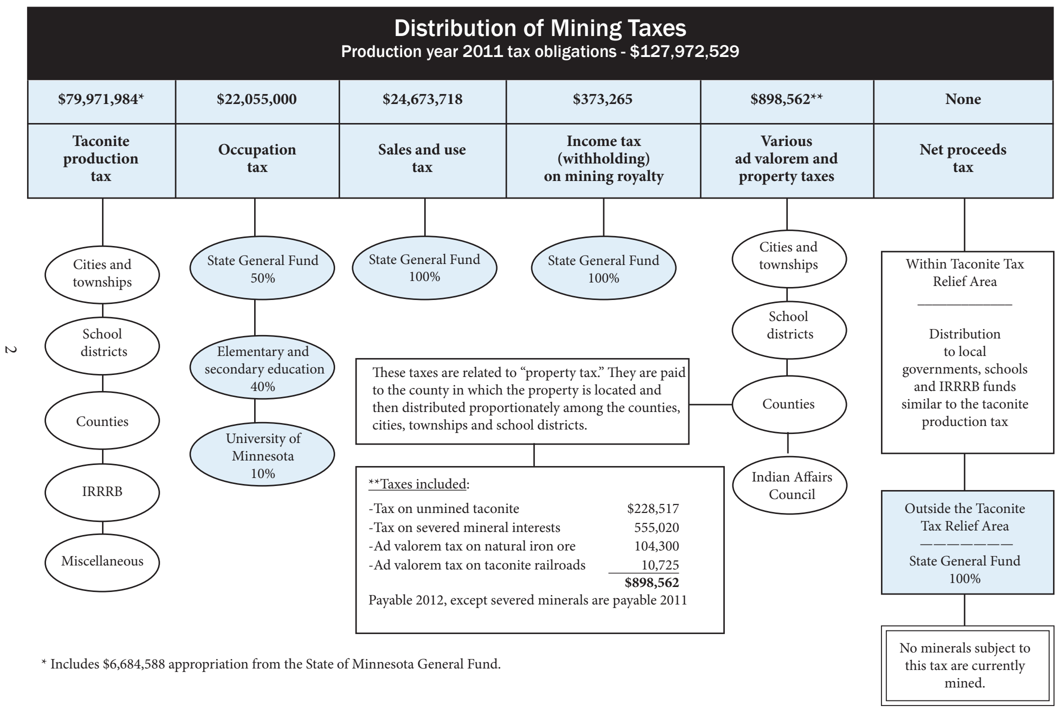

Figure 7: Tax Distribution [22]

A number of development projects have received substantial funding in the form of loans. These loans have allowed both greenfield and brownfield projects to move forward, building the base for the next generation of mining in the area. In 1986 the Butler mine closed after production of over 40 million tonnes of iron ore pellets and in 2001 the Erie Mine close after producing roughly 323 million tonnes of iron ore [22]. There are still sizable reserves of taconite on the Mesabi Iron Range, roughly 1.5 billion tonnes, although these projects will require substantial capital investment to bring to fruition. The Minnesota Department of Natural Resources, in a 2012 document focusing on iron ore mining states, "Although much of Minnesota's iron ore is dedicated to support the six existing commercial operations, there are additional resource areas that offer additional iron ore potential. The major areas include the reserves of the former LTV operation and the identified resources known as the Sherman, Buhl, Kinney, and McKinley deposits. These deposits together contain 1.5 billion tonnes of potential high-grade iron ore pellets" [21].

In addition to the six large mines there are a number of smaller enterprises that are attempting to produce iron ore or steel. Mesabi Nugget LLC has pioneered new technologies to produce 97% metallic iron directly from iron ore. The processes are believed to be more environmentally friendly and will be used in electric arc and oxygen based steel making [21].

Essar Steel is developing an ambitious project that integrates all aspects of the steelmaking process in one location. The Minnesota DNR describes the project by saying, "is developing a $1.6 billion fully integrated, onsite mining through steel-making project on the Mesabi Iron Range in northern Minnesota near Nashwauk, MN. It is designed to produce up to 2.5 million tonnes of steel products each year and employ up to 700 people" [21]. These potential projects will bring additional jobs to St. Louis County and the surrounding area. St. Louis County has traditionally higher unemployment that the Minnesota state average, but lower than the United States average. In August 2013 for example, St. Louis County unemployment was 6.1% while the state of Minnesota stood at just under 5% [23]. Nearby Itasca County shows a similar trend with unemployment at 6.7% for the month of August 2013.

Magnetation LLC is the third new operation on the Mesabi Iron Range. Magnetation reprocesses abandoned stockpiles from iron ore operations that have closed and produces a 'high quality iron ore concentrate" [24]. Magnetation will then send the iron ore concentrate to their processing facility in Reynolds, Indiana, which will use the concentrate in the production of pellets. Magnetation explains the limited environmental impact of their reprocessing by stating, "As a result of our business plan, most of the carbon footprint from our final product was incurred last century because our operations process lean-ore tailings from previous iron ore mining operations. Additionally, our mining techniques do not include stripping or blasting of any undisturbed landforms, and we do not discharge any mining or process water into the natural environment" [24]. The benefits detailed by Magnetation show a commitment to sustainable development by allowing production to increase without the environmental impact of traditional mining methods.

Regulating Agencies

While there are dozens of agencies that have some form of input and stake in Minnesota mining and the sulfate standard, there are four main entities that will be examined. These four groups are the US Environmental Protection Agency (EPA), the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Natural Resources, and the Minnesota Legislature. The MPCA will be the front line regulator making sure that the limits established in the National Pollution Discharge Elimination System permits are being met by current and proposed mines, as well as municipalities. The major population centers near the Mesabi Iron Range are Duluth, Hibbing, Virginia, Eveleth, Chisholm, Mt. Iron, and Grand Rapid among other smaller establishments.

Ojibwe People

The Ojibwe people are a unique stakeholder group in that they have a great deal of exposure to social impacts while other groups are more economic or environmentally focused. There is a book that delves into the cultural importance of wild rice to the Ojibwe people [12]. Wild rice is a crucial component of their culture, as well as a source of income for the tribe and individuals. A distinction must be made between commercially grown wild rice and truly ‘wild” wild rice. The latter is harvested by the Ojibwe and demands a premium on the free market because of the natural growth and care in harvesting. Additionally, wild rice makes up a large part of the diet of many of the Ojibwe people, who have been harvesting it for centuries. The Ojibwe received a number of rights to harvest wild rice in land they ceded to the United States in the 1854 Treaty [13]. It is more difficult to quantify the impact certain risks will have on the Ojibwe culture because it is a social issue. There are well-established guidelines to quantify both economic and environmental impacts; however, social impacts are much more subjective and difficult to interpret.

Advocacy Groups

It is difficult to categorize the many different advocacy groups into a single category as they have decidedly different agendas and motivations. Additionally, the individuals that make up these advocacy groups are often part of other stakeholder groups. There are campaigns for and against new mining, as well as those that simply focus on the environmental effects of potential mines that would exploit minerals in the

Duluth Complex. Advocacy groups are the most vocal proponents of their beliefs and there are a number of websites and campaigns to further these ideals. Often advocacy groups are the vocal wing of a particular stakeholder group. Advocacy groups are significant because of their reach and impact, but will not be included in the risk analysis because they compromise such a variety of opinions and beliefs as well as being well represented by other stakeholder groups. Advocacy groups are a crucial stakeholder in Minnesota, and deserve recognition. However, it would be excessively complex to determine which groups warrant a place in the risk profile, and then to analyze their risks and mitigation options.

Potential Mines - Duluth Complex

In addition to the taconite mining in Minnesota a number of companies are pursuing the potential of opening and operating mines that focus on the Duluth Complex. The Duluth Complex has been described as the world's largest undeveloped Copper – Nickel resource on Earth [25]. Furthermore, the USGS has identified the resources contained within the Duluth Complex as the "#1 or 2 in contained Copper, #2 in contained PGE, #3 in contained Nickel" [25]. The data presented by Jim Miller, from the Department of Geosciences at University of Minnesota – Duluth, suggests that the benefits to exploiting the Duluth Complex are vast.

The companies assessing the potential non-ferrous deposits on the Duluth Complex have a great deal at stake as well, mostly in the form of investment for drilling and exploration. Additionally, a number of entities are in the process of submitting economic assessments and/or environmental impact statements (EIS). Table 4 shows relevant deposits with the potential to be developed, as well the companies, mineral characteristics, and which if any assessment have been conducted. Table 4 provides a detailed view of mineral deposits as well as mineral leases.

Deposit	Company	Mineral	Assessment Underway
Spruce Road Deposit	Twin Metals MN	Cu + Ni + PGE	NI-43-101
South Filson Creek Deposit		Cu + Ni + PGE	
Maturi Deposit	Twin Metals MN	Cu + Ni + PGE	NI-43-101
Birch Lake Deposit	Twin Metals MN	Cu + Ni + PGE	NI-43-101
Dunka Pit Deposits		Cu + Ni + PGE	
Serpentine Deposit	Encampment Minerals Inc.	Cu + Ni + PGE	
Mesaba Deposit	Teck American Inc.	Cu + Ni + PGE	
Northmet Deposit	PolyMet Mining Corp.	Cu + Ni + PGE	NI-43-101 and SEIS
Section 17 Deposit		TiO2	
Wetlegs Deposit		Cu + Ni + PGE	
Longear Deposit		TiO2	
Longnose Deposit	Cardero Resource Corp.	TiO2	NI-43-101
Skibo Deposit	Encampment Minerals Inc.	Cu + Ni + PGE, TiO2	
Sention 22 Deposit	Encampment Minerals Inc.	Cu + Ni + PGE, TiO2	
Water Hen Deposits	Prime Meridian Resources	Cu + Ni + PGE, TiO2	
Titac Deposit	Cardero Resource Corp.	TiO2	

Table 4: Duluth Complex Deposits

Municipalities

Municipalities are a unique stakeholder group as they do not currently have a large stake in the overall debates, but stand to become central to the debate if a low standard is set. While it is currently unclear where the sulfate standard will begin to negatively affect municipal water discharges, it is clear that such a level exists. Currently, municipalities are required to obtain an NPDES permit for discharges, such as those from wastewater treatment plants. A pivotal decision regarding the sulfate standard will be how to determine which waters quality, indirectly deciding which municipalities will be required to meet the new standard. There is also the potential indirect effect of businesses choosing not to invest in the area because of the strict discharge limits they would have to meet by using public waterworks.

Agricultural Industry – Potential Stakeholders

Taconite mining operations are not the only large scale industry in Minnesota with the potential to release high levels of sulfate into the water. The agriculture industry, particularly in the southwest area of the state, operates in areas that have tested much higher than the current limit of 10mg/L. Currently, large-scale agricultural operations do not need to meet the 10 mg/L limit, instead they are only required to meet a 250 mg/L limit.

A study from the North Dakota Water Resources Research Institute, in partnership with North Dakota State University and the University of North Dakota, examined the use of constructed wetlands to remove sulfate from agricultural tile drainage water [15][16].

The limit for sulfate in waters that do not produce wild rice is set to 250 mg/L. This is similar to limits set in nearby states. The Minnesota guidelines do not elaborate on the particular distinction between the two limits beyond stating "Sulfates, wild rice present, mg/L (10)." [17].

An important distinction must be made when comparing wild rice between US states and Canadian provinces. The numbers reported are for wild rice that is grown in the wild, excluding any wild rice that is cultivated. Cultivated wild rice is outside the scope of the Minnesota sulfate standard, and will be excluded in this paper as well. It should be noted that California produces the vast majority of wild rice in the United States, all of which is cultivated. As the rice is cultivated it undergoes a different growing cycle because of the treatment, nutrition, and method of harvesting when compared to naturally occurring wild rice stands.

Michigan, particularly the northern peninsula, is a suitable environment for the production of wild rice and once produced sizable crops. A number of issues have contributed to the decline including water level rise because of dam construction, lake front homeowners clearing wild rice stands, and invasive species [18]. Roger LaBine, chair of the conservation and cultural committees for the Lac Vieux Desert Band of Lake Superior Chippewa Indians in the western Upper Peninsula, explains efforts to return wild rice production to traditional levels stating, “Nineteen other lakes in the western U.P. have been identified as suitable habitat for rice, and will be heavily seeded in 2013 and 2014 [18].” These nineteen lakes are in addition to three lakes that have begun producing wild rice after rehabilitation efforts.

The implications for farming in the state of Minnesota are important because of the potential to limit discharges from farming. If farms in certain areas of Minnesota cannot release sulfates above a certain level they will be forced to change their fertilizing methods. Currently, sulfates come from both soils, which are naturally higher in sulfate in the farming areas, and fertilizers. By limiting the discharge levels for sulfates farms will need to switch to a fertilizer that does not contain sulfates, or very little levels if an absolute necessity. The size and importance of the farming industry will carry a large amount of weight if regulation begins to limit production.

Sustainable Development and Risk Management

Sustainable Development

Sustainable development has become a crucial part of the mining industry in the United States, and all around the world. The concept of sustainable development began many years ago [26], and took on special significance in 1987 when the Bruntland Commission released *Our Common Future*[26]. The report puts forth one of the most prominent definitions of sustainable development by stating, “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.”

The mining industry has always been at the crossroads between meeting the needs of the present without compromising the ability of future generations to meet those same needs. Even before the concept of sustainable development became prominent, mining operations were taking future generations into account.

Extractive activities are inherently unsustainable. The removal and displacement of minerals and waste rock through the mining process means that a resource has been taken, never to be replaced. Minerals are not renewable resources, even when considering recycled materials. One of the greatest challenges facing mining is how an industry devoted to production of nonrenewable resources can contribute to sustainable development.

Sustainable development consists of several pillars, and the number of pillars is dependent on the specific definition one finds most appropriate. Markku Lehtonen explains the development of the pillars; “Although the original definition by the Brundtland Commission from 1987 does not make such a distinction, sustainable development has later become perceived as a combination of three dimensions or ‘pillars’, namely, the environmental (ecological), economic, and social dimensions” [27]. Although they often overlap, the divisions between social, economic, and environmental considerations are distinct, resulting in altered perceptions of the pillars.

It is important to consider the different levels of risk that each stakeholder (group) is willing to accept. This is where the differences in opinion often manifest themselves and create group obstacles. Individuals or groups that stand to lose their livelihood because of an incident are likely to be much more risk averse than a company that would face a penalty or fine because of that same incident. The tenants that produced the three pillars of sustainable development can be applied risk management.

Defining Risk – How It Relates to Mining and Sustainable Development

There is no strict definition of risk management, as it is an ever-evolving theory and concept. According to Pediaditi et al [28] risk can be measured by a simple equation. They explain, “*Risk = [Probability * Magnitude * Outcry]*.” This definition is unique in that it incorporates the social response to an incident, along with the tradition components. Probability is often listed as the “likelihood” of an event occurring, or as the “frequency.” Similarly, magnitude can be called “severity.” The difference methods are designed to accommodate varying parameters that are encountered by the group doing the risk analysis.

Risk Management as a Crucial Step to Sustainable Development

Risk management allows an enterprise to examine the potential failures in a system and mitigate those. By looking at the three pillars of sustainable development it is possible to derive a number of categories on which to focus risk management efforts. Systems have been developed that dictate a procedure and provide certification when that standard level of service is met. Additionally, there are established standards that do not provide certification, but can be beneficial in developing a risk management plan For example, ISO 31000 focuses on risk management as explained in the mission statement,

"ISO 31000:2009, *Risk management – Principles and guidelines*, provides principles, framework and a process for managing risk. It can be used by any organization regardless of its size, activity or sector. Using ISO 31000 can help organizations increase the likelihood of achieving objectives, improve the identification of opportunities and threats and effectively allocate and use resources for risk treatment.
However, ISO 31000 cannot be used for certification purposes, but does provide guidance for internal or external audit programmes. Organizations using it can compare their risk management practices with an internationally recognised benchmark, providing sound principles for effective management and corporate governance." [29].

The use of a framework and benchmark system can improve risk management techniques by providing information on best practices and industry standards. Furthermore, it allows enterprises to gain knowledge from successful risk management implementation projects and critical review. The need to evaluate different potential scenarios and outcomes is a important step towards preventing incidents rather than reacting to them. The benefits from preventive vs reactive responses have been validated in a number of cases.

Risk Management as an Intermediate Step Between Compliance and Sustainable Development

The International Institute for Sustainable Development [30] has championed the role of risk management in business and sustainable development. Figure 8 illustrates the IISD take on how risk management, sustainable development, and compliance are intertwined.

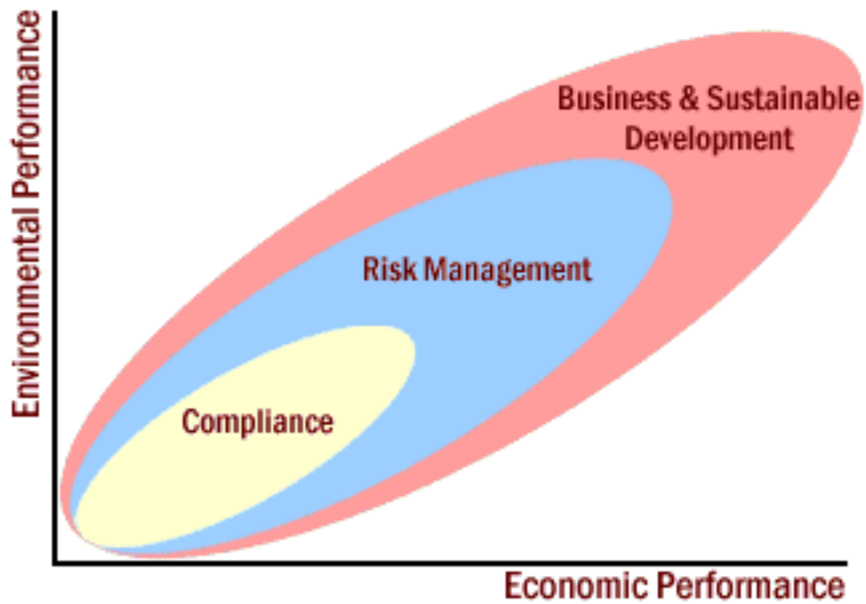

Figure 8: Risk and SD [30]

Two of the three sustainable development pillars are represented by the axes. Environmental performance is on the Y axis while economic performance is on the X axis. The IISD method is useful because it allows metrics to be graphed in a way that will allow for optimization, which would theoretically yield the best possible outcome. While the IISD figure is very helpful, it lacks social considerations, which is one of the three pillars to sustainable development. The potential exists to include a third axis that represents the social aspects related to a particular project. It is also possible to add the social aspects of sustainable development to the graphic, as the social aspects cannot be understated in both likelihood and magnitude. The resulting three dimensional (3-D) image would more accurately represent all aspects of sustainable development. By measuring in three dimensions it is possible to look at economic, social, and environmental considerations at one time.

In an annual study by Ernst and Young [29], mining industry executives were asked to identify different factors that pose the most significant threats to the industry as a whole. The study lists the top ten risks for the mining and metals industry for 2012-2013. Table 5 shows a breakdown of the rankings as well as which of the three pillars to sustainable development are involved with that particular risk.

Ranking		Social	Economic	Environmental
1	Resource Nationalism *	X	X	
2	Skills Shortage *	X	X	
3	Infrastructure Access *	X	X	X
4	Cost Inflation *		X	
5	Capital Project Execution		X	
6	Social License to Operate *	X	X	X
7	Price and Currency Volatility		X	
8	Capital Management and Access		X	
9	Sharing the Benefits	X	X	
10	Fraud and Corruption	X	X	X

Table 5: E & Y Study and Sustainable Development Pillars

The rankings offer insight into what industry insiders consider the most pressing challenges of 2012-2013. It is important to note that economic issues are at the heart of all these risks, providing insight into the basic motivation for entities operating in mining and metals. If these risks were examined over time a recurring theme develops. Five risks have stayed in the top ten over a five-year period, and are marked by an asterisk. Those include, Skills Shortage, Infrastructure Access, Maintaining a Social License to Operate, Rising Costs (cost inflation), and Resource Nationalism. Of these recurring risks, four have social impacts, two have environmental impacts, and all have economic ramifications. The recurrence of these risks means that they have not been mitigated as effectively as other risks or threats that have fallen off the list or have been replaced since the last study was conducted in 2011-2012. Enrst and Young provides a brief explanation of each risk, as well as potential methods of mitigation or remediation.

With social issues representing six of the top ten responses in 2012-2013, and four of five over the previous five years, it is clear that improvement can be made. Social issues are consistently within the top ten ; perhaps due to a fundamental lack of understanding or experience in managing such risks. There is not a clear path for entities to take in order to mitigate such risks as no methodology has been extensively developed. Furthermore, the risks are often unique for each project, unlike economic and environmental issues that often overlap. Economic issues can be broken down to whether or not the project can achieve the financial goals and timeframe set forth by invertors or the board of directors. Environmental risks can also be controlled or mitigated by meeting the regulations agreed upon in the permitting process. The lack of environmental concerns on the Ernst and Young list does not imply such risks are no longer present, rather that methods have been developed to mitigate and reduce those risks.

Seven Questions to Sustainable Development

In 2002 the International Institute for Sustainable Development released a report detailing seven questions to consider and examine in order to further the goals of sustainable development. The stated goal of the project is, "1. to develop a set of practical principles, criteria, and/or indicators that could be used to guide or test the exploration for, design, operation, closure, post-closure and performance monitoring of individual operations, existing or proposed, in terms of their compatibility with concepts of sustainability; and 2. to suggest approaches or strategies for effectively implementing such a test/guideline" [30]. Figure 9 is an adaptation of the seven questions presented by the Mining, Minerals and Sustainable Development North America report.

Number	Category	Question
1	Engagement	Are engagement processes in place and working effectively?
2	People	Will people's well-being be maintained or improved?
3	Environment	Is the integrity of the environment assured over the long term?
4	Economy	Is the economic viability of the project or operation assured, and will the economy of the community and beyond be better off as a result?
5	Traditional and Non-Market Activities	Are the traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local people?
6	Institutional Arrangements and Governance	Are rules, incentives, programs, and capacities in place to address project or operational consequences?
7	Synthesis and Continuous Learning	Does a full synthesis show that the net result will be positive or negative in the long term, and will there be periodic reassessments?

Figure 9: Seven Questions

The ability of the mining industry to effectively answer these questions is at the heart of the risk management debate, and also crucial to the success of similar projects. These seven questions were used when building the risk profiles because of the wide variety of potential risks they cover. While the questions were used to develop the risk profiles, they are not directly answered here. All were considered for each stakeholder group within each risk scenario.

Keewatin Taconite Expansion

In 2008 U.S. Steel began to undertake a draft Environmental Impact Statement (EIS) in order to expand their Keewatin Taconite mine and plant from 6 million tons per year to 9.6 million tons per year of finished pellets. The final EIS was completed in 2010, with a section specifically devoted to wild rice. The final publicly stated on October 25th, 2011 that the mine and plant expansion permits had been approved and issued [30]. The EIS concludes,

Major Environmental Resource	Potential Environmental Impact	Incorporated Into Proposed Project	Additional Identified Measures1
Wild Rice	Unknown, however the changes in water levels and sulfate concentrations resulting from Proposed Project appear to be within the observed range of variation for lakes containing wild rice	· Installation of dry scrubber air pollution control for SO2 removal · Installation of a sulfate removal treatment system on the existing wet scrubber · Permit limits in NPDES/SDS permit · Water quality monitoring required through NPDES/SDS permit	Conduct follow-up field surveys to monitor the extent of wild rice and track changes in density · Monitor water levels in affected water bodies during critical life cycle stages of wild rice · Monitor sulfate concentrations in affected water bodies · Installation of additional sulfate removal technologies · Alternate discharge location and/or water re-use

Table 6 :Keewatin Taconite EIS [30]

The Final EIS for the expansion project provides an in-depth examination of the potential effects on wild rice, and the efforts to mitigate those effects. In section 4.7.2.1, titled *Ojibwe Cultural Value* the EIS touches on the social and cultural factors that make wild rice important to the Ojibwe People. The EIS provides a brief examination of the sustainable development pillars (social, economic, environmental), but does not provide a course of action that takes all three into account.

Steps to Creating a Risk Profile

The process for determining the effects of a particular risk begins with establishing the risk in the first place. As an example the **Limit staying at 10 mg/L** is examined. The likelihood is then determined by locating the bracket that most accurately represents the risk. Figure 7 provides an example of the categories and choices for each category. In the risk tables the sustainable development pillars will be represented as follows: Social – S, Environmental – En, and Economical – Ec. Note that the row do not align in any particular order, they merely list all the possibilities for that category.

Risk	**Likelihood**	**Stakeholders**	**Result**	**SD Pillar**	**Magnitude**	**Mitigation Potential**
	Rare <1%	Ojibwe People		Social	Negligible	
	Unlikely <10%	Current Mines		Economic	Minor	
	Possible <25%	Potential Mines		Environmental	Moderate	
	Likely <50%	Regional Population			Severe	
	Certain >50%	Tourists			Catastrophic	
		Mine Employees				
		Minnesota Regulators				
		Wild Rice Harvesters				
		Landowners				
		Environmental Groups				
		Municipalities				

Table 7: Risk Profile

The following tables illustrate the full assessment for each risk. The risks examined are based on the potential mg/L limit that the state of Minnesota is reevaluating. The limits chosen are 10 mg/L, 100 mg/L, 250 mg/L, and 1,000 mg/L. These have been chosen as they represent current Minnesota effluent discharge levels or levels determined by neighboring states and provinces. The likelihood was determine by evaluating regulatory limits established in neighboring states and provinces, as well as similar cases regarding effluent discharges. Additionally, it was assumed that any limit that is established would be done in a way that would not affect the growth of wild rice. This is a critical assumption and can be justified as the overarching goal of the sulfate standard study is to identify a sulfate limit that does not impact the growth or production of wild rice. Therefore, any decline in wild rice abundance or acreage is regarded as not being related to sulfate levels in the water.

The tables can be used to quantify the potential risks as well as determine ways to mitigate those risks if at all possible. The two ways to reduce the overall risk are to reduce the likelihood of that event, or to change the magnitude of the event. A brief examination of each risk analysis will be provided followed by an investigation of all four tables, focusing primarily on their differences.

Risk	*Limit stays 10 mg/L*	Likelihood	*Unlikely*	
Stakeholders	**Result**	**SD Pillar**	**Magnitude**	**Mitigation Potential**
Ojibwe	WR resurgence	S, Ec	Minor	None
	WR continues to decline	S, Ec	Catastrophic	Further study to find cause of WR decline
Current Mines	Additional water treatment (major)	S,Ec, En	Severe	RO, wetlands creation, zero discharge,
	Change to LOM projections	Ec	Severe	Reevaluate economic grade
	Geology limits ability to mine areas because of higher sulfate discharges as a result	Ec, En	Moderate	Don't mine these areas or limit production from them
Potential Mines	Inability to gain permit approval	S, Ec, En	Catastrophic	Abandon mineral exploration, loss because of failed exploration/development
	Implementation of water treatment	Ec, En	Severe	RO, wetlands creation, zero discharge,
	Uneconomical to open mine with water quality parameters	S, Ec, En	Catastrophic	Loss of investment
Regional Population	Decline in job growth as mines are more conservative	S, Ec	Moderate	Seek other employment
	Decline in tax revenue based on production (mines)	Ec	Moderate	Identify new sources of revenue
Tourists	Change in water chemistry affects fish populations	S	Negligible	Find alternate fishing location
Mine Employees	Potential reduction in output - Layoffs	S, Ec	Catastrophic	Seek additional employment, potential to relocate
Minnesota Regulators	Dealing with opposition to the standard	S, Ec, En	Major	Ensure decision is based on sound research and provide justification
	Ensuring standard is met	Ec, En	Minor	Provide strict and clear guidance on requirements including sampling, no loopholes
Wild Rice Harvesters	WR resurgence	S, Ec	Negligible	None
	WR continues to decline	S, Ec	Moderate	Further study to find cause of WR decline
Municipalities	Discharges no longer meet NPDES limit	Ec, En	Severe	Examine water treatment methods, increased cost to users

Figure 10: 10 mg/L limit

If the limit were to stay at 10 mg/L the effects would be the most severe. Nearly all stakeholders would be affected negatively as regional economic growth would be stifled. The primary driver of this is the inability of new mining projects to meet a 10 mg/L limit. The risks represented in figure 10 are similar to those present in the other tables, however the magnitude is much greater. The reason being that a 10 mg/L standard will be exceptionally difficult to meet for any mine or municipality that utilizes a discharge system. The analysis of a 100 mg/L limit can be found in figure 11 below.

Risk	*Limit is changed to 100 mg/L*	Likelihood	Possible	
Stakeholders	**Result**	**SD Pillar**	**Magnitude**	**Mitigation Potential**
Ojibwe	WR resurgence	S, Ec	Minor	None
	WR continues to decline	S, Ec	Catastrophic	Further study to find cause of WR decline
Current Mines	Additional water treatment (moderate)	S,Ec, En	Moderate	Wetlands creation, zero discharge, water retreatment
	Change to LOM projections	Ec	Moderate	Reevaluate economic grade
	Geology limits ability to mine areas because of higher sulfate discharges as a result	Ec, En	Minor	Avoid areas of that result in high sulfate, maintain higher grade
Potential Mines	Implementation of water treatment	Ec, En	Moderate	Wetlands creation, zero discharge, water retreatment
	Permitting delay as water treatment options are tested/proven	S, Ec, En	Severe	Use proven method, if alternative is necessary begin testing immediately
Regional Population	Decline in job growth as mines are more conservative	S, Ec	Severe	Develop cross functional skills
	Decline in tax revenue based on production (mines)	S, Ec	Moderate	Identify additional sources of income, evaluate cost/benefit of mines
Tourists	Change in water chemistry affects fish populations	S	Negligible	Find alternate fishing location
Mine Employees	Potential reduction in output - Layoffs	S, Ec	Severe	Develop cross functional skills
Minnesota Regulators	Dealing with opposition to the standard	S, Ec, En	Minor	Use sound reasoning and information to establish standard
	Ensuring standard is met	Ec, En	Moderate	Ensure methods are in place to regulate standards, close loopholes
Wild Rice Harvesters	WR resurgence	S, Ec	Negligible	None
	WR continues to decline	S, Ec	Moderate	Further study to find cause of WR decline
Municipalities	Discharges no longer meet NPDES limit	Ec, En	Moderate	Examine water treatment methods, increased cost to users
	Discharges require additional treatment	S, Ec, En	Moderate	Increased costs to users

Figure 11: 100 mg/L limit

The immediate difference is that there are no longer any catastrophic risks associated with a 100 mg/L limit. There are no longer any stakeholders that will suffer to the extent that they will have to cease operation, move, or drastically change their way of life. There are still several risks that fall under the category of "severe" however. These risks should be the first to be mitigated because of the severity. This risk analysis is unique in that the individual stakeholder groups, as opposed to a joint exercise that is more common, usually undertake the mitigation efforts. The reasoning being that different stakeholders rely on different motivations, and what is beneficial to one stakeholder group may in fact be detrimental to the motivations of efforts of another. Figure 12 shows the risk analysis if a new limit of 250 mg/L is established.

Risk	*Limit is changed to 250 mg/L*	**Likelihood**	Likely	
Stakeholders	**Result**	**SD Pillar**	**Magnitude**	**Mitigation Potential**
Ojibwe	WR resurgence	S, Ec	Minor	None
	WR continues to decline	S, Ec	Catastrophic	Further study to find cause of WR decline
Current Mines	Additional water treatment (minor)	S,Ec, En	Minor	Wetlands creation, water retreatment
	Change to LOM projections	Ec	Minor	Reevaluate economic grade
	Geology limits ability to mine areas because of higher sulfate discharges as a result	Ec, En	Minor	Avoid areas of that result in high sulfate, maintain higher grade
Potential Mines	Implementation of water treatment	Ec, En	Moderate	Wetlands creation, zero discharge, water retreatment
	Permitting delay as water treatment options are tested/proven	S, Ec, En	Moderate	Use proven method, if alternative is necessary begin testing immediately
Regional Population	Decline in job growth as mines are more conservative	S, Ec	Minor	Develop cross functional skills
	Decline in tax revenue based on production (mines)	Ec	Minor	Identify additional sources of income, evaluate cost/benefit of mines

Tourists	Change in water chemistry affects fish populations	S	Moderate	Find alternate fishing location, encourage development of protected waters
Mine Employees	Potential reduction in output - Layoffs	S, Ec	Minor	Do not fill positions as employees leave or retire willingly
Minnesota Regulators	Dealing with opposition to the standard	S, Ec, En	Minor	Use sound reasoning and information to establish standard
	Ensuring standard is met	Ec, En	Minor	Ensure methods are in place to regulate standards, close loopholes
Wild Rice Harvesters	WR resurgence	S, Ec	Negligible	None
	WR continues to decline	S, Ec	Moderate	Further study to find cause of WR decline
Municipalities	Discharges no longer meet NPDES limit	Ec, En	Minor	Examine water treatment methods, increased cost to users
	Discharges require additional treatment	S, Ec, En	Minor	Marginal increased costs to users

Figure 12: 250 mg/L limit

A 250 mg/L limit would still pose the same risks as the previous levels (10 mg/L and 100 mg/L). The main difference would be in the severity or magnitude of those risks. Notably there is only one risk that earns a rating of severe or catastrophic. This is a good measure of the success of mitigation efforts if they have been applied, or the relative risk of a particular action which is the case in this example. To fully understand the gradual decline it magnitude it is necessary to look at a level that has dropped a number of previous risks as they are no longer applicable. Figure 20 illustrates the sulfate standard being changed to 1000 mg/L. This is the both the highest level and presents the fewest risks. The number of risks has dropped significantly because at a 1000 mg/L level nearly all of the mining operations, both current and potential, will meet the regulation. This level is easily met by current discharges, and only outliers have surpassed it in passed sampling. These outliers are significant, however they should be examined on a case by case basis instead of being part of a larger group since their mitigation needs are more likely to be unique.

Risk	Limit is changed to 1000 mg/L	Likelihood	Possible	
Stakeholders	**Result**	**SD Pillar**	**Magnitude**	**Mitigation Potential**
Ojibwe	WR abundance declines further	S, Ec, En	Catastrophic	Further analysis of potential factors involved with decline, develop alternate form of income
Current Mines	Minimal water quality treatment beyond current practices	Ec, En	Negligible	Ensure standard is being met
	Renew necessary permits to allow continued operation and/or expansion	S, Ec, En	Minor	Ensure environmental quality measures are in place and working
Potential Mines	Gain regulatory approval, specifically NPDES permit	Ec, En	Moderate	Use best practices and/or best available technology to meet NPDES requirements, ensure test scale results can be replicated on commercial scale
Regional Population	Boost to economy as potential mines gain regulatory approval	S, Ec	Severe	Utilize a development plan to avoid boom-bust cycle
	Additional construction and full time jobs at existing and potential mines	S, Ec	Severe	Undergo technical and safety training to obtain position
Tourists	Potential to create water imbalance affecting fish	S, Ec, En	Moderate	Encourage DNR to monitor waters of the state
Minnesota Regulators	Potential lawsuits	S, Ec	Moderate	Provide strong evidence for decision
Wild Rice Harvesters	WR abundance declines further	S, Ec	Moderate	Further analysis of potential factors involved with decline, identify new source of income
Municipalities	Meet current permit requirements	Ec	Negligible	Continue to follow established procedures

Figure 13: 1000 mg/L limit

Risk Management and Mitigation Analysis

The four risk analysis tables can be used in conjunction to demonstrate the potential sulfate standard level that poses the greatest level of overall risk. It also allows for the examination of patterns, which when identified allow for more suitable mitigation efforts to be developed. The first clear pattern primarily affects the Ojibwe people and wild rice harvesters. The potential that wild rice continues to decline, in light of a new sulfate standard, is present in all four risk analysis tables. It is important to note that the new sulfate standard is assumed to not affect wild rice growth. This assumption is important because it means any decline in wild rice growth is not related to sulfate levels in the water. Furthermore, if the decline in wild rice acreage and abundance continues, there is another cause for that decline. There are several issues associated with a continued decline in wild rice. First, the regulation that has been in place has not done what it was intended to do. It was also presumed to alleviate the chemical strain on wild rice, which meant research to find the true causes never took place. Additionally, regulatory pressure was placed on mines, potential mines, and municipalities that resulted in added expense without any benefit to wild rice growth. While valid arguments can be made that sulfates are a contributing factor, they do not account for the continued decline in areas unaffected by mining or sulfates. This continued decline necessitates increased research in order to determine all the factors involved, and limit the ones that can be controlled. These mitigation efforts are necessary to reduce the likelihood of wild rice decline continuation.

A second noticeable pattern is that the first three tables all contain the same risks. The risks are still present and have an assessable magnitude making it necessary to include them. The primary differences between these risks are the magnitudes and mitigation options. As stakeholder groups utilize the mitigation options they can reduce the associated magnitudes. What is not possible in the first three tables is to remove risks entirely. This is the result of risks still being noticeable and measurable if they were to occur. It is often difficult to differentiate when a risk no longer belongs in a risk analysis. For this reason, risks that are on the edge should be included with an appropriate consideration of likelihood and magnitude. What is different between the risks that are present in the first three tables is the mitigation potential. Since the likelihood and magnitude are changing the mitigation needs of a particular risk are also changing. For example, currently operating mines will have a much harder time meeting a 10 mg/L limit as opposed to a 250 mg/L limit. A 10 mg/L limit would require implementation of reverse osmosis or ensuring all activities are zero discharge. This capital investment could instead be used for beneficial use in the community, whether in the form of an infrastructure project or higher wages. Both of the mitigation options are expensive and difficult to achieve. However, if a 250 mg/L limit is appropriate, then operation mines should be able to continue operating as they have been, meaning very little capital investment for new technology and lower variable expense for maintenance.

The social development pillars are also useful when looking for patterns. If completed as each risk is analyzed, they offer an unbiased categorization of the risk. These can be analyzed together to determine which pillar presents the greatest risk to all stakeholders, as well as which ones decline as the sulfate standard increases. Figure 21 illustrates the number of risks for each sustainable development pillar at a given sulfate standard level. It also provides the percentage of risks containing each sustainable development pillar.

mg/L Sulfate	Social	Environmental	Economic	Total
10	11	8	16	17
100	11	8	16	17
250	11	8	16	17
1000	7	5	10	10
10	65%	47%	94%	
100	65%	47%	94%	
250	65%	47%	94%	
1000	70%	50%	100%	

Table 8: Risk Profile Breakdown

The sustainable development pillars are well represented in all four risk tables. The economic considerations are the most prominent, which is intuitive when you consider the underlying motivations of the stakeholder groups. Table 8 also allows users to interpret ways to mitigate which may not have otherwise been obvious. Economic concerns affect nearly all stakeholder groups, and are a good area to focus mitigation efforts. By eliminating the economic risk for a stakeholder, it is possible to eliminate that risk entirely. For example, if a mine employee is trained in a skill that can be used by another industry, and is in high demand, that employee will be able to move to a new position more easily if he or she is laid off. The reduction in severity of the risk means that a mine employee is no longer severely affected by potential lay offs, since he is economically able to cope by finding a comparable job.

A final pattern that can be gleaned from the risk analysis tables covers the risks that do not change in magnitude and do not fall out of the tables at any point. In particular, a continued decline in wild rice would be catastrophic to the Ojibwe and would have a serious impact on wild rice harvesters. The Ojibwe would be affected socially, environmentally, and economically while wild rice harvesters would be affected socially and economically. This risk does not diminish in magnitude because the potential outcomes are so severe for the affected stakeholder groups. If wild rice were to continue to decline because of another factor then past regulation was misguided and has not been minimizing the impacts to wild rice. Additionally, the belief that sulfates were causing wild rice decline means research and regulation was not directed towards finding the true cause(s).

With the breakdown in mind it is necessary to compare how past survey samples meet the criteria. Figure 22 illustrates the breakdown for samples in the area around the Mesabi Iron Range. It is important to note that this does not reflect the state as a whole since a large number of samples are taken around the Minneapolis-St Paul metro area and do not reflect conditions near the mines. The important takeaway is that very few samples fall about 250 mg/L and only one falls above 1000 mg/L. These are attainable levels of sulfate in discharges based on past results.

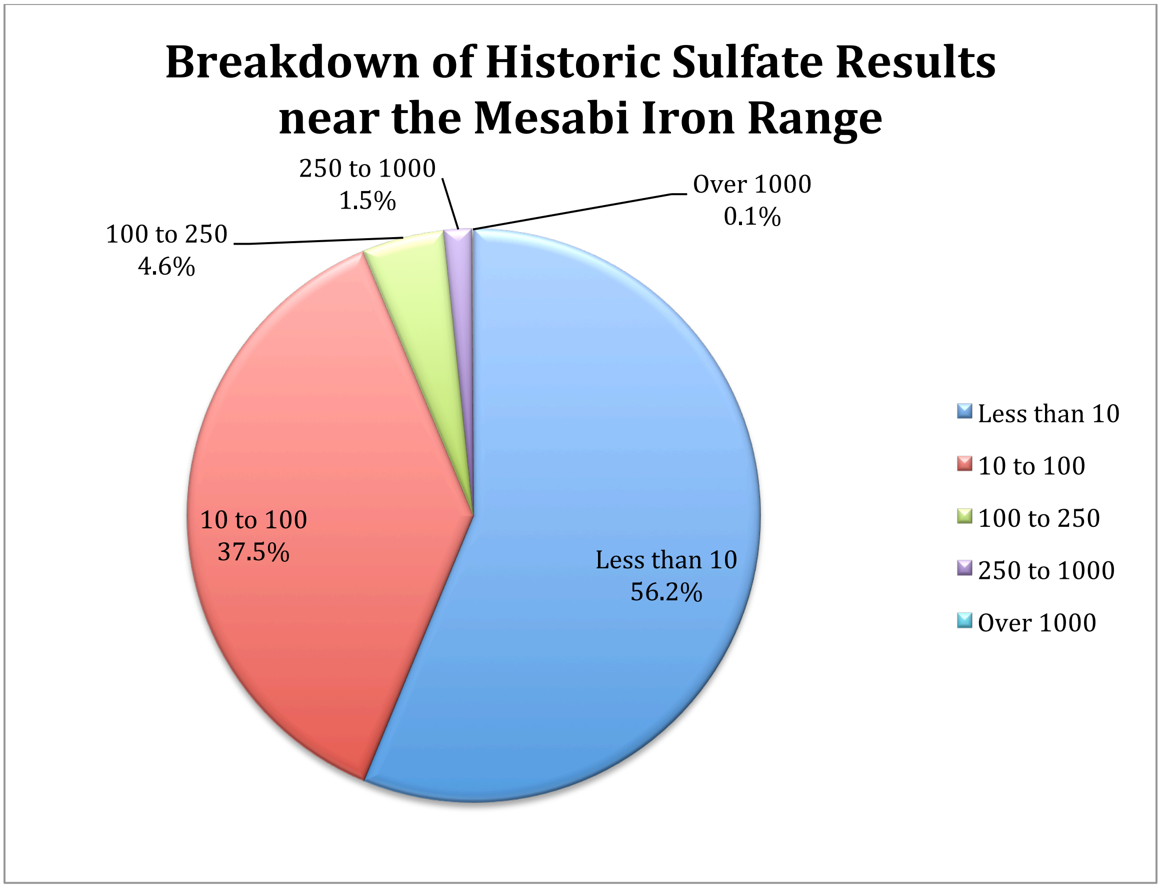

Figure 14: Sulfate Results

Conclusion

Risk analysis can be used to promote and supplement sustainable development efforts. The ultimate goal of risk management is to reduce the likelihood or severity of a particular risk. By changing one of these variables it is possible to lower the overall exposure of a stakeholder. There is unlikely ever to be an optimal solution that benefits all stakeholders equally, however, it is possible to find a solution that reduces the overall exposure of all stakeholder groups. What will be difficult for those using risk management techniques is finding a method that values each risk in a way that accurately reflects the sentiments of the stakeholder group it affects.

Minnesota stakeholders can use a risk analysis profile to gain a better understanding of where particular risks lie, how they developed, and potentially, how to reduce the likelihood or magnitude of such incidents. By examining four potential sulfate standard levels, it is possible to delve into patterns and risks that persist between different levels. The ability of each stakeholder group to successfully defend their beliefs and motivations can be aided by a better understanding of the risks posed to other stakeholder groups. The potential benefit to all stakeholders is realized when a "middle ground" is determined that presents the least unfavorable risk to the overall stakeholder group.

The different stakeholder groups should use these risk profiles when the results of the wild rice survey are released. There is not a situation that is favorable for all groups, but there are mitigation options for each stakeholder group for each scenario. By identifying the mitigation potential beforehand, individuals and groups will be able to adapt and respond to the new standard more quickly and appropriately.

Based on the relative risk to all stakeholder groups it is suggested that a limit of 1000 mg/L be established as long as it does not interfere with wild rice growth. If this is not feasible, then the highest allowable limit should be established as higher limits present lower risk magnitudes for the majority of stakeholders.

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Final Conclusion

The process of risk management involves assessing different scenarios on the basis of likelihood and severity of that scenario occurring. These scenarios are each referred to as a specific risk, and can be analyzed in comparison to other risks or projects. Once a list of risks is compiled it is possible to delve into patterns that may not have otherwise been present or apparent. By utilizing risk assessment matrices it was possible to identify, plan for, and reduce the likelihood or magnitude of risks present during CO_2 injection. A focus on leakage yielded several mitigation options that alleviated the relative risk.

The manuscripts both utilize risk management to promote sustainable development. Comparisons can be made by reviewing the three pillars of sustainable development examined in the second manuscript and the five categories from the first manuscript. The first manuscript, focusing on CO_2 injection leakage, analyzes risks based on the categories of cost, reputation, health and safety, environment, and schedule. These categories are similar to the sustainable development pillars analyzed in the second manuscript concerning wild rice. Clearly, there are parallels between the two projects even though they cover widely different topics. The application of risk management and sustainable development allow stakeholders to operate in a preventive way as opposed to a reactive manner. The use of these mitigation efforts was successful in the past as was shown in manuscript 1, and has potential to be successful as with manuscript 2.

Future work should include a continuation of mitigation efforts and a thorough and periodic evaluation of the progress of those efforts. These techniques should further be refined based on examination of how risk management work and failed in the past. A thorough study of the successes and failures post completion or termination of these case studies would be beneficial in developing a quantitative method of analysis. Such a method would be useful in that it could apply financial results that are known.

Appendix – Risk Registry

Table 1: Risk Registry, January 2013

Id-H	*Id-A*	*Name*	*Potential risk/ Due*
R-0002		**CBM test - Unusually large CO2 release during unloading and storage in four 60-ton vessels near injection site.**	Cost Rep H&S Env Sched.
	A-0014	CBM - Monitor unloading diligently	
	A-0015	CBM - Inspection of valves and vessels	
	A-0016	CBM - Protect/lock valves	
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0020	CO2 loading/unloading procedures	
	A-0023	Arrange Emergency response training	
	A-0101	Identify escape routes	
	A-0102	Review wind socks	
	A-0103	Implement procedure with daily HASP planning before work occurs.	
R-0003		**CBM test - Unusually large CO2 release during storage in four 60 ton vessels**	Cost Rep H&S Env Sched.
	A-0015	CBM - Inspection of valves and vessels	
	A-0016	CBM - Protect/lock valves	
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0090	Reduce on-site personnel to only CO2 operator and site supervision/engineer.	
R-0004		**CBM test - Unusually large CO2 release during transfer to two 50 ton vessels at injection well DD7, and possibly release and ignition of diesel from transfer truck.**	Cost Rep H&S Env Sched.
	A-0014	CBM - Monitor unloading diligently	
	A-0015	CBM - Inspection of valves and vessels	
	A-0016	CBM - Protect/lock valves	
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0019	Road use protocol	
	A-0020	CO2 loading/unloading procedures	
	A-0021	Road maintenance procedures	
	A-0022	Fire extinguisher in truck.	
	A-0023	Arrange Emergency response training	
	A-0104	Use site supervision to review transfer practices.	
R-0005		**CBM test - Unusually large CO2 release during storage in two 50 ton vessels at DD7**	Cost Rep H&S Env Sched.
	A-0015	CBM - Inspection of valves and vessels	
	A-0016	CBM - Protect/lock valves	
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0024	Safety distances	
R-0006		**CBM test - Failure or unplanned down-time of tri-plex pump creates project delays**	Cost Rep Env Sched.
	A-0025	CBM - Regular maintenance of pump	
	A-0026	Maintain purity of CO2 stream	
R-0007		**CBM test - Failure or unplanned downtime of heater creates project delays**	Cost Rep Sched.
	A-0027	Spare heater/alternative heater	
	A-0028	Evaluate liquid injection	
R-0008		**CBM test - Release and ignition of propane causing harm to people or knock-on effects to CO2 vessels, DD7 and tri-plex pump.**	Cost Rep H&S Env Sched.
	A-0015	CBM - Inspection of valves and vessels	
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0024	Safety distances	
	A-0029	Explosive atmosphere protection	
R-0009		**CBM test - Unusually large CO2 release along pipeline distribution system**	Cost Rep H&S

Id-H	*Id-A*	*Name*	*Potential risk/ Due*
			Env Sched.
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0030	Pressure monitoring and control system	
R-0010		**CBM test - Internal or external corrosion of pipeline requiring corrective action.**	Cost Rep H&S Env Sched.
	A-0026	Maintain purity of CO2 stream	
	A-0031	CO2 purity monitoring	
R-0011		**CBM test - Pipeline construction delay affects project schedule (Milestone Log)**	Cost Rep H&S Env Sched.
	A-0033	Communication with suppliers	
	A-0034	Procedures for acceptance check of equipment	
R-0012		**CBM test - Lack of communication protocols between field team members leads to system downtime.**	Cost Rep H&S Env Sched.
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0032	Operational procedures and communication protocol	
	A-0105	Ensure oversight and review of CO2 supply, injection process and HASP.	
R-0013		**CBM test - Leakage along existing or new wellbores due to inadequate well integrity**	Cost Rep H&S Env Sched.
	A-0003	CBM - Redistribute injection among wells	
	A-0004	Stop injection in one (or more - CBM) well(s)	
	A-0005	Repair well(s)	
	A-0068	Employ best management practices for CO2 injection and monitoring	
	A-0091	Diagnose extent of leakage	
R-0014		**CBM test - Leakage along transmissive faults or natural fractures.**	Cost Rep H&S Env Sched.
	A-0002	Appropriate site selection	
	A-0004	Stop injection in one (or more - CBM) well(s)	
	A-0068	Employ best management practices for CO2 injection and monitoring	
	A-0091	Diagnose extent of leakage	
R-0015		**CBM test - Leakage through existing fractures in seals**	Cost Rep H&S Env Sched.
	A-0002	Appropriate site selection	
	A-0003	CBM - Redistribute injection among wells	
	A-0004	Stop injection in one (or more - CBM) well(s)	
	A-0006	Lower injection pressure	
	A-0082	Perform microseismic monitoring	
	A-0091	Diagnose extent of leakage	
R-0016		**CBM test - Injectivity insufficient to inject 7 kt in three wells over 1 year.**	Cost Rep Sched.
	A-0007	Change injection pressure	
	A-0008	Start injection with slow rates	
R-0017		**CBM test - Lower capacity than required for 7kt.**	Cost Rep Sched.
	A-0002	Appropriate site selection	
R-0018		**CBM test - Monitoring program unable to track movement of CO2 and demonstrate containment**	Cost Rep H&S Env Sched.
	A-0009	Detect co2 breakthrough in monitoring wells.	
	A-0010	Use history matching to calibrate models.	
	A-0011	Use wells (and geophysical monitoring for CBM) to image CO2 plume.	
	A-0012	Develop robust MMV plan to meet these objectives with sufficient response time for implementing contingency options.	
	A-0013	Escalate monitoring program if lack of resolution / sensitivity is suspected.	
	A-0068	Employ best management practices for CO2 injection and monitoring	
R-0019		**CBM test - Size/direction of plume expansion not consistent with baseline monitoring and predictions.**	Cost Rep Sched.
	A-0007	Change injection pressure	
	A-0008	Start injection with slow rates	
	A-0009	Detect co2 breakthrough in monitoring wells.	
	A-0010	Use history matching to calibrate models.	
	A-0011	Use wells (and geophysical monitoring for CBM) to image CO2 plume.	
R-0020		**CBM test - Delayed baseline characterization infers delay in start-up of injection.**	Cost Rep Sched.

Id-H	Id-A	Name	Potential risk/ Due
	A-0083	Modify access agreements	
	A-0084	Separate CX for characterization	
R-0021		**CBM test - Baseline insufficient to differentiate indicators of CO2/formation fluid/gas migration**	Cost Rep Sched.
	A-0085	Utilization of tracers for monitoring the extent of CO2 migration.	
R-0023		**CBM test - Leaky packer**	Cost Rep H&S Env Sched.
	A-0038	Attempt to reset packer or pull packer and replace	
R-0024		**CBM test - Leaking tubing**	Cost Rep H&S Env Sched.
	A-0039	Pull tubing and replace bad joint.	
	A-0040	Use fiberglass lined tubing to prevent holes for CBM wells	
R-0025		**CBM test - Casing leak**	Cost Rep Sched.
	A-0041	Mechanical Integrity Test prior to injection.	
	A-0086	Inspect casing at regular intervals	
	A-0087	Repair casing	
R-0026		**CBM test - Loss of monitoring well during drilling**	Cost Rep H&S Env Sched.
	A-0088	Use driller experienced in area	
R-0027		**CBM test - Tool fishing**	Cost Rep H&S Env Sched.
	A-0042	Retrieve tools using service rig	
	A-0043	Tool fishing insurance	
R-0028		**CBM test - Delayed reporting/deliverables/milestones leading to action by DOE**	Cost Rep Sched.
	A-0044	Contractual arrangements with subcontractors regarding reporting requirements.	
	A-0045	VCCER will assist, if needed, with reporting to regain schedule slippage	
	A-0065	Requirements not constrained by a single participant or event	
R-0029		**CBM test - Lack of availability of 10-ton trucks**	Cost Sched.
	A-0046	CBM - Assess contingency options for CO2 delivery at DD7	
	A-0065	Requirements not constrained by a single participant or event	
R-0030		**CBM test - Third party damage to equipment, pipeline, pumps or wellheads**	Cost Rep
	A-0047	Bury pipeline and identify ROW with appropriate safety markers	
	A-0048	Supervision of injection site during injection period.	
	A-0089	Implement wellhead safeguards and perimeter control	
	A-0106	Security planning and monitoring	
R-0031		**CBM test - Lack of personnel availability**	Cost Rep Sched.
	A-0049	Develop contingency plans for replacing key project personnel.	
	A-0065	Requirements not constrained by a single participant or event	
R-0032		**CBM test - Extreme weather causing interruptions in injection operations**	Cost Rep H&S Env Sched.
	A-0050	Prepare plans for securing and protecting equipment/instruments based on severe weather forecast.	
	A-0051	Prepare protocol for suspending operations if necessary.	
	A-0052	Prepare plans for timely snow removal and road repair.	
R-0033		**CBM test - Failure to start injection by Q2 2014.**	Cost Rep Sched.
	A-0053	Good communication with permitting agency.	
	A-0054	Submit permit applications early.	
	A-0055	Seek to conclude contract negotiations early	
R-0034		**CBM test - High budget overruns due to unforeseen technical or commercial challenges results in alteration of scope.**	Cost Rep Sched.
	A-0056	Utilize established cost tracking and project controls utilized in similar on-going large scale capital projects.	
	A-0057	CBM - Reduce purchased volumes of CO2.	
	A-0058	Revise monitoring program	
	A-0066	Periodic financial statement vs. project progress	
R-0035		**CBM test - Delayed return of wells to CNX Gas**	Cost Rep Sched.
	A-0092	Extend access agreements to wells	
R-0036		**CBM test - Cost of CO2 exceed expectations**	Cost Rep

Id-H	Id-A	Name	Potential risk/ Due
			Sched.
	A-0093	Consider alternative vendors	
R-0037		**CBM test - Loss of funding beyond BP1 (assuming all requirements are met)**	Cost Rep Sched.
	A-0094	Prepare contingency plan for early termination	
R-0038		**CBM test - Public opposition, claims that may delay or stop project**	Cost Rep Sched.
	A-0059	Implement an aggressive outreach program, including open houses.	
	A-0095	Initial meetings and briefings for regulators and public officials.	
R-0039		**CBM test - Delay in or failure to deliver DOE necessary documentation to move ahead with project at go/no-go decision point 1**	Cost Rep Sched.
	A-0060	Seek to finalize access agreements and CO2 procurement agreements early.	
	A-0066	Periodic financial statement vs. project progress	
R-0040		**CBM test - Project delayed/terminated prior to submission of UIC permit application or Decision point 2.**	Cost Rep Sched.
	A-0002	Appropriate site selection	
	A-0061	Consider alternative site as back-up option	
	A-0062	Use experienced personnel/service providers for site characterization.	
R-0041		**CBM test - Delay in issue of Class II UIC permit**	Cost Rep Sched.
	A-0063	CBM - Keep open communication with EPA Region 3 and allow extra time for decision	
R-0042		**CBM test - Change of permit requirements for UIC permit (change of class or change of class requirements)**	Cost Sched.
	A-0063	CBM - Keep open communication with EPA Region 3 and allow extra time for decision	
R-0043		**CBM test - Delay in, or unable to get NEPA categorical exclusion**	Cost Rep Sched.
	A-0096	Modify scope of test	
	A-0097	Advance preparation of Environmental Information Volumes for EA review	
R-0044		**CBM test - Delay in issue of state permits**	Cost Sched.
	A-0064	Allow plenty of extra time when preparing and submitting documents for state permits in order to address any discrepancies	
R-0048		**CBM test - Unable to secure injection and monitoring wells**	Cost Rep H&S Env Sched.
	A-0067	Select sites that have existing wells and infrastructure	
	A-0069	Move to an alternative site	
R-0049		**CBM test - CO2 not available for injection tests**	Cost Rep Sched.
	A-0093	Consider alternative vendors	
R-0050		**Shale test - Unplanned CO2 release during unloading in two 60-ton vessels near injection site**	Cost Rep H&S Env Sched.
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0020	CO2 loading/unloading procedures	
	A-0023	Arrange Emergency response training	
	A-0070	Shale - Monitor unloading diligently	
	A-0071	Shale - Inspection of valves and vessels	
	A-0072	Shale - Protect / lock valves	
R-0051		**Shale test - Unplanned CO2 release during storage in two 60 ton vessels**	Cost Rep H&S Env Sched.
	A-0017	Lay-out review	
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0024	Safety distances	
	A-0071	Shale - Inspection of valves and vessels	
	A-0072	Shale - Protect / lock valves	
	A-0081	Vent CO2 at storage vessels to maintain CO2 in liquid phase	
R-0052		**Shale test - Failure or unplanned down-time of pump creates project delays**	Cost Rep H&S Env Sched.
	A-0026	Maintain purity of CO2 stream	
	A-0073	Shale - Regular maintenance of pump	
	A-0098	Ensure authorized personnel have immediate access to parts warehouse.	
R-0053		**Shale test - Failure or unplanned downtime of heater creates project delays**	Cost Rep H&S

Id-H	*Id-A*	*Name*	*Potential risk/ Due*
			Env Sched.
	A-0027	Spare heater/alternative heater	
	A-0028	Evaluate liquid injection	
R-0054		**Shale test - Release and ignition of propane causing harm to people or knock on effects to CO2 vessels and pump**	Cost Rep H&S Env Sched.
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0024	Safety distances	
	A-0029	Explosive atmosphere protection	
	A-0071	Shale - Inspection of valves and vessels	
R-0055		**Shale test - Plume breakthrough at 3rd party production wells.**	Cost Rep Sched.
	A-0007	Change injection pressure	
	A-0008	Start injection with slow rates	
	A-0009	Detect co2 breakthrough in monitoring wells.	
	A-0011	Use wells (and geophysical monitoring for CBM) to image CO2 plume.	
	A-0068	Employ best management practices for CO2 injection and monitoring	
	A-0099	Stop injection if third party objects	
R-0056		**Shale test - Failure to start Shale Test Injection by CY-Q4 2013**	Cost Rep Sched.
	A-0053	Good communication with permitting agency.	
	A-0055	Seek to conclude contract negotiations early	
	A-0074	Shale - Allow plenty of extra time to seek authorization from state for well stimulation	
R-0057		**Shale test - New permit required vs. well stimulation**	Cost Sched.
	A-0075	Shale - Keep open communication with EPA Region 4 and State of Tennessee and allow extra time for decision	
R-0059		**Shale test - Third party damage to equipment, pumps or wellheads**	Cost Rep H&S Env Sched.
	A-0048	Supervision of injection site during injection period.	
	A-0089	Implement wellhead safeguards and perimeter control	
	A-0106	Security planning and monitoring	
R-0061		**Shale test - Difficulty determining integrity during injection into horizontal well**	
	A-0079	Shale - Add Instrumentation at bend in horizontal well and additional logging during or after injection	
R-0062		**Shale test - Ability to successfully monitor with a Huff and Puff**	Cost Rep Sched.
	A-0080	Shale - Deploy instrumentation and sampling procedures to double check results and provide a back-up to primary instrumentation	
R-0063		**Shale test - Lack of communication protocols between field team members leads to system downtime.**	Cost Rep H&S Env Sched.
	A-0018	Emergency philosophy and procedures	
	A-0023	Arrange Emergency response training	
	A-0032	Operational procedures and communication protocol	
	A-0100	Provide clear supervision and oversight	
R-0064		**Shale test - Leakage along existing or new wellbores due to inadequate well integrity.**	Cost Rep H&S Env Sched.
	A-0003	CBM - Redistribute injection among wells	
	A-0005	Repair well(s)	
	A-0068	Employ best management practices for CO2 injection and monitoring	
	A-0091	Diagnose extent of leakage	
R-0065		**Shale test - Leakage along transmissive faults or natural fractures.**	Cost Rep H&S Env Sched.
	A-0002	Appropriate site selection	
	A-0068	Employ best management practices for CO2 injection and monitoring	
	A-0091	Diagnose extent of leakage	
R-0066		**Shale test - Leakage through existing fractures in seals**	Cost Rep H&S Env Sched.
	A-0002	Appropriate site selection	
	A-0003	CBM - Redistribute injection among wells	
	A-0004	Stop injection in one (or more - CBM) well(s)	
	A-0006	Lower injection pressure	
	A-0082	Perform microseismic monitoring	
	A-0091	Diagnose extent of leakage	
R-0067		**Shale test - Injectivity insufficient to inject 300 tons in 1 well over 1 year.**	Cost Rep

Id-H	Id-A	Name	Potential risk/ Due
			Sched.
R-0068		**Shale test - Monitoring program unable to detect lateral extent of injected CO2 and demonstrate containment.**	Cost Rep H&S Env Sched.
	A-0009	Detect co2 breakthrough in monitoring wells.	
	A-0010	Use history matching to calibrate models.	
	A-0011	Use wells (and geophysical monitoring for CBM) to image CO2 plume.	
	A-0012	Develop robust MMV plan to meet these objectives with sufficient response time for implementing contingency options.	
	A-0013	Escalate monitoring program if lack of resolution / sensitivity is suspected.	
	A-0068	Employ best management practices for CO2 injection and monitoring	
R-0069		**Shale test - Delayed baseline characterization infers delay in start-up of injection**	Cost Rep Sched.
	A-0083	Modify access agreements	
	A-0084	Separate CX for characterization	
R-0070		**Shale test - Baseline insufficient to differentiate indicators of CO2/formation fluid/gas migration**	Cost Rep Sched.
	A-0085	Utilization of tracers for monitoring the extent of CO2 migration.	
R-0071		**Shale test - Leaky Packer**	Cost Rep H&S Env Sched.
	A-0038	Attempt to reset packer or pull packer and replace	
R-0072		**Shale test - Leaking tubing**	Cost Rep H&S Env Sched.
	A-0039	Pull tubing and replace bad joint.	
R-0073		**Shale test - Casing leak**	Cost Rep Sched.
	A-0041	Mechanical Integrity Test prior to injection.	
	A-0086	Inspect casing at regular intervals	
	A-0087	Repair casing	
R-0074		**Shale test - Tool fishing**	Cost Rep H&S Env Sched.
	A-0042	Retrieve tools using service rig	
	A-0043	Tool fishing insurance	
R-0075		**Shale test - Delayed reporting / deliverables / milestones leading to action by DOE**	Cost Rep Sched.
	A-0044	Contractual arrangements with subcontractors regarding reporting requirements.	
	A-0045	VCCER will assist, if needed, with reporting to regain schedule slippage	
	A-0065	Requirements not constrained by a single participant or event	
R-0076		**Shale test - Lack of personnel availability**	Cost Rep Sched.
	A-0049	Develop contingency plans for replacing key project personnel.	
	A-0065	Requirements not constrained by a single participant or event	
R-0077		**Shale test - Extreme weather causing interruptions in injection operations**	Cost Rep H&S Env Sched.
	A-0050	Prepare plans for securing and protecting equipment/instruments based on severe weather forecast.	
	A-0051	Prepare protocol for suspending operations if necessary.	
	A-0052	Prepare plans for timely snow removal and road repair.	
R-0078		**Shale test - High budget overruns due to unforeseen technical or commercial challenges results in alteration of scope.**	Cost Rep Sched.
	A-0056	Utilize established cost tracking and project controls utilized in similar on-going large scale capital projects.	
	A-0057	CBM - Reduce purchased volumes of CO2.	
	A-0058	Revise monitoring program	
	A-0066	Periodic financial statement vs. project progress	
R-0079		**Shale test - Delayed return of wells to CNX Gas**	Cost Rep Sched.
	A-0092	Extend access agreements to wells	
R-0080		**Shale test - Loss of funding beyond BP1 (assuming all requirements are met)**	Cost Rep Sched.
	A-0094	Prepare contingency plan for early termination	
R-0081		**Shale test - Public opposition, claims that may delay or stop project**	Cost Rep Sched.
	A-0059	Implement an aggressive outreach program, including open houses.	
	A-0095	Initial meetings and briefings for regulators and public officials.	

Id-H	*Id-A*	*Name*	*Potential risk/ Due*
R-0082		**Shale test - Delay in or failure to deliver DOE necessary documentation to move ahead with project at go/no-go decision point 1**	Cost Rep Sched.
	A-0060	Seek to finalize access agreements and CO2 procurement agreements early.	
	A-0066	Periodic financial statement vs. project progress	
R-0083		**Shale test - Project delayed/terminated prior to submission of UIC permit application or Decision point 2.**	Cost Rep Sched.
	A-0002	Appropriate site selection	
	A-0061	Consider alternative site as back-up option	
	A-0062	Use experienced personnel/service providers for site characterization.	
R-0084		**Shale test - Delay in, or unable to get NEPA categorical exclusion**	Cost Rep Sched.
	A-0096	Modify scope of test	
	A-0097	Advance preparation of Environmental Information Volumes for EA review	
R-0085		**Shale test - Unable to secure injection and monitoring wells**	Cost Rep H&S Env Sched.
	A-0067	Select sites that have existing wells and infrastructure	
	A-0069	Move to an alternative site	
R-0086		**Shale test - CO2 not available for injection tests**	Cost Rep Sched.
	A-0093	Consider alternative vendors	