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Putting Scientific Information into the Service of Environmental Justice for Residents Facing Groundwater Contamination

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PUTTING SCIENTIFIC INFORMATION INTO THE SERVICE OF ENVIRONMENTAL JUSTICE FOR RESIDENTS FACING GROUNDWATER CONTAMINATION

By

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FOREWORD

This paper represents an effort to use my educational, professional and civic experience to support democratic resolution of environmental dilemmas. In the years prior to enrolling in the Environmental Studies Masters program, I worked in several positions as a science educator. In these positions, I worked mostly with school-age individuals in programs that stressed experiential learning. During this time I was also heavily engaged in grassroots community groups and activities that addressed a wide range of topics, but that all focused on supporting the attainment of a more democratic and just sociopolitical reality for all communities.

This involvement gave me the opportunity to personally meet, work with, and learn from people with widely diverse backgrounds and experiences. I slept in a humble, bullet-riddled, wooden chapel in the high mountains of Chiapas, Mexico and heard the stories of indigenous people fighting political repression and natural resource degradation. I sat in city council meetings with members of the homeless community as we advocated to protect essential services. I learned about the lives and experiences of U.S. service members, Hurricane Katrina survivors, political prisoners, community organizers, laborers, former black panthers, gay rights activists, international journalists, and others. Those experiences forever shaped my perspective on meaningful work and my responsibility as a community member.

At the same time, because of my academic and personal studies, I grew increasingly concerned about the mounting environmental dilemmas that we must face and adapt to. The stories I had heard about the ways in which the dominant sociopolitical structure repeatedly failed some communities and ideals caused me to question whether we, as a society, would respond to these dilemmas in ways that were just and democratic. I decided, then, to use my educational and professional background to support more just and democratic outcomes for communities dealing with issues of natural resource use and access.

Through the professional paper and project, I integrated my experience as an outreach educator, community activist, and student of the natural sciences in an effort to support the attainment of justice and democracy in decisions about an environmental dilemma: the pollution of drinking water. Instead of working with school-age children to fulfill science education goals, I have worked with an adult population to address community concerns about a natural resource. I plan to partner with area nonprofit organizations to publish and distribute the materials resulting from this project.

In the following years, I hope to engage in public outreach and education work with organizations that acknowledge and address the social justice dimensions of issues such as aquifer depletion, hydrofracking, water privatization, and climate change effects on water resources. This may involve the use and development of other skills that I have acquired, such as statistical analysis or GIS. They will all, however, continue to draw on the integration of skills, experience, and knowledge that this project represents.

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Chairperson: Dr. Robin Saha

Opportunity, Montana is a small town within the 300 square mile Anaconda Smelter Superfund site in Western Montana. Waste from 100 years of ore processing has impacted the area. Arsenic exceeds Montana drinking water standards within the aquifer system feeding residential wells of Opportunity, causing resident concern about current and future safety of drinking water. The project described in this paper engages with this context from an environmental justice (EJ) perspective that views meaningful participation of affected communities as integral for sound and democratic decisions about environmental risks. Because Opportunity residents are left out of important decision making processes regarding local groundwater remediation, they experience procedural injustice, an aspect of EJ calling for meaningful participation. The project aims to reduce barriers to meaningful participation by improving residents' abilities to access and use scientific information and better understand explanations for local groundwater contamination, needs identified through previous literature and resident comments. Science education, risk communication, and science communication literature, along with Superfund site studies, provided general insights about relevant groundwater information and concepts as well as effective ways of communicating this technical information to residents. I used a three-step process to further specify and address resident needs and concerns regarding groundwater contamination. First, I conducted focus group interviews with ten Opportunity residents in the spring of 2012. Qualitative analysis of these interviews identified needs regarding site data and relevant groundwater concepts. Secondly, this analysis, along with literature, informed creation of a public presentation about groundwater contamination in the Opportunity area, offered to receive feedback from residents for development of an informational booklet. I received an unsatisfactory amount of feedback from this step. Thirdly, I adapted presentation material with the received feedback and applied a more rigorous application of insights from the literature into a 24-page informational booklet, containing images designed for the project. This booklet includes content that responds to community needs and concerns regarding well water safety, and offers support for better understanding the scientific explanations for local groundwater conditions.

ABBREVIATIONS

AEEI – Anaconda Environmental Education Institute
ADLC – Anaconda Deer Lodge County
ARCO - Atlantic Richfield Company
ARWWS – Anaconda Regional Waste Water and Soils
BP - British Petroleum
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CFRTAC – Clark Fork River Technical Assistance Committee
COC - Contaminant of Concern
EPA – Environmental Protection Agency
EJ – Environmental Justice
OCPA – Opportunity Citizen's Protection Association
OU – Operable Unit
OW/EADA - Old Works/East Anaconda Development Area
Ppb – parts per billion
RI/FS – Remedial Investigation/Feasibility Study
RD/RA – Remedial Design/Remedial Action
ROD – Record of Decision
SO GWAOC or SOAOC– South Opportunity Ground Water Area of Concern
µg/L - microgram per liter

1. INTRODUCTION

Opportunity, Montana is a rural town in the southern Deer Lodge Valley of Western Montana with approximately 260 households and 570 residents (Census Bureau, 2011). It is situated amidst a 300 square mile federal Superfund remediation site dubbed the "Anaconda Company Smelter Site." Contamination in the area is the result of historic ore processing activities carried out until 1980 (U.S. EPA 1998). Since 1983, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the "Superfund" law or program, the United States Environmental Protection Agency (EPA) has overseen emergency contaminant removal actions and remediation of the site in order to reduce risks to human health and the environment. As of this writing, remediation activities are ongoing.

Area soils, surface water and groundwater reveal the impact left by a legacy of ore processing. A 1995 study (Woessner, 1995) estimated between 368,000 and 494,500 acre-feet of groundwater within the larger Superfund site exceeded drinking water standards for several contaminants. This contamination is expected to persist for thousands of years. Arsenic is the primary contaminant of concern (COC) affecting aquifers in the Opportunity area. Arsenic also contaminates area surface waters and soils. Human exposure to arsenic through groundwater consumption is a concern since residents of Opportunity obtain domestic water from private wells. Superfund plans designate 10 parts per billion (ppb) of arsenic, the federal standard for public drinking water supplies, as the upper limit of acceptable arsenic concentration in area drinking water (US EPA, 2011b). The concern that residents may be exposed to higher levels in drinking water led to repeated and ongoing testing of residential and monitoring wells by government agencies, consultants and residents within the town (Silberberger, McKinley, Cuffe, Scarborough and Striby, 2006). Despite arsenic exceedances of Superfund standards in nearby groundwater (CDM, 2009b), collected data revealed very few wells within the town of Opportunity containing more than 10 ppb of arsenic (CDM, 2009b; WET, 2009).

Studies of Opportunity and the nearby area performed under the auspices of the Superfund program offer explanations for the pattern of groundwater contamination (CDM, 2009a; CDM, 2009b; Coover, 2010; Pioneer, 2006b). They identify potential sources of arsenic to Opportunity and conclude that a suite of local hydrogeologic conditions prevent arsenic from reaching levels above 10 ppb in residential wells of Opportunity. They do not ensure that domestic wells in Opportunity are absolutely safe from future contamination. Study conclusions have informed decisions about remediation plans, including the decision to accept that reduction of arsenic levels in certain area waters and soils will not be achieved. Hence, the current cleanup plan is not expected to effectively reduce arsenic in surface waters, soils, and groundwater that interact with Opportunity-area aquifers. Instead, the plan uses monitoring and institutional controls to manage the risk posed by possible human exposure to contaminated groundwater.

This paper and the project described herein engage with this context from an environmental justice (EJ) perspective that views meaningful participation of affected communities as integral to making sound and democratic decisions about environmental risks. The need to incorporate risk-bearers, such as the residents of Opportunity, into environmental remediation decisions is at the core of the "procedural justice" aspect of EJ. In his review of EJ concepts, Robert Kuehn (2000) defines "procedural justice" as "fairness in the decisionmaking [sic.] process" (p. 10691). This fairness entails the meaningful participation by communities affected by environmental degradation in determining what is acceptable risk. As Professor of Law Sheila Foster (2000) articulates, "the question of whose values are represented in risk assessments is central to environmental justice norms, particularly the requirement of a fair decision-making process" (p. 10002).

The need for community involvement emerges from recognition that lay people perceive and assess risks based on factors often not considered by those tasked with forming official risk assessments (Foster, 2000; NRC, 1989). Leaving out these considerations can result in decisions that are unjust, immoral, incomplete, undemocratic and/or ineffective (Fischer, 2005; Foster, 2000; Kinsella, 2004). In essence, procedural justice requires that the expertise to address problems of environmental degradation be constructed through a discursive process between agency decision-makers and the public. Agency decision-makers need public input to make better decisions and affected communities need opportunities for meaningful participation in order to contribute to decisions. Residents in Opportunity feel they have experienced environmental injustice (Backus, 2006; Cobler, 2005; Hasenbank, 2006; McQuillan, 2005; Robbins, 2005; Silberberger, 2006; Tyer, 2011) and that a lack of opportunities for meaningful participation is part of that experience.

The purpose of the project is to support meaningful participation by providing access to technical information and supporting the ability of residents in Opportunity to use it. Kuehn (2000) points out that complaints of procedural injustice often result when communities feel they have not been given adequate information and technical assistance to assess and make informed statements about the risks they are exposed to. As affirmed in case studies of public participation, "lack of access to and understanding of technical information is a major impediment to citizen participation in local environmental struggles" involving industrial clean-ups (Teske, 2000, p. 664).

Previous studies in Opportunity and public comments by Opportunity residents indicate that residents believe they have been provided with inadequate information about groundwater safety (Cobler et al., 2005; Hasenbank, 2006; Silberberger et al., 2006). Other literature indicates that technical explanations of groundwater contamination may be difficult for lay people to understand and assess (Ben-zvi-Assaraf & Orion, 2005; Covitt, Gunckel & Anderson, 2009; Dickerson & Dawkins, 2004; Dickerson, Callahan, Van Sickle & Hay, 2005; Dickerson, Penick, Dawkins & Van Sickle, 2007; Fischer, 2000; Foster, 2000; Gunckel, Covitt, Salinas & Anderson, 2012; NEETF, 2005; Shepardson, Wee, Priddy, Schellenberger & Harbor, 2009; Weigold, 2001). Without the ability to access and use this information, Opportunity residents are not provided with the tools they need to understand and assess statements made about the safety of their residential wells or to meaningfully participate in the Superfund discourse about remediation decisions. This informational project focuses on making technical information concerning arsenic contamination of groundwater in the Opportunity area accessible and useful in order to fulfill the larger purpose of supporting meaningful participation and, therefore, procedural justice.

This project has three main goals:

1. To identify informational needs and desires of Opportunity residents.
2. To identify ways of appropriately communicating that information to the intended audience of Opportunity residents.
3. To offer accessible informational materials about groundwater and groundwater contamination that fulfill the needs and desires of Opportunity residents.

These goals were met by fulfilling five main objectives.

1. Conducting a review of Anaconda Smelter Superfund site documents and related information to identify groundwater contamination and Superfund remediation concepts relevant to understanding official explanations for the existing risks to domestic wells.
2. Conducting a review of materials that provide a preliminary assessment of the informational needs and concerns of Opportunity residents relating to groundwater concepts, well water contamination and the Superfund site.
3. Conducting focus group interviews to better understand Opportunity resident needs and concerns.
4. Creating and offering a presentation about local groundwater contamination to receive resident feedback about content and design.
5. Preparing a booklet about groundwater contamination in the Opportunity area.

A local need for information

Two major aspects of the situation in Opportunity illustrate the need for this endeavor. Firstly, Opportunity residents have expressed frustration with the amount and quality of information they have received about remediation efforts (Hasenbank, 2006; Silberberger et al., 2006). Secondly, the remediation tackles contamination in a complex groundwater system by applying hydrogeological concepts that are unfamiliar to most lay people.

Opportunity residents in previous studies revealed that they viewed information provided about the site as inadequate to address their concerns and questions regarding arsenic contamination in well water, among other site-related concerns. In some instances, this dissatisfaction had to do with a lack of information. This was expressed emphatically by one resident in Kate Hasenbank's study (2006), "'And that's why people are pounding on the table, because they have no idea. I mean, information, information, information!'" (p. 45). In other cases, residents viewed provided information as confusing, incomprehensible, or contradictory (Hasenbank, 2006).

Residents have engaged in various activities to better understand and participate in remediation efforts. Members of the Opportunity Citizens Protection Association (OCPA), an organization formed to address community concerns about the site, have been active in organizing and attending informational meetings, contributing public comment to Superfund decision makers, and sharing information about Superfund developments (Hasenbank, 2006). Residents have also requested and received water testing to examine possible contamination of their private wells (Silberberger et al., 2006).

The studies (Hasenbank, 2006; Silberberger et al., 2006) describe how even active members of the community that participated in some of these activities felt "left out of important decision-making processes that affect them" (Hasenbank, 2006, p. 2), and reveal how a lack of sufficient and relevant communication by technical experts contributed to this sense of a lack of agency. Ongoing concerns led members of the community to collaborate with University of Montana students in spring of 2007 to test 25 private wells for the presence of arsenic, lead and cadmium (Feeley, 2008). During early stages of this project, members of OCPA expressed that a need for better information about local groundwater contamination still existed (S. Myers, personal communication, April 23, 2011; G. Niland, personal communication, March 12, 2011).

Secondly, groundwater science, which is unfamiliar to most lay people, provides the basis for agency evaluations of risk posed to domestic water supplies and, hence, for appropriate risk reduction measures. For example, a groundwater movement analysis based on hydrogeologic principles determined that a waste storage area north of town is not a risk to domestic wells in Opportunity. Groundwater movement analysis did indicate that a contaminated area south of Opportunity is upgradient in the aquifer. This informed the location of monitoring wells and collection of data. (US EPA, 1998)

Various literature illustrates a general lay unfamiliarity with the science that provides the basis for analysis of risks to wells within the Anaconda Smelter site. A report based on ten years of research by the National Environmental Education and Training Foundation (NEETF, 2005) found that most U.S. adults did not have a functioning understanding of the origin and behavior of water pollution or familiarity with terms related to water systems and pollution. Science education literature concerning lay and student understanding of hydrology and groundwater reinforces and elaborates on this finding, attesting to a need to support development of literacy or competency in the subject of hydrogeology (Ben-zvi-Assaraf & Orion, 2005; Covitt, Gunckel & Anderson, 2009; Coyle, 2005; Dickerson & Dawkins, 2004; Dickerson & Callahan et al., 2005; Dickerson & Penick et al., 2005; Shepardson & Wee et al., 2009).

Assuming that Opportunity is not an exception to these findings, lay person unfamiliarity with the scientific understanding of groundwater presents a barrier to the participation of Opportunity residents in the decision-making process concerning acceptable risk due to arsenic in area groundwater. Altogether, the expressed lack of satisfactory information about the cleanup and this unfamiliarity with hydrogeology limits the capacity of residents to engage in meaningful discourse with local officials, agency employees, Superfund-site personnel and each other about their concerns with arsenic contamination of their water supply.

Informed by these insights, this project seeks to support procedural justice at the site by developing the ability of residents to understand and use technical information about local groundwater contamination, thereby reducing barriers to meaningful public participation. In order to serve this purpose, I conceptualized my role as a "facilitator of client discourse" (Kinsella, 2004, p. 94) and defined my "client" as residents of Opportunity who are not technical experts at the Superfund site. Specifically, I intended to facilitate the ability of the public to effectively use technical information for advocating residents' concerns and for better informing agency decision-makers.

Paper Organization

The remainder of this paper is organized as follows. The next chapter (2) provides necessary context for understanding the project by discussing the historical, regulatory and hydrogeologic background of the project site. Topics covered include the local history of mining, the history of Opportunity, the origins and organization of the Anaconda Superfund site, local hydrogeology, the pattern of local groundwater contamination, remediation plans for groundwater, and previous resident responses to local remediation activities.

Chapter 3 consists of a literature review that provides the remaining context defining this project. There are two main sections: one addressing the EJ framework that views the ability of citizens to access and use information about environmental risks as an essential part of meaningful public participation and another that summarizes insight from literature helpful for developing materials that support the ability of citizens to access and use that information. The chapter includes discussion of how the EJ framework is applicable to the specific case of Opportunity.

The following chapter (4) describes the design, conduct and analysis of two focus group interviews: a larger one involving eight people and a smaller one with two individuals. These were conducted to collect data that could refine the insights provided in literature about possible informational needs that Opportunity residents may have regarding the ability to access and use information about groundwater. I discuss my choice of focus group interview methods, my planning, and the results of the interviews. A brief conclusion section reflects on the efficacy of this stage of the project.

Chapter 5 discusses the preparation and results of a preliminary presentation of information about groundwater and contamination in the Opportunity area offered in order to receive resident feedback for construction of the booklet. The following topics are detailed in the chapter: literature that informed the presentation; the presentation structure; the materials developed for the presentation; event recruitment; the presentation content, and presentation results. This chapter concludes with a brief reflection on the success of the presentation in fulfilling its purpose.

The next chapter (6) provides information about the construction and content of the informational booklet: "What's going on down there? A Citizen's Guide to Understanding Groundwater, Wells and Arsenic in the Opportunity Area," the final product of this project. It begins with a section explaining the process used to create the booklet. It then describes the content included in the booklet and provides a brief discussion about the reasoning used to adapt material from the presentation for the booklet.

The seventh and last chapter is a personal reflection and assessment of the project. It engages with the following questions: Did the project, as conceived, serve the purpose of environmental justice? Was it successful at meeting the stated goals? What are possible limitations and areas of improvement? I also describe further plans for producing and distributing a refined version of the booklet to residents of Opportunity. In conclusion, I briefly discuss how similar projects addressing groundwater are useful for attaining the ultimate EJ goal of a clean and healthful environment for all outside of the local context of Opportunity.

2. THE SUPERFUND CONTEXT

This chapter summarizes my review of Superfund and other documents concerning the Anaconda Smelter site and the town of Opportunity. It orients the reader by describing aspects of the historic, regulatory, and hydrogeologic setting. As a summary of the project's first step in identifying important technical concepts and community needs and desires, it provides background for decisions made during the project. The first section describes the origins and organization of the Opportunity area as a Superfund site. It shows how Opportunity fits into and is affected by the surrounding area by providing an overview of Superfund site geography, process and progress. Because site wide contamination affects groundwater quality, the chapter then provides a general overview of contamination in the regulatory area and describes the observed pattern of groundwater contamination. Following this, a discussion of remediation plans shows the risk conditions that will remain after the cleanup ends. Then, a section on local hydrogeology illustrates groundwater concepts that play a role in site conditions and explanations. The explanations for groundwater conditions are discussed in the following section, which shows the relevancy of groundwater concepts for understanding the regulatory setting in Opportunity. The final section, on community response to the cleanup, describes community actions, concerns and organizations addressing the cleanup. This section shows that there was a preexisting need for the Superfund process to better address community concerns and speaks to the need for this project.

Historical context: from rural town to Superfund site

A local history of mining and contamination

Opportunity, Montana's origin and history, along with that of its neighbors (Butte and Anaconda), is inextricably linked to the area's mining past. In his book, *Smoke Wars* (2000), historian Donald Macmillan details the often difficult relationship between residents of the region and the Anaconda Mineral Company in the early days of mining. The Anaconda Company first began operations in Butte and Anaconda in the late 1880s. Mined ore came out of nearby Butte, then known as the "richest hill on earth." This ore was processed in both Butte and Anaconda. Smelting operations in Butte created intense pollution in the city, causing a dramatic increase in illness and resident deaths. In response, the city pursued and won legal challenges against the company's release of airborne waste (Macmillan, 2000).

This prompted the company to move all of its smelting operations to an area southeast of Anaconda. In 1902 the company began processing several thousand tons of primarily copper ore each day at the newly constructed Washoe Smelter on the foothills of the Anaconda Pintler Mountains. During smelting, the stack released thousands of pounds of smoke-born particulate daily. This flue dust was primarily arsenic trioxide, but also included sulfur dioxide and compounds of copper, lead, zinc and antimony. In the following years, thousands of livestock died, farmers in the Deer Lodge valley complained of reductions in crop yields, and residents expressed concern over mysterious ailments and deaths (MacMillan, 2000; McQuillan, 2005). A legal battle ensued between the Anaconda Company and a coalition of local cattlemen and farmers. During this period, in 1912, the Anaconda Company founded the town of Opportunity, partly because a thriving company town built near the new smelter would support its assertion that local ore processing operations did not threaten community health (McQuillan, 2005). It purchased approximately 500 acres several miles east of the smelter from area farmers and sold this land off cheaply in 10-acre tracts to company employees (Macmillan, 2000). Much of this land was waterlogged or marshy. In 1915, to encourage development, the company built a drain tile system underneath the town to lower the water table (Pioneer, 2006b).

Opportunity, Montana grew in the shadow of the Washoe smelter. Local production, disposal and dispersal of tailings, furnace slag and flue dust from ore processing continued until the smelter closed in 1980. In 1983, due to high levels of smelter-related contamination, the United States Environmental Protection Agency (EPA) designated approximately 300 square miles of the area as the "Anaconda Company Smelter Site" and listed it as a location in need of remediation efforts according to the national Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), otherwise known as the "Superfund" law or program. Under CERCLA, the EPA can lead or order cleanup of hazardous materials that pose risks to human health or the environment and hold responsible parties liable for remediation. Because they are the modern inheritors of the Anaconda Copper Company holdings, the EPA identified the Atlantic Richfield Company (ARCO), a subsidiary of British Petroleum (BP), as the party responsible for contamination and cleanup costs (US EPA, 1998). The towns of Anaconda and Opportunity are located within this site (US EPA, 2009a). The Anaconda Company Smelter Site is one of four Superfund sites that span watersheds from Butte to Missoula, Montana, and result from the historical mining activity in Butte. Parts of the nearby Silver Bow/Butte area Superfund site abut the boundaries of the Anaconda Smelter site.

The Anaconda Smelter Superfund site

Opportunity occupies about 1.5 square miles of the approximately 300 square mile Anaconda Company Smelter site (Pioneer, 2006b). The site is so large that it was originally divided into five Operable Units (OUs): Mill Creek; Flue Dust; Old Works/East Anaconda Development Area (OW/EADA); Community Soils; and Anaconda Regional Water, Waste and Soils (ARWWS). The delineation between OUs is not necessarily geographic (see Table 2-1). Different aspects of contamination within Opportunity and the surrounding area are addressed by different OUs. For example, the Community Soils OU addresses contamination of soil within Opportunity, whereas surface water and groundwater contamination within town is addressed in the ARWWS OU. Each OU proceeds through the same general steps of remediation (US EPA, 2009a):

- Remedial Investigation/Feasibility Study (RI/FS) – an investigation into the nature and extent of contamination and the feasibility of remediation options
- Records of Decision (ROD)– documentation that explains which remediation strategy will be applied to the site, i.e.: how the site will be remediated and to what goals
- Remedial Design/Remedial Action (RD/RA) – the preparation and implementation of actions that fulfill the goals of the chosen remediation strategy
- Construction Completion (CC) – the cessation of physical construction aspects of a remedial action
- Post Construction Completion (PCC) – non-construction activities such as monitoring and maintenance that are necessary to ensure long-lasting effectiveness of the chosen remedy
- National Priorities List Deletion – removal of a site from the Superfund program after determination that cleanup goals are achieved. Monitoring and maintenance activities continue after deletion

If, at any point during this process, it is discovered that contamination poses an immediate threat to human health, the EPA can take emergency response measures that are not part of any remedial design. For example, the EPA removed arsenic contaminated soils in residential yards of the town of Anaconda out of concern over immediate risks to human health before the Community Soils OU had been issued an ROD. The EPA is required to review progress for each OU and make any necessary changes to the ROD every five years during a five-year review process.

Table 2-1: Anaconda Smelter Site organization

OU	Focus	Remediation status
Mill Creek	Contamination in the small community of Mill Creek located near Anaconda and the former smelter	Construction completed. Ongoing PCC monitoring. Remaining issues addressed by the ARWWS OU.
Flue Dust	Flue dust stockpiled on Smelter Hill, near Anaconda	Construction completed. Ongoing PCC monitoring.
OW/EADA	Various wastes associated with ore processing facilities used prior to construction of the Washoe smelter.	Remedial actions being implemented. Approaching construction completion within next year.
Community Soils	Contaminated soils in residential and commercial properties, including attic dust.	Remedial actions being implemented. Changes to the original remedial design being made.
ARWWS	All remaining contamination in surface water, groundwater, waste source areas and non-residential soils that has not been addressed by other OUs.	Remedial actions being implemented. Revisions to the original ROD made in 2011.

US EPA, 2010b; US EPA, 2012c;

Site investigation began in 1983. Studies estimated that over 260 million cubic yards of slag, tailings and flue dust are dispersed about the site (US EPA, 2010). Investigations of the site affirmed the presence of several specific contaminants of concern (COCs), substances that pose risks to humans, the environment and wildlife, in the soils and waters of the area. These include arsenic, beryllium, cadmium, copper, iron, lead, and zinc (ARCO, 1996). Over 20,000 acres of soil and millions of gallons of groundwater in the Anaconda Smelter site have been impacted by these contaminants (US EPA, 2010).

Opportunity as a contaminated area of concern

The primary COC driving remediation efforts is arsenic. Arsenic has been found throughout soils and waters of the site (ARCO, 1996; US EPA, 1998; US EPA, 2009b). Groundwater, surface water, non-residential soil and non-commercial soil contamination in Opportunity and nearby areas is addressed by the ARWWS OU. Contamination of residential yards is addressed in the Community Soils OU (see Table 2-1). The ROD for the ARWWS OU, addressing groundwater contamination, was issued in 1998 (US EPA, 1998). The ARWWS OU is split into subareas (see Figure 2-1). Opportunity is within the South Opportunity subarea. Within this area the EPA delineated a South Opportunity Area of Concern (SOAOC) that is impacted by contamination. It comprises most of the South Opportunity subarea (US EPA, 1998).

Figure 2-1 ARWWS subareas

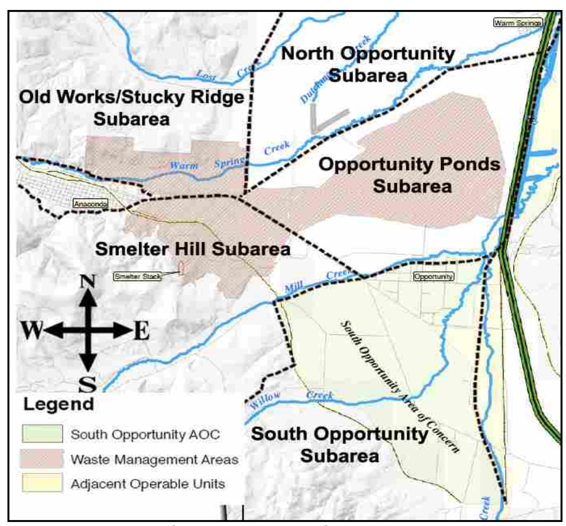

Image adapted from EPA 2011 and CDM 2009a

ARWWS investigations confirmed that arsenic in groundwater and surface water of the SOAOC exceeds acceptable cleanup levels

(CDM, 2009a; Pioneer, 2006). The current drinking water standard for arsenic enforceable at the site is 10 parts per billion (ppb), which is equivalent to 10 micrograms per liter (μg/L). At the time of the initial ARWWS ROD, this remedial action goal (RAG) for groundwater was set at 18 ppb, the "Montana Human Health standard" (MTDEQ, 2010) for water in 1998. In 2001, however, the federal limit set for arsenic in the Safe Drinking Water Act (SDWA) was lowered to 10 ppb. In order to comply with this change, the Montana Human Health standard and, therefore, the RAG at the ARWWS became 10 ppb as well (MTDEQ, 2010; US EPA, 2011b). Currently, all streams, including irrigation ditches, and some areas of groundwater exceed 10 ppb.

Soil and ore processing waste in the SOAOC also contains elevated levels of arsenic. The remediation defines "soil action levels," arsenic concentrations that trigger removal or containment actions, for residential (250 ppb) and non-residential (1000 ppb) areas (US EPA, 1998). The majority of soil samples taken through the remediation program did not contain arsenic above these levels, but exceedances have been found in Opportunity and nearby locations (CDM, 2009b). It is worth noting that wide-scale sampling of non-residential and non-commercial areas southwest of Opportunity have not been conducted and are not planned (C. Coleman, personal communication, March 16, 2011). Also worth noting is that under the sampling protocol used, soil samples are mixed from several points of collection at specified depths, so that the results represent an average of soil arsenic concentration over an area and can mask variation (US EPA, 1998).

Arsenic in Opportunity area groundwater

The presence of groundwater contamination is problematic because residents of Opportunity rely exclusively on privately owned wells for their domestic water. Since the RI, government agencies, consultants and residents have conducted additional testing and investigation to gather information about the extent and possible causes of arsenic contamination of groundwater in the SOAOC and in Opportunity (CDM, 2009a, b; Coover, 2010; Feeley, 2008; Myers, 2007; Pioneer 2006a, b; Silberberger et al., 2006; US EPA, 2010; WET, 2008; WET, 2009). This section describes the extent of detected contaminated groundwater. Later sections will discuss the suspected sources of arsenic to these contaminated areas.

While surface water and soil within and near Opportunity contain arsenic, exceeding health standards in places, only a small number of wells sampled within the town of Opportunity have exceeded drinking water standards (CDM, 2009a, b; Pioneer 2006a,b; WET, 2008; WET, 2009). Well arsenic levels have rarely exceeded 10 ppb within Opportunity, but arsenic has repeatedly been detected at lower concentrations (Pioneer 2006a; WET, 2008; WET, 2009). In the most comprehensive recent (2008 and 2009) sampling of 36 domestic wells by Water and Environmental Technologies (WET), an environmental consulting firm based in Butte, seven wells within Opportunity had detectable levels of arsenic (WET, 2008; WET, 2009). Three of these wells yielded arsenic measurements exceeding 10 ppb.

Figure 2-2: Arsenic contamination in Opportunity

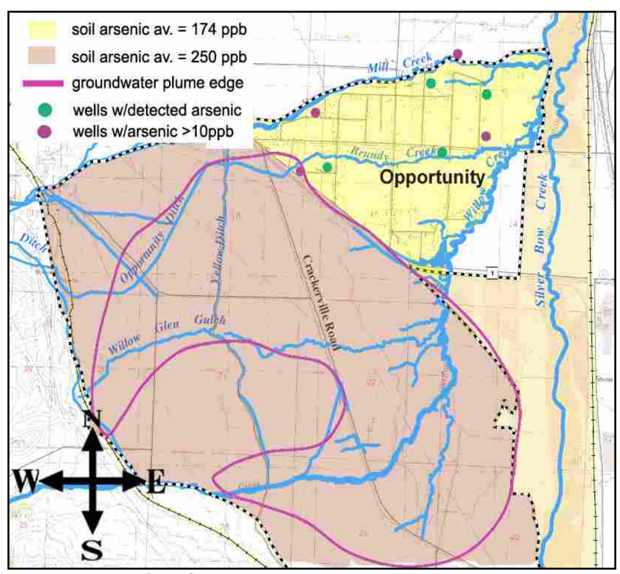

Image adapted from CDM 2009a

A contaminated plume of groundwater with arsenic levels above 10 ppb to the southwest of Opportunity poses particular concern. The area impacted by this plume is located within the SOAOC. In a 2009 report (CDM, 2009a), the plume boundary was represented as running along the length of Highway 1, south of Opportunity, with a small incursion into town limits in the area of Brundy Creek (see Figure 2-2). According to studies, the plume is situated upgradient of town within the top 10 feet (3 meters) of the aquifer, and roughly coincides with areas historically flood irrigated (ARCO, 1996; Pioneer, 2006a).

Remediation plans for Opportunity area groundwater

As of this writing, Superfund program studies indicate that the pattern of local groundwater contamination is not expected to change. Current suspected arsenic sources, discussed later, are not slated for active remediation (US EPA, 2011b). Although some contaminated materials in the SOAOC are being removed, none of these are identified as primary contributors of arsenic to aquifers in the Opportunity area. The strategy being used to address groundwater-related contamination for the SOAOC and prevent human exposure to contaminated well water consists of technical impracticability (TI) waivers, monitoring and institutional controls (ICs). Institutional Controls are administrative actions designed to prevent human exposure to contaminants, such as restrictions on developing housing in land parcels with soil arsenic levels above 250 ppb (US EPA, 2011b).

Technical Impracticability Waivers

Technical Impracticability waivers remove the requirement to meet certain cleanup goals in instances when the EPA considers practical remediation strategies (such as removal or capping of contaminants) incapable of reducing contaminant levels enough to meet those goals. The waivers refer to specific contaminant goals, materials and geographic areas. The EPA issues "Technical Impracticability" designations when it accepts an evaluation that cleanup to the remediation goal for a contaminant is impracticable "from an engineering perspective" (US EPA, 1993, p. 9). A study of TI waivers applied to groundwater resources found that this assertion could be based on contaminant-related factors, hydrogeologic factors, economic factors, physical limitations to remediation (such as the pre-existence of physical structures), and limitations of current technology (USAEC, 2004). TI designations are not permanent, but there is no process defined for removing one (USAEC, 2004). Three different TI designations within the ARWWS site are relevant to arsenic contamination of groundwater in and near Opportunity. Within these TI zones the 10 ppb human health standard for arsenic is waived for surface streams and groundwater (US EPA, 2011a,b; CDM, 2009a, c).

One of these TI waivers applies to all surface waters of the SOAOC, which includes the streams that run by and through Opportunity (Mill Creek, Willow Creek and Brundy Creek) as well as the system of irrigation ditches within the SOAOC (see Figure 2-2). This TI became part of the revised remediation plan released in 2011 (US EPA, 2011b). Site reports consider contaminated surface water from Mill Creek to be the source of the few elevated arsenic concentrations detected in the groundwater of Opportunity. Thus, the primary arsenic influx to Opportunity aquifers will not be removed.

Additionally, the ultimate source of arsenic to Mill Creek is not being removed. Mill Creek originates from springs and influxes of groundwater in the Flint Creek Mountains and Anaconda Pintler Mountains to the west of town, in parts of the ARWWS that abut the SOAOC. The bedrock aquifer feeding these streams and soil in the area both contain high levels of arsenic, most likely due to historic ore-processing (CDM, 2009d). Therefore, all streams in this headwaters area are contaminated, reaching arsenic levels above the Montana human health standard before entering the SOAOC (CDM, 2009c). The original Record of Decision for the ARWWS OU included a TI waiver for the bedrock aquifer that feeds these streams (US EPA, 1998). Hence, arsenic contamination of Mill Creek is expected to continue (CDM, 2009c).

Another TI incorporated into the 2011 revisions applies to the groundwater plume southwest of Opportunity. Widespread soil contamination in non-residential areas is considered the source of arsenic to this plume (CDM, 2009a). The initial remediation plan of 1998 (US EPA) sought to reduce arsenic in groundwater in this area by interrupting activities thought to mobilize arsenic from soil into groundwater. This included: minimizing flood irrigation practices; allowing "monitored natural attenuation" (natural processes that remove arsenic from water) and dilution to reduce arsenic concentrations; and engineering a soil cover for an irrigation ditch of the area. Monitored natural attenuation includes any natural process that reduces arsenic levels in groundwater. Since implementation, irrigated acreage in the area has dropped by approximately 25% (CDM, 2009b) and studies have concluded that the irrigation ditch does not contribute arsenic to groundwater (Pioneer, 2006a).

However, according to the most recent interpretations of data in the area, monitored natural attenuation and the reduction in irrigated acreage have not significantly reduced arsenic in groundwater and will not reduce arsenic levels of the plume to 10 ppb within the 5.5to 28 years predicted in the ROD (CDM, 2009b). Although soil throughout the SOAOC is contaminated, interpretations of collected data assert that, aside from a few isolated areas slated for removal actions (see Figure 2-3), soil arsenic levels are below cleanup action levels. Therefore, no wide scale removal of any soil below this threshold level is planned (C. Coleman, personal

Figure 2-3: Material being removed

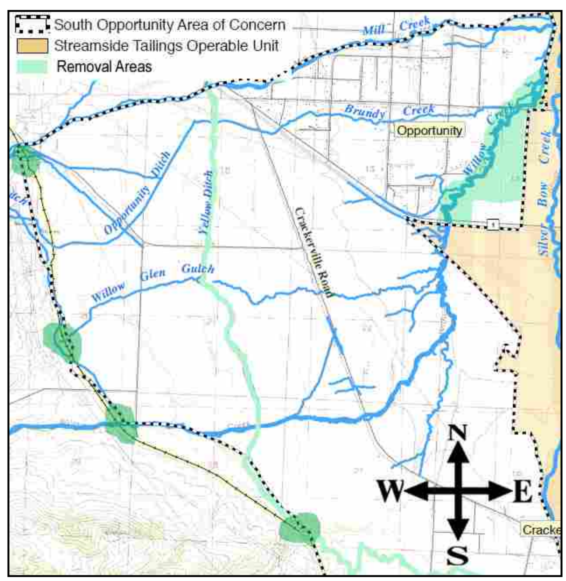

Image adapted from CDM 2009b

communication, March 16, 2011; CDM, 2009b). The new TI waiver will apply to an area that encompasses the plume and butts up against the southwestern border of Opportunity with an incursion around Willow Creek (see Figure 2-4). Thus, the source of arsenic to the South Opportunity plume will remain.

TI waivers of the health standard are subject to future review during the five-year review process. However, according to the most recent study of TI waiver use, no TI waivers at any national Superfund site have been removed (USAEC, 2004). The five-year review for CERCLA sites evaluates the protectiveness of a plan, but doesn't necessarily evaluate the use of a waiver. If an engineered solution to practicably remediate a TI zone was developed, but incorporation of the TI waiver still resulted in a plan meeting standards of protectiveness, it is unclear what process would be available to undesignate that zone (USAEC, 2004). In summary, contamination within the TI zones and, therefore, arsenic contamination of Opportunity groundwater, is expected to continue for an extended period of time beyond the eventual delisting of the area as a Superfund site.

Figure 2-4: Groundwater TI zone

Image adapted from CDM 2009a

Monitoring and Institutional Controls

The current remediation plan relies on the use of monitoring and ICs to prevent human exposure to arsenic via domestic wells. The permanent monitoring network will incorporate a selection of domestic and non-domestic wells that will be tested on an annual or semi-annual basis. Wells that repeatedly test at levels exceeding 10 ppb will trigger a contingency plan in order to provide affected residents with safe water. If analysis determines that well arsenic originates from site-related contamination, a new well or alternative water supply will be provided (US EPA, 2011b; Pioneer, 2006c). A controlled groundwater area (CGWA) will be used as an institutional control to prevent exposure (US EPA, 2011b). CGWAs limit the ways that water can be obtained and used within problem areas. New well construction within the CGWA will require a permit from the Montana Department of Natural Resources. The CGWA will place requirements on the location and depth of new domestic wells to avoid tapping arsenic contaminated water. The CGWA will be implemented through a coordinated effort among the Montana Department of Natural Resources, the Montana Bureau of Mines and Geology and Anaconda-Deer Lodge County Government. Monitoring and ICs will remain in place once the Anaconda Smelter site is delisted (US EPA, 2011b).

The hydrogeologic context of well water contamination

Arsenic threats to Opportunity wells occur within the larger hydrogeological system of the southern Deer Lodge Valley. The physical structure of the system and the way that water moves through it affects how arsenic can enter and move through the groundwater system and the aquifers within it. The following sections describe aspects of the local groundwater system that are involved in technical explanations for the pattern of groundwater contamination and that affect decisions about how to address groundwater contamination in the SOAOC.

Subsurface structure of the area

The Boulder, Anaconda Pintler, and Flint Creek mountains bound the Deer Lodge Valley (Konizeski et al., 1962;Konizeski et al., 1968; Nimick, 1993; Smith, 2009). Surface waters and groundwaters are part of the Upper Clark Fork drainage basin. The groundwater system is a result of local geology and weathering processes. It is a basin-fill system, where sediment fills a basin created by underlying impermeable basement rocks that form the structure of the surrounding mountain ranges (see Figure 2-5). Some sediment in the valley is the result of glaciation. The majority of sediment, however, has been lain down over geologic time by the activity of multiple streams originating in the local mountain ranges.

Figure 2-5: Local subsurface structure

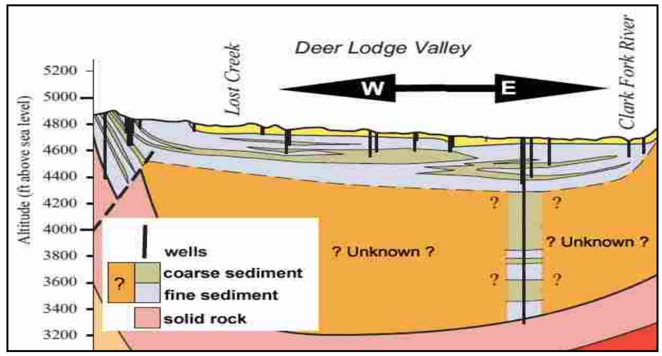

Image adapted from Smith 2009

As a result of this geologic history, the underlying stratigraphy, and, therefore, hydrogeologic characteristics vary from place to place (Konizeski et al., 1962; Konizeski et al., 1968; Nimick, 1993; Smith, 2009). Sediments of varying size and degree of uniformity occur in many layers that range in extent and thickness. Some of these layers predominantly contain sediments as small as clay, while others predominantly contain sediments the size of cobbles. Other sediments may contain a mix of varying particle sizes, resulting in a ground media less porous than the more homogenous layers. This variation leads to a complex groundwater system comprised of layers that hold water in different quantities and transmit water at different rates. In general, water moves much more slowly through the mixed layers and predominantly clay layers. Some of the water in layers is under pressure because it is confined by overlying impermeable sediments. In the southern Deer Lodge Valley geological explorations estimated that the sedimentary basin-fill is at least 5000 feet thick (Konizeski et al., 1962; Konizeski et al., 1968; Nimick, 1993; Smith, 2009).

Location of groundwater and aquifers

Wells of the area pump groundwater from the pores of the sedimentary basin-fill. The water table in and near Opportunity is relatively shallow, ranging from 0 to 30 feet below the ground surface (Pioneer, 2006a). In general, the water table is deeper in the western mountains and shallower towards the Clark Fork River and Silver Bow Creek to the east (Pioneer, 2006b).

Productive layers that yield ample water to wells, aquifers, are located throughout this groundwater system at different depths (CDM, 2009b; Konizeski et al., 1968; Konizeski et al., 1962; Nimick, 1993; Smith, 2009; Pioneer, 2006a, b). There are no geologic data that comprehensively and clearly indicate the occurrence and boundaries of aquifers. Thus, descriptions of the local "aquifer" are generalizations that do not capture the variation in the system. They imply that a single, well-connected aquifer provides water to all wells, which is not entirely accurate.

Superfund documents refer to the local groundwater source as "the alluvial aquifer" or "shallow aquifer" (ARCO, 1996; CDM, 2009b; Pioneer, 2006a, b; USEPA, 1998). According to those reports the aquifer surface aligns with the water table at 0 to 30 feet below ground level. The total depth of this aquifer is unknown, but has been measured to be at least 100 feet below ground surface (Pioneer, 2006a). In this singularly described "aquifer," however, well depths within the 1.5 square miles of Opportunity vary from 22 to 258 feet. This variation among well depths reflects the heterogeneity of underlying sediments. There is, however, one noticeable well trend that results from the distribution of sediments. Because of a general increase in clay content to the east, wells tend to be deeper as properties approach the Clark Fork River (Pioneer, 2006b).

Figure 2-6: Groundwater movement

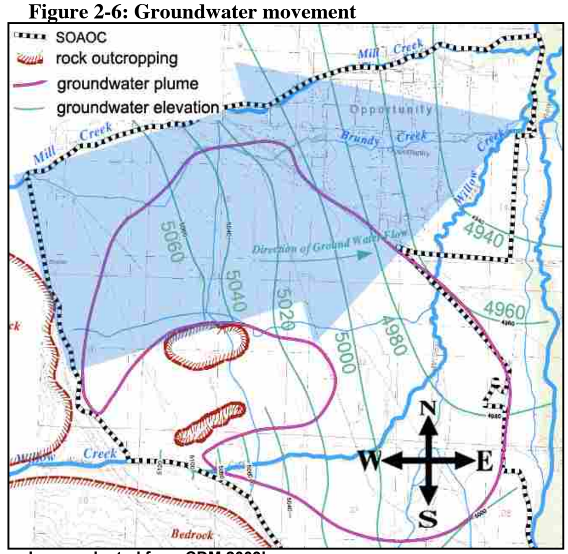

Image adapted from CDM 2009b

Large-scale movement of groundwater

Groundwater moves from the Flint Creek range to the west of Opportunity in a northeasterly direction towards the Clark Fork River valley (see Figure 2-6) at a rate of approximately 1.5 feet per day (ARCO, 1996). It then flows northward along the valley, contributing water to the Clark Fork River (Konizeski et al., 1968; Nimick, 1993; Woessner, 1995). Inflow from deeper aquifers, infiltrating irrigation water, infiltrating precipitation, and losing streams all contribute water to this system (Nimick, 1993). Much of the groundwater ultimately originates in the mountains to the west. Because Opportunity is located in the valley near to the Clark Fork, it is situated in an area where groundwater often flows towards the land surface (Woessner, 1995).

Surface water and groundwater connections

Surface water plays a significant role in the local groundwater system. Two main streams flow along the boundaries of Opportunity. Both originate in the mountains to the west. Mill Creek flows along the northern boundary of town and Willow Creek approaches Opportunity from the south, forming a southeastern boundary. Another short stream, Brundy Creek, originates in town (see Figure 2-4). All streams ultimately flow into the Clark Fork River. Throughout different stretches, the streams either gain water from or lose water to the ground.

Irrigation ditches divert water from Mill Creek and Willow Creek. These ditches contribute to the groundwater system in two ways. Firstly, the leaky channels of these ditches lose water to the ground. Secondly, water withdrawn from the ditches is used for flood irrigation. Some of this water infiltrates into the ground and reaches the water table. These inputs can create localized effects on the level and movement of groundwater (Nimick, 1995). For example, the flow of Brundy Creek comes from irrigation ditch water losses. All surface streams, including irrigation ditches, exceed the 10 ppb arsenic level (CDM, 2009a, b; Pioneer, 2006a, b).

As mentioned earlier, in 1915 the Anaconda Company installed a system of drain tiles in Opportunity to lower the local water table and render land developable. These drain tiles also influence local groundwater. This system consists of seven separate slotted pipes several feet underground that run generally west to east within Opportunity. They drain shallow groundwater along their length and discharge it to surface streams towards the eastern edge of town (CDM, 2009b; Pioneer, 2009b). Perhaps four more of these tiles exist south of town across Highway 1. Studies have detected conditions that imply the existence of drain tiles in this area, but their existence has not been confirmed (CDM, 2009b).

Official explanations for the contamination pattern

Opportunity is a community affected by contamination, yet few wells have revealed high arsenic levels. As mentioned earlier, attempts to understand this pattern of contamination have been made. ARCO-BP consultants, the EPA, and other consultants conducted several studies providing data on local hydrology and contamination. These were used to characterize the origins and behavior of arsenic in local aquifers (ARCO, 1996; CDM, 2009a,b; Pioneer, 2006a,b; WET, 2008; WET, 2009). Although these studies are not conclusive regarding the source and movement of arsenic through the groundwater system, they provide the basis for working conceptual models that inform choices made about the cleanup.

Arsenic sources to the town of Opportunity

In 2006 a consulting firm contracted by ARCO synthesized information from previous studies into a report, titled "Draft Final Town of Opportunity Data Interpretation and Analysis Report," on possible arsenic threats to the Opportunity aquifer (Pioneer, 2006b). This report informed development of the long term Groundwater Management Plan for the ARWWS (Pioneer, 2006c). It proposed a conceptual model of how arsenic may enter the aquifer in Opportunity, identifying likely sources and ruling out others. According to the analysis in this report, arsenic enters the Opportunity aquifer through leaky streambeds of Mill Creek, Brundy Creek, and associated irrigation ditches. Because groundwater moves horizontally and generally parallel to these streams, this source should manifest in a shallow and "limited horizontal extent" (Pioneer, 2006b, p. 17) of contamination in the aquifer. Contamination levels should vary due to a combination of factors including fluctuations in stream flows, stream arsenic content and water table elevations (CDM, 2009a, b, c; Pioneer, 2006a, b).

This report asserted that other sources of arsenic to the Opportunity aquifer were unlikely. Although Willow Creek also exceeds the 10 ppb arsenic level, it does not lose water to the ground in the Opportunity vicinity and, therefore, is not expected to affect nearby wells. Overall, both water and arsenic flow into this stream as it approaches Opportunity (CDM, 2009b). Additionally, all irrigation water in town is diverted from Mill Creek (Pioneer, 2006b). Therefore, Willow Creek water and the arsenic it carries are not considered threats to wells within Opportunity.

The report (Pioneer, 2006b) also deemed that applied irrigation water is an unlikely source of contamination due to several reasons. It pointed out that wells with detectable arsenic are not distributed throughout town. It also noted that all but the northernmost samples of shallow groundwater collected in the drain tiles within town contained less than 10 ppb arsenic. Both of these results indicate that contamination does not occur over the widespread area that irrigation occurs in. Lastly, it argued that the arsenic content of Opportunity soils is "predominantly low" (p. 16), so that application of irrigation water would not be expected to mobilize enough arsenic from soil to affect groundwater. The report referred to results from various groundwater studies in Montana to assert that the arsenic in irrigation water attenuates in the unsaturated soils of the pastures and hay fields to which it is applied. It is worth noting that irrigation is not seen as a source of arsenic to groundwater in Opportunity, but is viewed as a source of arsenic to local soils. According to the report, this soil arsenic is not mobilized into the groundwater within town limits (Pioneer, 2006b).

Because of the direction of groundwater flow, the report also addressed the contaminated groundwater plume southwest of Opportunity as a potential contaminant threat to Opportunity groundwater. Groundwater chemistry readings from wells in the plume, contaminated wells in Opportunity and surface water in Mill Creek were used to support the idea that contaminated water located within Opportunity comes from surface water lost to the ground from Mill Creek and not from the groundwater plume. The location of three wells with arsenic concentrations below 10 ppb between the plume and Opportunity was also used as evidence that this plume does not contribute measurable arsenic to the Opportunity aquifer (Pioneer, 2006b).

This raises the question of "where does the arsenic in that plume go?" The proffered conceptual model suggested in the initial report (Pioneer, 2006b) attributes low arsenic in Opportunity to the dilution effect of a large influx of groundwater from the Mill Creek drainage area as it flows into the plume. Later reports agreed with this (CDM, 2009b; Coover, 2010). While some groundwater in the drainage is contaminated and flows upward into springs that feed Mill Creek, a much larger quantity of uncontaminated groundwater flows through this geographic area. Once again, water chemistry is used as support. The water chemistry of Opportunity wells is similar to groundwater that originates in the Mill Creek drainage. Wells further south have the chemical signature of water in the Willow Creek drainage. The difference in these two signatures is considered large enough to represent two sources, one associated with the Mill Creek drainage and one with the Willow Creek drainage. There is a large quantity of low arsenic water flowing from the Mill Creek drainage area, into the shallow plume area and on to Opportunity. The reports concluded that this flow is large enough to have a diluting effect on groundwater that moves from the plume towards Opportunity (CDM, 2009b; Coover, 2010).

These later studies also concluded that the Opportunity drain tile system plays a role in creating the lower groundwater arsenic levels found throughout most of town. The role of the drain tile system is presented as twofold. Firstly, it prevents soil from being saturated over prolonged periods of time, therefore preventing arsenic in soil from releasing into the groundwater system (CDM, 2009b; Pioneer, 2006b). Secondly, the drain tiles take in shallow groundwater. In the southern part of town, shallow contaminated water enters the drain tile system, preventing mixture with deeper uncontaminated water (CDM, 2009b).

Arsenic sources to the nearby plume

The proposed model for where and how arsenic may enter groundwater in Opportunity contrasts with explanations for arsenic contamination in the groundwater plume southwest of town. Earlier reports suggested that, similar to the Opportunity model, arsenic might enter the plume through leaky stream and ditch bottoms here as well (Pioneer, 20006a). However, later data interpretations asserted that contaminated surface streams southwest of town, including irrigation ditches, do not contribute arsenic to the groundwater plume (CDM, 2009a, b).

Instead, the most recent reports assert that arsenic in the plume originates from widespread soil contamination in the South Opportunity area (CDM, 2009a, b). This model considers aerial deposition of smelter dust and application of irrigation water as the source of arsenic in soil. It proposes that two interacting processes release arsenic from contaminated soil and into the groundwater system. First, applied irrigation water and, to a lesser extent, precipitation, percolates downward through contaminated soil. This activity releases soil arsenic, carrying it downward and creating an area of high arsenic concentration near the water table. Secondly, arsenic may "desorb" from materials that become saturated during periods of water table rise. This rise is seasonal and can be due to natural inputs or result from local flood irrigation practices. These later reports appeal to studies of arsenic behavior in similar environments to support the conceptual model. They also refer to collected data that show: the groundwater plume area seems to coincide with historically irrigated acreage; and arsenic levels in groundwater are higher during periods of saturation and when the water table is high (CDM, 2009a, b).

To summarize, site studies and reports concluded that surface streams are the most likely source of arsenic to Opportunity well water, but that contaminated soil is the most likely source of arsenic to the nearby groundwater plume. In Opportunity, elevated arsenic levels in groundwater are caused by losing, or "influent", streams and ditches. In the plume area, soil arsenic is released into the groundwater system by the movement of water in the upper soil layer.

Wells at risk

According to these working concepts, several well characteristics may affect the safety of well water. A low wellhead or cracked well casing may allow contaminated surface water or shallow groundwater to enter the well. Shallow wells are also considered to be at higher risk of contamination. In the reports, "shallow" is defined as "less than 40 feet" below ground level (Pioneer, 2006b). Specifically, shallow wells close to sections of Mill Creek and associated irrigation ditches that lose surface water to the ground are considered more at risk (Pioneer, 2006b). According to one report by WET (2005), average well depth in Opportunity is between 5 to 25 feet. Among the residents that Silberberger and colleagues (2006) surveyed, over half of residential wells were less than 40 feet deep (p. 26). Another document by consultants to ARCO reported that of 56 wells with recorded depth information, 11 are shallower than 35 feet (Pioneer, 2006b). Despite this variation in well depth estimates, it is clear that some residents in Opportunity drink from wells that are shallower than 40 feet. Although the reports do not assert this, wells that do not primarily draw groundwater coming from the Mill Creek drainage area to the west would also be at higher risk since reports attribute the large influx of this clean groundwater to be partially responsible for keeping arsenic levels in Opportunity lower than those in the nearby upgradient plume.

The importance of post construction activities for well safety

Within the hydrogeologic and regulatory setting described, the future safety of domestic wells in Opportunity depends largely on the effectiveness of post construction completion activities to ensure that remaining arsenic sources do not threaten Opportunity wells. Groundwater monitoring and administration of the CGWA must retain their integrity. They must also be able to detect and respond to changes in hydrogeologic conditions that may affect how groundwater enters and moves through the Opportunity groundwater system.

If the current data set and interpretations are correct, the quality of well water depends on the persistence of certain hydrogeologic conditions that reduce the amount of arsenic in the Opportunity aquifer. As mentioned, a large influx of groundwater associated with the Mill Creek drainage reduces arsenic concentrations in water. If the quantity or quality of this groundwater influx changed, it may affect water quality in Opportunity. According to the working model, increases in the extent or duration of soil saturation in town would also lead to more arsenic loading of groundwater. Various events could result in those conditions, ranging from climatic changes in precipitation regimes to changes in local irrigation practices to failure of the drain tile system. In addition, the successful functioning of the drain tile system is not only important in controlling soil saturation conditions in town, but also in protecting southern wells from the nearby groundwater plume. If the tiles failed in this area, the contaminated water currently being diverted by them may become a threat to wells in that area. Hence, the tile system's future integrity plays a role in the protectiveness of the remediation.

Clearly, decisions made about the final conditions, programs and policies remaining in place after site delisting will be instrumental in protecting Opportunity residents from possible future arsenic contamination of well water. Opportunity residents have the ability to contribute to decisions affecting their well water prior to final delisting.

Opportunity community response to the cleanup

Since listing of the Anaconda Superfund site in 1983, various citizens' groups have formed within the larger area to address concerns with remediation efforts. The earliest one formed in Opportunity was the "Opportunity Concerned Citizens" group, which came together in 1989 to oppose remediation plans occurring in an area northeast of town (US EPA, 1998). This group no longer exists, but in the summer of 2005 the Opportunity Citizen's Protection Association (OCPA) formed to address Superfund issues impacting Opportunity (Hasenbank, 2007). OCPA is a grassroots group composed of Opportunity residents concerned with remediation efforts. Their mission is "to educate residents on Superfund issues and to provide a united voice in the decisions that impact the Opportunity community" (Hasenbank, 2007, p. 2). Members of OCPA have organized and participated in public meetings, published newsletters, held community events, initiated legal actions, and advocated for changes to the remediation plan. Community members have also participated in non-OCPA activities including public meetings, public comment periods and voluntary well testing (Feeley, 2007; Hasenbank, 2007; Silberberger et al., 2006; US EPA, 1998; US EPA, 2011b).

Members of OCPA, who make an effort to seek out and share site-related information as part of their organizational mission to educate residents, have received technical assistance from the Clark Fork River Technical Assistance Committee (CFRTAC) and Anaconda Environmental Education Institute (now the Arrowhead Foundation), two technical assistance grant (TAG) groups in the area (Hasenbank, 2007). TAG groups are funded through grants administered by the EPA and are intended to "help …communit(ies) participate in decision making" at Superfund sites (US EPA, 2012). The grants are provided so community groups may "contract with independent technical advisors to interpret and help the community understand technical information about their site" (US EPA, 2012).

While CFRTAC has worked with OCPA and Opportunity residents, its ability to provide technical assistance in that geographic area is limited. Officially, CFRTAC is tasked with assisting communities along the Clark Fork River. The Clark Fork River begins north of Opportunity and does not flow through town. Funding restraints have created additional limitations in their ability to serve Opportunity residents (D. Barton, personal communication, January 31, 2011). The Arrowhead Foundation does include Opportunity within its service area, which is defined as Anaconda and Deer Lodge County, but its work has not involved much active technical assistance with residents. This TAG works closely with Anaconda-Deer Lodge County administration, concentrating largely on coordinating ICs used in the site between the county and the various agencies involved (J. Davison, personal communication, February 10, 2011).

Resident concerns about well water

Through their involvement, citizens have expressed concern about various aspects of the cleanup including the use of cleanup related funding, the efficacy of containment efforts, the level of monitoring, the availability of monitoring information and the extent of removal activities (Chaney, 2010; Hasenbank, 2007; OCPA, n.d.; Robbins, 2005; Silberberger et al., 2006; Tyer, 2011; US EPA, 1998; US EPA, 2011b). As of this writing, residents are engaged in a lawsuit against ARCO concerning contaminated residential soil and attic dust (G. Niland, personal communication, May 12, 2012).

In addition to the participation of residents in voluntary well testing (Feeley, 2007), two studies conducted through the University of Montana (Hasenbank, 2007; Silberberger et al., 2006) revealed that, along with other issues, residents are concerned about groundwater. In a survey of over 30 Opportunity households conducted in 2005 by University of Montana students, respondents expressed concern over current and future contamination of water (Silberberger et al., 2006). More residents were concerned with future contamination (90%) compared to current contamination (80%) (Figs 10 & 11). A significant percentage, 33%, of residents were "extremely concerned" about current well water quality (fig. 10) while 57% were "extremely concerned" about the future (fig. 11). In 2006, Kate Hasenbamk (2006) interviewed a total of 21 Opportunity residents in three separate group interviews. This general concern for groundwater was echoed in those discussions and reaffirmed in my preliminary meetings with Opportunity residents (S. Myers, personal communication, April 23, 2011; G. Niland, personal communication, March 12, 2011). The history of resident activity and concern shows that some residents of Opportunity are motivated to address Superfund issues and have an interest in learning more about water quality threats.

3. LITERATURE REVIEW

This project engages with information access and scientific literacy as they pertain to the achievement of environmental justice (EJ) in the context of groundwater contamination in Opportunity, Montana. Providing access to and supporting lay understanding of technical information regarding groundwater contamination in Opportunity is one necessary element for meaningful participation of residents in remediation decisions. In turn, meaningful participation is one essential element for achieving procedural justice, an aspect of EJ. This chapter illustrates the link between the goals of this project and its larger purpose to support procedural justice. The first main section provides some background on Opportunity as an EJ community and the framework for conceiving of information access and scientific literacy in Opportunity as an issue of procedural justice. The second main section summarizes the insights I derived from science education, science communication and risk communication literature for developing relevant, useful and effective communications that fulfill the goals of this project.

Environmental justice, procedural justice and Opportunity

This section provides an orientation to how an information and literacy project supports the attainment of procedural justice for Opportunity residents dealing with issues of groundwater contamination. It begins by discussing the main conceptualization of EJ. The following subsection then briefly describes Opportunity as a community that has experienced distributional injustice, another aspect of EJ. After defining procedural justice, the next subsection then discusses how meaningful participation is involved in achieving it. The remaining subsections then discuss the importance of support for lay capacity to access, understand and use technical information for the attainment of meaningful participation.

The concept of environmental justice

Environmental justice, as professor of law Robert Kuehn points out (2000), is a concept with many meanings to diverse groups of people. As defined by the EPA, environmental justice is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (US EPA, 2012b). According to Dr. Robert Bullard, as Kuehn explains, "environmental justice seeks to make environmental protection more democratic…" (2000, p. 10684). At the core of all conceptions discussed by Kuehn is this idea of democracy with respect to the environmental risks and benefits affecting and available to communities. This concept is related to the notion of environmental rights articulated in Article 2 of the Montana State Constitution: "All persons are born free and have certain inalienable rights. They include the right to a clean and healthful environment…" (Montana Legislative Services, 2011).

EJ, as a concept and movement, has been historically concerned with identifying, addressing and preventing racist and classist processes and outcomes in community experiences of local environmental quality (Kuehn, 2000). The U.S. government specifically defines EJ as a concept that concerns impacts on minority and low-income populations (Kuehn, 2000). However, official definitions articulate the federal vision of EJ as applying to "all Americans" (Kuehn, 2000, p.10683). Notably, the EPA has explained that "people of all races, cultures, incomes and education levels" deserve fair treatment and that "*no population* should be forced to shoulder a disproportionate share of exposure to the negative effects of pollution due to lack of *political or economic strength*" (as quoted in Kuehn, 2000, p. 10683, emphasis added). EJ is the recognition that class and race distinctions have denied this inalienable right to defined groups of people. However, while focusing on low income and minority populations, the EPA acknowledges that factors such as educational level, degree of political strength, and degree of economic strength affect the attainment of fair treatment. This is one example of how the concept of EJ recognizes that people who are not part of a well-defined race or class minority may experience environmental wrongs that constitute injustice.

Opportunity and lack of distributional justice

The federal government does not recognize Opportunity as an EJ community (R. Saha, personal communication, April 4, 2011). Despite the lack of recognition, residents feel they are experiencing a lack of EJ and that their right to a "clean and healthful" environment has been violated (Backus, 2006; Cobler et al., 2005; Tyer, 2011). Several studies conducted through the University of Montana (Cobler et al., 2005; Hasenbank, 2006; Silberberger et al., 2006), found evidence that Opportunity residents feel exposed to a disproportionate share of contamination and the negative effects associated with it as a result of Superfund program activities. This sense that remediation efforts have shifted the burden of risks onto their community demonstrates a lack of "distributive justice" (Kuehn, 2000, p. 10685). This aspect of EJ concerns the equitable distribution of environmental risks and benefits. One vivid example of this is the relocation of contaminated sediments from several other areas affected by historic ore-processing activities of the region (including waste from areas located in other Superfund sites) to a waste repository immediately north of Opportunity. Much of this material remained uncovered after relocation. Residents voiced concern about dust from the repository contaminating their town during high wind conditions and about the repository affecting local groundwater. They questioned why they were exposed to material deemed too toxic for other communities (Hasenbank, 2006; McQuillan, 2005; OCPA, n.d.; Robbins, 2005; Tyer, 2011).

Procedural justice and meaningful participation

When remediation of the Anaconda Smelter site is completed, a certain degree of risk will remain. The distribution of risk remaining for Opportunity residents will be the outcome of decisions made through the Superfund process. The project detailed in this paper engages with another aspect of EJ, "procedural justice", which concerns the "fairness of the decision making process" (Kuehn, 2000, p.10691). It has been defined as "the right to treatment as an equal…equal concern and respect in the political decision about how goods and opportunities are to be distributed" (Kuehn, 2000, p. 10692). Attaining this fairness, for scholars, government agencies and communities concerned with issues of EJ, involves the meaningful participation of environmental risk-bearers in the determination of what is acceptable risk (US EPA, 2012b; Foster, 2000; Kuehn, 2000).

This participation is essential because agency methods for assessing risk are based on technical, utilitarian models that do not incorporate dimensions of risk considered important by non-expert publics (Fischer, 2005; Foster, 2000; NRC, 1989). These dimensions include such things as how familiar is the risk, does it affect children, is exposure to the risk voluntary, is it natural or man-made, how well is it understood, are effects permanent or reversible, are effects immediate or delayed, and will the risk affect future generations (Lin & Petersen, 2007)? As Professor of Law Sheila Foster (2000) articulates, "the question of whose values are represented in risk assessments is central to environmental justice norms, particularly the requirement of a fair decision-making process" (p. 10002) and "(t)he best way to incorporate public values into the risk assessment process is to incorporate the public itself, particularly those segments who are being asked to bear the very risks that are being analyzed" (p. 11010). In essence, a fair process with meaningful public participation ensures that the expertise to address problems of environmental degradation is constructed through a discursive process between agency decision-makers and the public. Agency decision-makers need "public expertise" (Kinsella, 2004, p. 83) to make informed, effective, and democratic decisions and affected communities need opportunities for meaningful participation in order to contribute that expertise (Fischer, 2005; Foster, 2000; Kinsella, 2004).

Procedural injustice in Opportunity

Based on the experiences of Opportunity residents, the Anaconda Site remediation lacks procedural justice. In their studies Cobler and colleagues (2005), Silberberger and colleagues (2006), and Hasenbank (2006) all reviewed previous resident comments and collected resident comments about the remediation. Through these they concluded that the community of Opportunity has not received fair treatment in the decision-making process. Residents in these studies (Cobler, 2005; Hasenbank, 2006; Silberberger et al., 2006) expressed feeling powerless and ignored. They felt their values and concerns were not incorporated into remediation decisions. Cobler and others (2005) pointed out that some residents were so disillusioned that they ceased speaking up or going to community meetings about the cleanup. Since then, technical assistance groups in the area noted this same trend and called for renewed efforts at community outreach (US EPA, 2011b). As Darryl Barton of CFRTAC wrote in his comments during the latest ROD review, "Public outreach regarding these important decisions should be much more extensive. Public meetings were held with very little attendance from residents of the areas affected" (US EPA, 2011b, Appendix A).

Information access as an element of procedural justice

Providing access to information about environmental risks is an essential component of enabling meaningful participation of affected communities. In the U.S. it is an extension of the

Jeffersonian idea that true democracy requires an informed public. The federal government recognized the importance of providing environmental information to the public long before it acknowledged the need to support EJ. Beginning in the 1970s, federal natural resource and environmental laws established requirements and procedures for disseminating environmental information to the public. By 1998 the EPA established an Office of Environmental Information specifically to ensure public access to environmental information held by the government. Information access is also acknowledged internationally as essential for equitably addressing environmental issues; U.N. Agenda 21 calls for improving the quality and availability of environmental information for involved publics (Irwin & Bruch, 2002).

As a well-acknowledged precondition for the participation of the public in matters of the environment, access to information is considered essential for achieving procedural justice (Chilvers, 2008; Hampton, 1999; Irwin & Bruch, 2002; Kellogg & Mathur, 2003; Kuehn, 2000; Teske 2000). As articulated by Greg Hampton (1999), "The provision of accessible information to all stakeholders…is critical to maintaining procedural fairness and formal equality" (p. 169). In recognition of this, the 1994 Executive Order establishing the government's commitment to EJ, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (EO 12898), specifically directs agencies to make information readily available to low-income and minority populations (Kellogg & Mathur, 2003; Kuehn, 2000). Both government agencies and non-governmental organizations (NGOs) have developed programs such as the Toxics Release Inventory and local environmental health guides specifically to support EJ by disseminating information about environmental risks (Irwin & Bruch, 2002; Kellogg & Mathur, 2003). The Technical Assistant Grant (TAG) program administered by the EPA's Office of Solid Waste and Emergency Response, which also provides expert assistance, is essentially an effort to increase information access for EJ communities assessing environmental risks (Teske, 2000). While access to information is not the only element necessary for achieving procedural justice (Kuehn, 2000; Webler & Tuler, 2002), case studies affirm that information access encourages public participation in addressing environmental dilemmas (Kellogg & Mathur, 2003; Kuehn, 2000; Teske, 2000).

Lack of information in Opportunity

For residents living within the ARWWS Superfund site, including Opportunity, the necessary information to enable meaningful participation in Superfund decisions has often been lacking. As one resident exclaimed at a meeting in 2009 regarding activity at the ARCO waste repository north of Opportunity, "Everybody here is feeling really betrayed. You guys have had information that we didn't have" (Tyer, 2011, p. 2). Public comments dating back to 1992 requested clearer, more consistent communication about site-wide activities and clarification on how the EPA would allow for meaningful public involvement (US EPA, 1998). The studies of Cobler and others (2005), Silberberger and others (2006) and Hasenbank (2006) all identified previous public comments that specifically revealed dissatisfaction among Opportunity residents with information provided about site risks and activities. The Silberberger and others study (2006), a community survey of 30 Opportunity residents, and the Hasenbank study (2006), a qualitative analysis of focus group comments by 21 different residents, elaborated on this.

One of the main themes of conversation among residents in Hasenbank's study was "lack of information" and the frustration this created (2006, p. 45). Residents wanted more information about dust and groundwater in the area and expressed a perception that monitoring efforts were inadequate and incapable of providing a satisfactory characterization of the extent and behavior of contamination in groundwater (pp. 45-46). This observation echoes the results from

Silberberger and others (2006) in which over 80% of respondents “wanted to know more about the health and safety of local air and water” (p. 34) and only 21% agreed that any of the government agencies involved in the cleanup were doing a “good job of informing Opportunity residents…” (p. 32). “’They know what’s going on, but they’re not sharing it,’” as one resident in Hasenbank’s study shared (2006, p. 46).

Attesting to a lack of basic information provision, less than 28% of those surveyed by Silberberger and others (2006) reported being familiar with residential well water testing programs available at the time (p. 46) and only 34% expressed a significant degree of familiarity with the Superfund program (p. 45), although most residents (90%) were aware of cleanup work being conducted in the area (p. 44). This lack of information may be at the root of concern that residents voiced for future groundwater conditions. In the survey (Silberberger et al., 2006), 57% percent of residents were “extremely concerned” about possible future contamination of their well (p. 43). As one resident commented to Hasenbank (2006), “’It's like the teenager [that] doesn't come home on time and you think the worse. It's no different here; we don't have the information, so what are we left to think?’” (p. 45).

Notably, OCPA members participated in this study (Hasenbank, 2006). In the Silberberger and others (2006) results, residents most frequently mentioned OCPA as their source of information (fig. 19) and indicated that OCPA, along with the EPA, was the most trusted provider of information (fig. 20). Although the Arrowhead Foundation, formerly AEEI, existed since the 1980’s (EPA, 1998), residents in the Opportunity studies did not mention this TAG group as a source of information when asked where they obtained Superfund site information (Hasenbank, 2006; Silberberger and others, 2006). It is problematic that members of the organization providing the most trusted and used information about the cleanup also expressed a lack of information access. If these individuals, who show a dedication to obtaining and providing information to the community, felt insufficiently informed, it is no surprise that other members of the community have expressed disappointment with information access.

Since the Silberberger and others (2006) and Hasenbank studies (2006), OCPA and the Anaconda-Deer Lodge County (ADLC) government have made efforts to provide more information to the public. Meetings in 2007, 2008, and 2009 included discussions about the cleanup and addressed groundwater contamination, among other issues. The county also made results from WET's monthly water sampling, mentioned in the previous chapter, available on their website (ADLC, n.d.). During this time, OCPA obtained some limited assistance from the Arrowhead Foundation (AEEI at the time) and CFRTAC, (Barton 2009; Hasenbank, 2006; Tyer, 2011), to better access information and perform community outreach.

However, concerns for greater public access to technical information have persisted. Public comments about activity at the site continued to show frustration with lack of access to technical information. In 2007 residents still questioned the ability of information they had received to explain the pattern of groundwater contamination surrounding Opportunity and still voiced questions about the future safety of their well water (Feely, 2008). Members of CFRTAC and the ADLC government have expressed both concern over the level of public attendance at the more recent informational events, and a need to provide more and better information about groundwater contamination issues to the public, specifically about the contaminated plume to the south and the condition and role of the drain tile system (US EPA, 2011b). Notably, these topics had been discussed at some of the public meetings held between 2007 and 2009 (OCPA, n.d.). Due to funding cuts CFRTAC is now limited to working within their defined service area, which does not include Opportunity (D. Barton, personal communication, March 12, 2011). Lastly, membership in OCPA and public attendance at its events has declined (G. Niland, personal communication, March 12, 2011; Tyer, 2011).

Providing accessible information

While prior studies and observations of Opportunity indicate a need for greater information access about existing contamination and cleanup activities, resident comments and existing literature point out that simple access to technical information is not enough to ensure the usefulness of that information for affected communities. Agencies and other technical experts working on environmental sites collect data, interpret data, and make remediation decisions based upon specialized knowledge and technical understandings of the landscape, the contaminants affecting it, and the potential risks (Fischer, 2005; Foster, 2000). For example, remediation decisions about adequate measures to protect residents from exposure to groundwater contamination are based on hydrogeologic analyses of groundwater movement, chemical analyses of contaminant mobility and bioavailability, and comparative risk assessment (US EPA, 1998).

Providing this technical information, couched in the language and concepts of science, does not necessarily equate to access. Indeed, the specialized and technical nature of environmental information has been characterized as a barrier to public participation (Fischer, 2005; Kinsella, 2004; Kuehn, 2000; Teske, 2000). For example, a study by Shortland & Gregory (as referenced in Weigold, 2001) pointed out that the language of science has become so specialized that literate audiences cannot comprehend it. The information used by agencies in decision-making is expressed in language and concepts unfamiliar and inaccessible to communities, such as the "water table" and "comparative risk assessment" (Foster, 2000; Kinsella, 2004; NEETF, 2005). Communities need to engage with that information to form their own evaluations of risk and engage in discourse about that risk with agency and other personnel. Simple provision of that information, which assumes the non-expert public is fluent in the use of this technical information, is not enough to serve the purpose of procedural justice.

Hampton's literature review (1999) clarified how technical and scientific information must be handled to be useful in public participation, "…methods need to provide *appropriate forms* of information…and *access to expertise and education* which enable the public to understand policy issues and formulate preferences" (p. 163, emphasis added). In recognition of this, government agencies, scholars, NGOs and communities have proposed and created different tools that offer the public access to appropriate information, expertise, and education (Fischer, 2005; Irwin & Bruch, 2002; Kellogg & Mathur, 2003; Kinsella, 2004; Teske, 2000). The TAG group program available to Superfund communities, which provides funding for communities to contract with technical experts to address their self-defined informational needs, is an example of such a tool (Teske, 2000).

A lack of accessible information in Opportunity

As discussed earlier, Opportunity residents expressed frustration with the amount of information provided to them. They have also repeatedly critiqued the nature and quality of information provided to them. As Hasenbank (2006) observed, "participants felt (the information that did exist) was largely inaccessible or incomprehensible" (p. 46). "' There is a letter that comes out…about, you know, what's going on and stuff to a certain extent…I get it every once in a while, but it really doesn't make any sense to me,'" one participant explained (p. 46). Some participants specified that information provided by the EPA should be "reader-friendly" (p. 47). The exchange between two participants in the study illustrates how information provided by experts at the site made assumptions about lay people's familiarity with the concepts and language being used to explain site conditions. This is their response to expert statements about water associated with the waste repository not posing a risk to Opportunity because of regional groundwater flow patterns:

> Frank stated, 'I don't know, I'm not an engineer or anything, but how often does the flow of water underground change directions?' which was followed by Edith who interjected, 'We don't know that. We should know that.' (p. 46)

Here, it appears that experts assumed that residents are familiar enough with hydrogeology to know that larger scale groundwater flow paths only change due to extreme changes in the local landscape. Other concepts unfamiliar to lay people will be discussed later.

The assessment that shared information has been largely inaccessible is reinforced by other observations. Silberberger and others (2006) attended one of the public informational sessions offered to Opportunity residents and characterized the information presented as "too technical for the lay person to understand" (p. 4). After surveying and speaking with community members, they concluded that Opportunity residents must be "provided with complete and comprehensible information about …their water quality," and that "communication of information should be straightforward in order to make the technical information accessible to the community" (p. 4). Hasenbank, after conducting her analysis of resident comments (2006), sent a letter to officials offering suggestions for improving the communication of technical information. As mentioned earlier, limitations have hampered the ability of OCPA and CFRTAC to provide more appropriate information about the cleanup to residents since then and residents do not receive significant technical assistance from the Arrowhead Foundation.

Overall, details about the experience of Opportunity residents suggest that whatever efforts have been made to share information in the area, they are not perceived as sufficient in empowering residents to participate in the decision-making process. Based on the local context described above, much information desired by residents has not been made available and the information shared was not always offered in a form appropriate for lay audiences. As the Hasenbank (2006) and Silberberger and others (2006) studies pointed out, even active members of the community felt "left out of important decision-making processes that affect them" (Hasenbank, 2006, p. 2) and a lack of sufficient and relevant communication by technical experts contributes to this sense of a lack of agency. Scoping discussions with members of OCPA prior to this project reinforced that residents still felt improperly informed and confused about cleanup explanations and efforts concerning groundwater.

Building lay capacity to use technical information

As discussed above, scholars have pointed out the importance of providing sufficient and appropriate information to communities faced with questions of environmental risk. While these principles are important to incorporate into communications, they treat the capacity of laypersons to understand and evaluate technical knowledge as static and unchangeable. Literature concerned with both democratic processes and science education discuss the importance of building public capacity to engage with technical and scientific information in the achievement of meaningful public participation. Kinsella says this need arises because "members of the public must listen to, evaluate, and contribute to conversations with substantial technical content" (2002, p. 195) when engaged as active and equal participants in the technical discourse of most governmental policy settings. Science education scholars assert that this capacity is necessary to participate in environmental decision making (Gunckel, Covitt, Salinas & Anderson, 2012).

Scholars of democratic processes and science education discuss this capacity in different terms. Fischer (2000) and Kinsella (2004), who examine public participation theory and practice, refer to this capacity building as supporting the development of “technical competencies”, which include the ability to understand and use scientific terms and concepts, and a general understanding of technical reasoning. Science education literature frames this capacity as “scientific literacy.” As Tytler, Duggan and Gott (2001) explain, “A scientifically literate individual is generally regarded of as one who can achieve a functional understanding of, and response to, science-related phenomena that impact upon the individual’s life” (p. 345).

The point of capacity building, however, for both public participation and science education scholars, is not to create a public whose analysis of environmental risks aligns with technical experts or to create a public composed of technical experts. Kinsella (2004) sees the development of technical competencies as a way for lay people to access and contribute to discourse that involves technical assessments. He argues that non-expert citizens provide other forms of valuable knowledge and expertise that are needed in decision making. Facilitating public participation in highly technical decision making processes challenges the ascendancy of scientific or technical analyses in determining appropriate solutions for dilemmas that affect non-expert communities. The value of public participation would, therefore, be lost if citizens simply adopted technical perspectives (Kinsella, 2004). From the view of science literacy, Gunckel and others (2012) reinforce that building this capacity does not replace other ways of understanding the world, but adds to it, providing the “opportunity to participate in communities that value and use scientific, model-based reasoning for environmental decision making” (p. 848). This includes the community of experts and personnel working on Superfund sites.

Strategies for developing supportive communications

Based on the literature reviewed in this chapter, communications about environmental risk contexts should consider several aspects of information to empower public participation: what information does the public consider necessary to be satisfactorily informed; what competencies that facilitate public use of that information can be supported; and how can information be communicated in a way that is accessible (and not alienating) to non-expert publics? While the residents of Opportunity are the best source for explaining what information they desire, previous research provides insight on how to address the other aspects. This section first presents a set of competencies suggested by literature to support lay capacity to understand and use technical information about groundwater. The next subsection then discusses how research into existing lay understandings of groundwater provide more specificity about what concepts should be addressed in communications to support those competencies. The final subsection then discusses insights that I gained from literature about how to communicate technical information and concepts accessibly to non-expert publics.

Building groundwater competencies

Science education studies and literature provide guidance and specificity for building public capacity to use technical information about groundwater. The work of Covitt, Gunckel and Anderson (2009) particularly addresses competencies related to groundwater:

> Environmentally literate citizens should understand the structure of systems through which water flows, and they should be able to trace matter (water and other substances) through natural and human-engineered systems at multiple scales from atomic-molecular (changes of state and solutions) to large

(watersheds, aquifers, human water purification and distribution systems) scales. (p. 38)

Their work (Covitt et al., 2009; Gunckel et al., 2012) has been conducted to inform the development of curriculum in educational school settings. This set of competencies is, however, instructive for the purpose of designing communications that support the ability of Opportunity residents to engage with information about groundwater. Based on these competencies, building resident understanding of the following elements should support residents' capacity to engage with technical information about local groundwater conditions:

- The structure of the local aquifer system and groundwater system in general, including the land surface
- The way this system connects to other water features (including domestic wells, irrigation ditches and drain tiles)
- The flow of water through the groundwater system and connected surface features (including surface water)
- The way arsenic moves through and interacts with surface and subsurface features (including at the molecular scale)

The depth and extent to which these aspects of the local groundwater system need be addressed is a function of their importance in the risk setting that Opportunity residents face. Informational materials should focus on aspects with larger roles in both the local distribution of arsenic and in the technical analyses used by experts, as discussed in the Superfund context chapter.

Getting a sense of existing capacity

Science education literature also provides a sense of what residents' existing capacity for engaging with technical groundwater information may be. This research explores student understandings of water and water systems, but is applicable to an adult audience. According to Covitt and others (2009), formal education does not help the vast majority of individuals attain the level of functional scientific literacy needed to address dilemmas involving water resources. Most students in American public schools do not receive groundwater-related instruction after the eighth grade (Dickerson & Dawkins, 2004). Graduating students have an incomplete knowledge of groundwater science, or "hydrogeology," and don't develop new knowledge in higher education unless it is their specialty (Dickerson, Penick, Dawkins & Van Sickle, 2007). It is reasonable to expect, then, that the majority of American adults who have not received any special training, possess knowledge and understandings of groundwater comparable to junior high or high school students.

The work of Covitt and others (2009), and Gunckel and others (2012) summarizes what education literature says about which groundwater concepts are commonly misunderstood or unfamiliar to individuals (Table 3-1). Understanding these concepts is necessary for achieving the competencies identified by Covitt and others (2009). Building resident understanding of these concepts is believed to support the set of competencies considered important for resident use of technical information about groundwater.

Table 3-1: Groundwater literacy needs

Unfamiliar groundwater concept*	Related competency
Groundwater occurs within the pore space of saturated ground materials.	• structure of the local groundwater/aquifer system
Infiltrating surface water enters the groundwater system	• flow of water through the groundwater system and connected surface features
Water flows in and between atmospheric, surface and ground systems	• the way this system connects to other water features (including domestic wells, irrigation ditches and drain tiles) • flow of water through the groundwater system and connected surface features (including surface water)
Contaminants interact with water on a molecular scale at the surface and underground (can be in solution or suspension)	• the way arsenic moves through and interacts with surface and subsurface features (including at the molecular scale)
Groundwater moves and controls the movement of groundwater contaminants	• the flow of water through the groundwater system and connected surface features (including surface water) • the way arsenic moves through and interacts with surface and subsurface features (including at the molecular scale)

**compiled from Covitt et al., 2009 and Gunckel et al., 2012*

The usefulness of these competencies and conceptualizations of groundwater in understanding and evaluating Superfund cleanup decisions and explanations is evident when considering the technical information, discussed in Chapter 2, with which residents seeking information about the local risk setting must engage. For example, analysis of groundwater movement was used to determine that the groundwater plume southwest of Opportunity posed a greater potential risk to Opportunity wells than the waste repository north of town, resulting in further studies and analysis to assess that possible threat. Understanding basic concepts about groundwater and contaminant movement are necessary for residents to understand, evaluate, ask questions about and respond to explanations that rely on this analysis.

Composing effective communications to support meaningful participation

Based on the literature reviewed in this chapter, communications about environmental risk contexts should consider several aspects of information to empower public participation: what information does the public consider necessary to be satisfactorily informed; how can information be communicated in a way accessible (and not alienating) to non-expert publics; and which competencies that facilitate public use of that information can be supported? While the residents of Opportunity are the best source for explaining what information they desire, previous research illuminates how to address the other aspects.

Science communication, risk communication and education studies elaborate on making information accessible and relevant. As a field concerned primarily with communicating highly technical information, the lessons of risk communication are helpful. The National Research Council (NRC, 1989) offers these recommendations: “present information in language and concepts that recipients already understand, that use magnitudes common in ordinary experience and are sensitive to the psychological needs of the recipient” (p. 129). According to the NRC, good risk communication reflects the technical capacity and concerns of the target audience. Advice to work with existing technical capacities and to use clear and simple language and concepts pervades literature (Chilvers, 2008; Gunckel et al., 2012; Fischer, 2000; Kinsella, 2004; Lin & Peterson, 2007; NRC, 1989; Rowan, 1999; Weigold, 2001).

Science education literature offers the most guidance for building competencies. Although some scientific and technical terms are fundamentally important to define for lay people because of their specific meaning and frequent use by experts in the Opportunity setting, concentrating on proper terminology is not a reliable tool for building competency. As Dickerson and Dawkins (2004) observed, the use of proper scientific terminology doesn't necessarily represent correct conceptualizations of groundwater phenomena and the use of vernacular language doesn't necessarily convey misunderstanding of them. Basing communication in clear and simple language is, then, reasonable for building competencies.

The science education literature on groundwater suggests that communications aimed at building upon the current level of technical competencies prevalent among the public should "address the structure and movement of water and other substances in individual systems, and then it should gradually move toward building connections among these systems" (Covitt et al., 2009). Gunckel and others (2012) further specify that individuals with typical competencies in water science need support for "tracing water through connected systems and recognizing the multiple and branching pathways that water takes as it moves through environmental systems…(and for) reasoning about water and water movements from atomic-molecular to landscape scales" (p. 864).

Several observations suggest tools that may be useful in addressing these topics and providing this support. Dickerson and Dawkins (2004) point out that non-standard, or technically inaccurate, ideas about groundwater often result from misapplying practical experience. These "non-standard" ideas held by the public can pose barriers to communicating technical information about groundwater. However, if lay conceptions are addressed and reframed into more accurate accounts of groundwater, they can provide the basis for developing more complex and scientific understandings of groundwater rooted in the context of people's daily experiences (Ben-zvi-Assaraf & Orion, 2005; Covitt et al., 2009). This approach can further support the development of technical competency.

On the other hand, groundwater concepts that are not presented as part of an individual's familiar landscape may not seem relevant. One review of science education literature points out that individuals often do not relate formal learning about water to their immediate surroundings (Covitt et al., 2009). Therefore, it is necessary to assist people in making connections between daily experience and scientific or technical conceptualizations to facilitate the ability of individuals to apply that understanding to their local environment

Because groundwater is a, mostly, invisible system difficult to observe, visualizations are important tools that help individuals understand concepts and phenomena (Dickerson et al., 2007). Cross-sectional images and diagrams are particularly helpful for grasping concepts associated with groundwater structure and scale. Practitioners must, however, take care to ensure that these are complete and accurate to avoid reinforcing groundwater concepts that are inaccurate or incomplete (Dickerson & Dawkins, 2004). Risk communication literature also emphasizes the use of simple imagery to convey complex and technical concepts (Lin et al., 2007).

The insights provided by literature discussed in this chapter about effective communication of scientific concepts and risk, common understandings of groundwater, and necessary competencies informed the design of all steps in this project. These insights clarified the general types of needs Opportunity residents may have regarding groundwater information and provided some guidance on how to put technical or scientific information into the service of the public. Latter steps in the project built upon this basis of understanding and sought to develop insights more specific to the Opportunity setting.

4. FOCUS GROUP INTERVIEWS

Previous public comments and literature provide some insight and guidance about the information desired by residents, how to make it accessible, and how to support the capacity of residents to use that information. This insight, however, is not very complete or specific to Opportunity wells and local arsenic threats in groundwater. This chapter describes and discusses focus group interviews I conducted to gather data specific to Opportunity residents' needs concerning knowledge and understanding of groundwater and contamination at the local cleanup site.

The focus group served as an informal way to provide a formative assessment for the creation of a booklet that would more closely serve the needs and concerns of Opportunity residents regarding the safety of local groundwater. This chapter begins by discussing what formative assessment is and why focus group interviews were appropriate for this purpose. It then explains my focus group interview planning and recruitment. The next section includes details about the conduct of the focus group interviews. Finally, the last section discusses my analysis of resident focus group comments.

Focus groups as an appropriate formative assessment tool

A national organization of educational leaders define formative assessment as "a process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes" (Popham, 2008). Although this project is not part of an educational curriculum, its "intended outcome" is the attainment, by Opportunity residents, of knowledge and competencies relevant to assessing and communicating about local groundwater remediation activities. The feedback from this assessment informed the composition of the presentation and booklet developed to support that intended outcome. An appropriate formative assessment method for this purpose gathers data about existing resident desire for information, current states of resident familiarity with scientific explanations for local contamination, and resident competencies necessary for engaging with those explanations.

Social science focus group methods are a reasonable approach for obtaining this formative assessment for an adult population. During a focus group interview, volunteers, usually six to ten, gather in discussion of a topic determined and led by the researcher/moderator. Hesse-Biber, Nagy and Leavy (2006) describe aspects of the focus group method well adapted to formative assessment. It is a tool effectively used for gathering exploratory data and developing educational and related programs. As such, it is an appropriate tool for developing informative materials seeking to support scientific understandings. Also, as a method that gives priority to "the respondents' hierarchy of importance, their language and concepts, (and) their frameworks for understanding the world," (p. 199) it is well suited for collecting data about residents' informational needs; their conceptual, linguistic and experiential understanding of groundwater; and their needs for developing relevant competencies. Because this technique is effective at challenging the researcher's assumptions about primacy of topics, and at finding language appropriate to the interviewed population, it helps avoid the alienating pitfalls possible in highly technical environmental communications, and orients content to the needs of the participants (Hesse-Biber et al., 2006).

Planning focus group interviews

As mentioned above, the objective of the group was to gather more concise information about community needs and concerns in understanding groundwater contamination. Focus group design choices discussed by Hesse-Biber (2006) and Krueger (2000) informed planning. I developed a protocol (see Appendix A), to be administered in approximately two hours, which consisted primarily of a short script and a set of questions for a group of 6-8 individuals. The protocol was designed to provide guide the discussion. The questions addressed groundwater concepts and information central to explanations of the pattern of local groundwater contamination as set out in Superfund site documents and previous public presentations by EPA and various technical consultants. Follow up prompts or questions were developed to draw out more detailed discussion on topics, if necessary.

A set of visual projections accompanied the protocol to support discussion of topics. The projected slides consisted of a simple cross-sectional domestic well diagram, which was created specifically for the focus group, and maps showing various features of the local area. Including these images aided discussion because many questions and concepts were about contaminant location and movement through the landscape (see Appendix B). The maps originated from various Superfund documents or public presentations. Using these offered some limited observation of how well previously created images communicated information about the area to participants and what changes may make them clearer. In order to provide a medium for the moderator and participants to draw and mark on these images, a dry-erase projection screen was fabricated. I also provided a handout of these images for volunteers who may be more comfortable offering comments without stepping up to the projection screen.

In order to allow me as the moderator to give full attention to the focus group discussion, record non-visual parts of the discussion, and make later observations of the participants, the protocol called for audio-visual recording of the meeting. This also allowed for later review of comments and group dynamics in order to identify the possible need to follow up with non-responsive participants. Additionally, I developed a short, anonymous "background questionnaire" (Appendix C) for collecting basic demographic information to assess how representative of Opportunity the group was.

I sought approval for this and subsequent stages of the study by filing an application with the University of Montana Institutional Review Board (IRB) in February of 2012. This application included a protocol for protecting the confidentiality of participants (described in Appendix G) as well as the following items developed for the focus group (Appendices A-G): a recruitment letter; a phone script for soliciting participation; a recruitment flier; the background questionnaire for participants; the focus group protocol; and an informed consent form to be signed by volunteers. The IRB determined the study as exempt from requiring their review and indicated that including an informed consent form was optional (P. Baker, personal communication, February 14, 2012). I opted to include the informed consent form with an explicit statement of consent to be audiotaped and videotaped.

I obtained funding to cover travel, outreach, videography, and participant compensation costs through the Environmental Studies Program of the University of Montana in spring of 2012. I obtained $1000 from the Pat Williams Scholarship Fund in general support of this project in spring of 2011.

Recruitment

I intended to offer the results of this project to concerned Opportunity residents. Therefore, recruitment targeted Opportunity residents who may have a concern about groundwater contamination. Lists of individuals who collaborated with studies or monitoring projects mentioned earlier (Cobler et al., 2006; Feeley, 2008) and local contacts, such as the members of OCPA, identified approximately 40 potential participants. After reviewing this list, I decided to conduct two focus group interviews: one with individuals not active in OCPA, and another with two individuals who were active members at the time. The two individuals interviewed separate from the larger group are vocal and active in addressing community issues of Superfund site contamination and there was concern that other individuals would not participate as fully if I interviewed everyone together. An announcement of the study also ran in the Anaconda Leader, the local paper distributed in Opportunity, approximately two weeks before the meeting. I also posted a recruitment flier with contact information and a sign-up sheet at the only grocery store in Opportunity. I offered volunteers modest compensation ($20) for their time and effort.

Individuals on the list received a short solicitation letter announcing the study and my intent to contact them by phone (Appendix D). A week later I contacted individuals by phone to discuss the study in more detail, ask if they were willing to participate, and survey possible participants about potential meeting times (see Appendix E for script used). I secured a reservation for the larger focus group at the Opportunity Community Club, a community hall centrally located in Opportunity. As recommended by Hesse-Biber (2006), after setting dates for focus group interviews, I phoned individuals to confirm their attendance.

Conducting focus group interviews

A total of ten Opportunity residents participated in the two focus group interviews. The larger focus group meeting consisted of eight participants and occurred on April 7, 2012. A hired videographer recorded this meeting. The interview with the remaining two individuals occurred at a private residence on May 12, 2012 and was only audio recorded. Before each interview I re-introduced myself and the project and participants had time to review and sign the informed consent form and complete the background questionnaire (Appendices G and C). The informed consent form described the confidentiality protocol. All attendees signed the informed consent form. No one objected to being recorded during the sessions. Each participant also received the image handout and was encouraged to submit written or drawn comments on it. Both interviews lasted approximately two hours.

Description of participants

The background questionnaire yielded the following information. In all, five men and five women participated. Most participants fell within the 50-69 year age range. One individual was within the 18-29 age range and two reported being in the 70+ range. Two participants were single and the others were married. Two married couples participated. Four of the volunteers reported having children who reside in Opportunity. Of these four, three also reported having grandchildren in Opportunity. A slim majority of participants (six) owned their residence and the remainder (four) rented. Participants resided in the town of Opportunity from 3 to 60 years. The median residence time reported was 52. Participants indicated which street cross-section was nearest to their home and this information showed a distribution of residences throughout the town of Opportunity. Half of the participants reported being retired. Three individuals were actively employed and the rest were either unemployed or disabled. The questionnaire requested information on current or past occupation. These occupations varied among participants. Importantly, no participants indicated active employment by ARCO or any other organization conducting remediation work, nor did any participants work in occupations requiring special knowledge about groundwater.

The information showed that the focus group is somewhat over-representative of individuals over 50. Census information identifies over 62% of Opportunity residents as over the age of 50 (Census Bureau, 2011). Married individuals and those who have resided in Opportunity for a longer period of time may also be overrepresented. It could be that these demographics are somehow more invested in the results of the cleanup. However, participation was varied enough to affirm that participants did not come from a homogenous group that may represent a specific viewpoint or understanding of the cleanup.

Description of participation

Residents in both interviews were talkative and friendly with me and each other, both before and after the discussion began. The tone of the discussion, overall, was conversational; residents often engaged in conversations with each other. This conversation almost entirely addressed aspects of the cleanup. Several residents posed questions to me about the cleanup immediately. I had to be clear that my purpose that day was to hear from them, but that I was working to provide information at a later time. Overall, it was clear that residents wanted more information about the cleanup. Several comments throughout the discussion voiced dissatisfaction or confusion with prior attempts by the EPA, ADLC and consultants to provide information, even though I never posed questions about the sufficiency of these attempts. Additionally, a few residents very clearly voiced feelings of environmental injustice related to remediation decisions, such as when one resident exclaimed, "…Missoula didn't want it, Silver Bow County didn't want it, and Deer Lodge County didn't have a choice. They got it!" in reference to the relocation of contaminated sediments to the nearby waste repository. This supported my previous assessment that the project addresses a community need.

In the two-person interview with members of OCPA, both individuals were very vocal and participated equally, often engaging in Superfund site-related topics that were not the topic of the interview. In the larger group interview, most of the participants were attentive to and engaged in the discussion. One participant was more talkative than others. He did, however, leave room for other residents to make comments and respond to questions. He also acknowledged and responded to topics that other residents brought up, sharing control of which topics were discussed. Two of the participants in this group were somewhat distracted by tending to an infant. One of these residents showed an active interest in the conversation, asking others questions and contributing comments. The other contributed almost no commentary. Unfortunately, no contact phone number was available to perform a follow up interview with this individual.

Individuals were generally hesitant to draw on the projected images. Two residents, when invited, stepped up to the screen and drew on the maps to explain their commentary. Mostly, I ended up drawing on the screen while trying to clarify or illustrate what participants were saying. Residents did not offer any significant written commentary on the visual handouts I provided.

My role as moderator

Because I was interested in hearing residents' perspectives and accounts of groundwater concepts and information, I limited the amount of time that I talked. I allowed conversations to develop among residents, steering them back towards the topics covered in the protocol questions when needed. Often, discussion of one topic led into another, such as when conversation in the larger group turned from groundwater movement towards the tile drains without my prompting. Often, if a topic came up organically, I engaged with it, whether or not it was happening in sequence. In these instances, I used the follow up questions to focus discussion. Focus group conversations addressed all but two of the main questions that I developed for the protocol. These were cut to provide time for other topics and asked specifically about resident experience with scientific explanations given for groundwater conditions in the area.

During interviews, I employed several techniques to draw out participation of less active volunteers and ensure that comments were representative. Sometimes this involved invitations for quieter participants to endorse, elaborate or disagree with existing comments, such as asking "Any concerns you want to add?" or "Is that the general understanding…or does anyone have a different idea?" At other times I sought clarification of resident comments and increased participation by rephrasing or asking for clarification on an idea. For example, I would often restate, in my own words, what I understood a resident comment to mean and then ask "Is that correct?" or something similar. I often used the dry erase screen to facilitate further discussion and clarification.

Analyzing focus group data

After gathering data from the focus groups, I prepared them for analysis. I transcribed both interviews, making sure to note any visual communication that occurred, such as any drawing, clarifying gestures, or written comments on handouts. There were very few written comments received on visual handouts. I did not transcribe discussion of tangential topics that did not comment on groundwater contamination or the local cleanup. According to the confidentiality plan (Appendix G), audiovisual recordings were erased after transcription, in late May 2012, and all participants received a pseudonym in the transcript.

Hesse-Biber and Leavy (2006) describe the analysis process of qualitative data as an iterative approach that involves several rounds of coding and analysis to arrive at detailed insights into participants' experiences. As a formative assessment tool, the goal of the focus groups was much simpler. I engaged in a simpler, less detailed, less rigorous process. I identified different groups of concepts, according to which concepts of groundwater contamination they addressed or were related to, such as concepts of aquifer shape/movement/speed, contamination sources and paths to groundwater, and connections between surface and groundwater.

After reviewing these groups of comments, I recorded notes and observations about them. This analysis reaffirmed some of the statements made in literature about the presence of common misconceptions, such as the concept that groundwater occurs as underground rivers. It also revealed that residents had ideas that could be built upon to develop more complete and accurate accounts of groundwater, such as the idea that precipitation and runoff can enter the groundwater system. Comment review also pointed out topics that residents wanted more information about such as arsenic health effects, and well testing results. Some comments revealed that residents did not have knowledge of certain information pertaining to the cleanup, such as where arsenic in water resources exceeds regulatory levels and that losing stream reaches are considered a local arsenic source to groundwater. Some comments revealed ways in which visual representation could become clearer. For instance, when presented with a map, most residents were disoriented until the relative location of landscape features such as the smelter, highway and surrounding towns or mountains was pointed out. These comments, in concert with previous public comments and literature, further refined my understanding of which topics necessitated special attention to strengthen understanding of local groundwater contamination issues of the Superfund site.

Results

Analysis of the two focus group interviews assisted in creating materials that were more responsive to local community needs and concerns. This analysis revealed that focus group participants had varying levels of familiarity with hydrogeology concepts central to official studies and conclusions, and varying levels of knowledge about the cleanup and the results of previous monitoring and studies. Participants also identified other topics that they desired more information about. The first sections below present my analysis and observations on resident comments about groundwater contamination topics and concepts addressed by protocol questions. The last section presents and discusses other topics and concepts of concern or uncertainty that came up freely in discussion.

Occurrence of groundwater

Question two of the protocol (Appendix A) asked about small-scale water flow into domestic wells and was designed to prompt discussion of groundwater structure. In the larger focus group, however, most comments that elaborated on this topic actually occurred in response to questions I posed about groundwater movement or the water table. In the smaller focus group, discussion of this topic frequently occurred throughout the conversation, mostly without my prompting.

Literature reviewed for this project mentioned that many lay people have difficulty conceptualizing the occurrence and movement of water underground, often describing groundwater as running in underground streams. Focus group comments indicate that residents in Opportunity also have difficulty conceptualizing the structure of water underground. Two residents directly stated this when asked what they would like to learn more about:

> Gary: I would like to know more about the aquifer and find out which way it goes. If there's more than one down there. I don't even know how aquifers work. I know it's just underground water. That's all I know.
>
> Steve: It's kind of been *held a secret* to us. Aquifer is just a word to us, you know? *They* show us a picture of a blob and *that's it*. We don't know if it's going this way, that way…whatever.

While only two interviewees, Earl and Steve, directly referred to groundwater as "rivers" or "streams" that feed wells, other residents' comments did not logically align with the concept of groundwater as a body of water permeating all available pore space below the water table. It is not surprising that, without this organizing concept, the aquifer is described as a mysterious "blob."

For most residents, groundwater occurrence was linked to the location of surface water features. For Earl and Anne, water underground occurs in isolated bodies that are fed by surface ponding. When discussing that groundwater in their area "runs" from south to north, these individuals pointed out the location of their wells on a linear path between two ponding areas as satisfying evidence. According to this idea, the source of water in their well is separate from other residents, who associate their well water with a surface stream to the west. Two other residents talked about the location of creeks indicating which way groundwater flows. As Tim explained when asked about how groundwater moves: "It all leads to the river (Clark Fork River). The same way the creeks go…that direction…Follow the creeks because it drops in elevation."

It is unclear exactly how residents link groundwater location to surface water features. Finer scale concepts of where groundwater exists may play a role. While the comments summarized above evidenced a need to offer information about groundwater occurrence on a large landscape scale, other comments revealed that the presentation and booklet needed to address the basic concept of groundwater existing throughout all available pore spaces underneath the water table. That residents did not conceive of water entering and occupying the pore space of materials below the water table was evidenced in one discussion of the removal of sediment from an area. When I asked Earl and Anne for clarification about their concern that removal of soil was responsible for turning an area from a “desert” to a “pond”, Earl explained that there was no longer any topsoil for water to “drain off of.” The area they referenced is near Willow Creek, where the water table is very shallow and wetland conditions exist nearby. In their interpretation, water in the ground is not revealed by removal of soil below the water table, but is introduced from above due to a change in topography and drainage. On a similar note, Gary discusses the water in a well bore as existing in separate layers from subsurface sediments “…when they drilled they got into water and clay, and then more water, and then sand and clay, and then another water underneath…we’ve got an aquifer running here, and another one…underneath this sand bed.” While Gary’s comments suggest that groundwater occurs in separate layers from ground materials, it does show an awareness of stratigraphy and how it might affect the location of aquifers.

Alternative concepts of groundwater occurrence were also evidenced in comments relating to well levels observed by residents. Because domestic wells are the way that most residents interface with the groundwater system, it is not surprising that their concept of where water occurs underground may be linked to the location and level of water in these wells. The dilemma this causes was revealed when I attempted to understand why Earl had confusion about the function of the drain tile.

> Earl: …Well, that might have made sense if it wasn’t flooded down there (in the east end of town) for 60 years. (Bonny, Jill and Tim nod in agreement). The further down you go in Opportunity, the deeper the wells get. My well’s 116 feet deep (in the east of town where the water table is shallow). My friend…who lives just down the road from me, his is almost 170 before they got water…and then

over on *that* side of Opportunity (gestures to the east) the wells are 60 feet deep. I mean…

ME: So the further west you go, it's shallower

…TIM: (in response to inaudible Jill comment) yeah??? That's what ours…

ME: Which is interesting because it seems counterintuitive.

ANNE: Yeah!

ME: You'd think that as you get closer to the river and closer-and the ground gets lower…?

TIM: It doesn't come up the way you think it would.

For Earl, Anne and Tim equating the water table with well levels created difficulty for explaining the presence of shallow groundwater in the same areas where wells up to 170 feet deep exist. This portrayal of well levels as equivalent to the water table was not always consistent, however. For example, Earl also explained that better drainage of shallow groundwater resulted in the "water table", but not his well level, dropping on his property. Also, as discussed above, Gary's comments recognized that ground material influences the location of wells.

As described in the Superfund Context chapter, the Deer Lodge Valley groundwater system, including the Opportunity area, is complex and difficult to map in detail. The heterogeneous nature of the sediments making up the valley creates many discontinuous layers with varying permeability. In a simpler hydrogeologic setting, resident ideas about the relationship of the water table and aquifer location would be accurate. However, in the Opportunity area relying on domestic well depth and location to conceptualize the location of groundwater is problematic: first of all because the resulting concept may equate productive well depth rather than saturated pore spaces with the water table; and second of all, the productive depth of a well in this heterogeneous system can vary so dramatically in different areas of town. It is reasonable to suggest that, lacking a concept of groundwater as occurring throughout all permeable materials below a certain level, and basing conceptualizations on observations of domestic wells would create a concept of groundwater as occurring in discontinuous and discrete bodies.

Overall, focus group results indicated that residents are aware that aquifers in the area are discontinuous and that this is a result of variation in subsurface soils and sediments. This suggested that discussion about groundwater occurrence at both a pore and landscape scale might be able to build upon resident ideas and help residents place their own observations into a more accurate, connected image of the local groundwater system. In order to build a more connected and scientifically accurate conceptualization of groundwater in the area, informational materials illustrated the spatial variation in the composition of valley sediments and the occurrence of groundwater, from the pore scale to the landscape scale.

Groundwater movement

Because groundwater movement is unavoidably linked to groundwater occurrence, resident comments discussed in the previous subsection suggested that residents may not be thinking about the full range of groundwater movement possible within a saturated ground system. However, when asked about the flow of water through the Opportunity area, all residents indicated groundwater moving from the south and west towards the north and east. This does align with gathered data and suggests that residents acknowledge the horizontal movement of groundwater. At least three residents discussed materials moving through the aquifer with water, more directly acknowledging that groundwater moves. As one of these residents explained, "…there's water going through there all the time, but a lot of people will say it's like a big bathtub down there." Although residents commonly discussed groundwater movement as linked to surface streams, several also linked it to local topography, explaining, "It runs downhill." One resident did assert that this was not necessarily inevitable when he said that "just because the ground we live on tilts *this* way, doesn't mean that the water can't run *that* way." The location of the water table and, therefore, groundwater movement *is* often, but not always, a reflection of land topography. This idea about groundwater movement, then, was generally accurate and presented an opportunity to build upon resident views in the developed materials.

Overall, despite the comments residents made about groundwater movement across the landscape, residents most commonly talked about groundwater moving vertically, not laterally. None of the protocol questions explicitly addressed vertical movement, but several questions (#s 3, 4, 9) asked participants to describe how water or contaminants could move through the landscape. In response to these questions, seven of the ten participants described water as moving down in various comments about the aquifer. One participant, Bonny, resorted to talking about the fluctuation of water up and down in her well in response to a question about speed of movement through the aquifer. Most individuals discussed noticing well levels moving up and down. There were, however, no comments about water moving upwards through the ground.

Based on the literature review, I had anticipated that lateral movement of water might not be clearly integrated into residents' conceptions of local groundwater. Water table elevation maps are commonly used to assess the general lateral flow direction of groundwater. Hence, one focus group question asked residents to look at a water table elevation map and discuss whether it communicated anything to them about the aquifer. This was an effort to explore the usefulness of this image in showing lateral groundwater movement. None of the residents indicated that they had seen this type of image before. A couple of participants easily saw the parallel between this image and a topographic map and said, “With the water levels like that, you can almost tell which way the water flows.” This reasoning about the shape of the water table and how it relates to groundwater movement represents a sophisticated understanding. Two other individuals made comments suggesting that they saw a parallel between topographic maps of the land surface and water elevation maps of the water table. While residents expressed interest in the meaning of the image, most indicated that this image did not show them anything about groundwater movement. One resident suggested that it would be helpful to “overlay…a contour map to get…across…that this is the ground we live on and this is the aquifer down underneath” to which several other individuals responded favorably. This reinforced my determination to include cross-sectional diagrams in materials.

Understanding movement of water underground is important in assessing and evaluating information about local contamination of groundwater, especially in consideration of the arsenic contaminated plume upgradient of Opportunity wells. Both lateral and vertical movement of water affects the distribution of arsenic. Based on resident comments, I concluded that materials needed to describe that groundwater movement can and does occur in any direction within a three dimensional field. Since residents related to groundwater movement most directly through the level in their well, it would be important to acknowledge and discuss the pattern of this rise and fall and relate it to lateral flow of groundwater in the area. As a way to connect well levels with lateral movement, the water table elevation map was still useful. Resident comments suggested that this visual tool may present a way to build upon resident understanding of water movement. However, based on participants’ reactions to the water table elevation map, some background explanation about the image’s construction and a cross-sectional illustration of the relation between topographic and water table elevation assisted the usefulness of this graphic tool in the presentation and booklet.

Surface and groundwater connections

Connections between surface water and groundwater play a role in the officially sanctioned explanation for the pattern of groundwater contamination. Several protocol questions (Appendix A) asked about the possible movement of water and contaminants between the surface and groundwater features (#s 4, 5, 9). Resident comments on this topic occurred most frequently in those discussions. Overall, residents acknowledged that groundwater and surface water are connected, but talked more confidently about some connections than others. Participants talked most about water on the land surface entering the groundwater system. Almost all residents addressed ponds or puddles "leaching" water down into soil. This was often in reference to concerns about surface arsenic entering the ground. Infiltration of precipitation that did not pond or puddle was not discussed. The idea that stagnant bodies of water can be influent (flowing into the ground) was also asserted more often and confidently than statements about surface streams or moving water having a connection to water underground.

Some residents did think there might be a connection between surface streams and groundwater. One resident brought up the subject himself during a conversation among the group about well levels:

> TIM: I've got a question. What about when they irrigate? …the water comes out of Mill Creek, goes through all these ditches and back into the river down below us, but floods all those fields. What does that do to our well?
>
> BONNY: It brings our well up.
>
> TIM:…Surprising, even though it's in the ditch, it raises the whole water table.
>
> ME: So there's a connection between the ditch and the groundwater that you've

noticed…do you have any concerns…about any of that surface water getting into the groundwater?

TIM: Yeah.

ME:…What about the irrigation ditches?

TIM: That's what they're running through, then it raises up and raises the whole water table. So is that going in my well?

When asked if they worried about surface water getting into their well, Steve and Gary also had concerns about irrigation water entering wells. When asked if this was due to irrigation water entering the aquifer, however, Gary explained that "I don't know if that's possible or not" and that his concern was that the tops of wells (wellheads) can be flooded during irrigation. Later on, however, these residents did express concern that water from Mill Creek and Brundy Creek could "infiltrate" into nearby wells. This body of comments showed that residents do often trace water and other substances from the surface into groundwater. These ideas could be built upon to develop more complete conceptualizations about infiltration and connections between surface water and groundwater.

Groundwater flow into surface waters was only briefly mentioned in passing as a few residents commented on the tiles in town draining shallow groundwater into local streams. However, none of the focus group questions addressed this type of connection and, therefore, whether residents have concepts about this connection is unknown. The aforementioned concerns that Earl and Anne expressed about the removal of soil creating a place for surface water to collect does, however, suggest that there is at least some disconnection between groundwater sources and wetlands or influent ponds in resident understandings about water connections in the landscape.

Overall, residents acknowledged a connection between water on the land surface and groundwater system, but appeared to need support for extending this idea to include connections that involve moving surface water and water moving from the ground onto the surface. There are surface streams, wetlands, and springs in the area that interconnect with the local groundwater system. Because these water features play roles in the local hydrogeology and flow of water through the landscape, the connections between these features and groundwater were highlighted in the developed materials.

The role of drain tiles

One question specifically inquired about residents' knowledge of the drain tile system and how water moved within it. Because Superfund documents describe the drain tiles as a factor contributing to relatively low arsenic levels in domestic wells within Opportunity, it was important to gauge how familiar residents are with their existence, structure, and possible role in local groundwater conditions. Seven of the participants were aware that multiple tile drains ran in a general west to east direction through Opportunity. Among these individuals, some mentioned their familiarity with the idea that "the drain tiles are what kept our water good." One individual elaborated that the tiles prevented the plume from "moving into Opportunity." Although the proposed role that the drain tiles may play was known to these residents, a few expressed doubt and/or uncertainty about the explanation. Jill couldn't recall what had been said about how the drain tiles played this role. For other participants the explanation "doesn't quite hold water." These individuals explained that it didn't conceptually fit with other information they had received. For instance, Gary talked about the low arsenic level in one of the tiles and exclaimed "Well, how's *that* work? It doesn't make sense."

On the whole, commentary from the groups indicated that a more detailed and accessible explanation of the drain tile explanation was desired. None of the participants offered to describe exactly how the drain tiles might be affecting the movement of water and arsenic, which indicates that prior efforts to communicate this theory were not effective. Based on their comments, it is clear that residents are attempting to evaluate the validity of the theory by applying knowledge they have about local conditions. A more accessible and comprehensive presentation of how drain tiles affect groundwater flow and, therefore, the pattern of groundwater contamination would enable residents to more fully participate in evaluating the drain tile concept by applying their local knowledge.

Source and location of high arsenic levels

Locating arsenic within the landscape is integral to forming ideas about where risks to arsenic exposure may occur. Six of the protocol questions (#s 7 – 12) asked about arsenic sources, movement and behavior. In response to these, participant comments revealed which areas and materials were of specific concern to residents, and which were unfamiliar. Individuals mentioned several materials as the origin of arsenic in the area. Over half of the individuals, when asked where the arsenic contamination came from identified smelter dust as the primary source of arsenic in the area. No one mentioned “tailings”, but residents did express concern over “the yellow crap” and “white, blue, (and) yellow” stuff in Yellow Ditch and along Silver Bow Creek and the Clark Fork River. Half of the participants also discussed cinders and slag from the smelter as arsenic laden materials that have been distributed throughout the area. Earl also mentions “ore dust” swept out of train cars and large plastic “molly bags plum full of arsenic”[1]

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[1] It is unclear if he is referencing any waste sources identified through Superfund investigations. Large amounts of smelter dust (primarily arsenic) were stored in the Smelter Hill area, but I did not find any reference to large bags of arsenic distributed in the area (US EPA, 1998).

that he suspects may be buried somewhere. One resident pointed out that arsenic is a "natural occurring substance in just about every soil there is [but] when you concentrate it, then you're in trouble."

The contamination associated with these materials has been distributed about the landscape. I asked residents, with the assistance of an area map, to identify places with high levels of arsenic in soil, surface water or groundwater. A few residents talked about contamination occurring in a larger pattern, such as when Jill said "They didn't understand why the water was bad all around us, but not in Opportunity." Another resident, when asked where contamination was, drew a large circle around Opportunity and said, "I'll say the contamination is about right here."

Most participants tended to mention specific properties or isolated spots where contamination was found rather than continuous areas or bodies of water. Several participants mentioned domestic and monitoring wells with high arsenic levels in water to the north, south, west, and within Opportunity. One individual was an exception to this, mentioning the groundwater plume to the southwest and specifying that high arsenic levels are found down to six feet in this water.

Participants also talked about contaminated soil in a small area north of town, and in the Willow Glen Ranch area southwest of town. When discussing Willow Glen Ranch, which is a property located within the arsenic plume to the southwest, residents associated the soil contamination with historic deposition of mining materials along the railway line in that area. They also expressed concern about the soil in the Yellow Ditch, a ditch to the west of town that runs in a northerly direction and was used to carry ore processing wastewater (see Figure 2-3). Within town, several participants also discussed the driveways and paths constructed out of ore-processing waste as locations high in arsenic. Two residents expressed concern over arsenic levels in residential soils located within Opportunity.

Few individuals identified Mill Creek or Willow Creek when asked if any streams were contaminated. One individual talked about a surface water pond in the Willow Glen Ranch as a high arsenic area. Two residents discussed the Clark Fork River, Warm Springs Creek and Silver Bow Creek as contaminated surface streams. Notably, these streams do not run through Opportunity. Two other participants explained that Mill Creek and the irrigation waters connected to it have high arsenic levels they are "leery of." Although Tim had mentioned earlier that he had concern over irrigation water entering his well, when asked if Mill Creek was contaminated he replied, "No, never heard it. Never said it."

Overall residents seemed to be unaware of some contaminated areas that are discussed in Superfund documents as possible arsenic sources and threats to the Opportunity area (see chapter 3). This included Mill Creek, Willow Creek, Brundy Creek, tile drains to the south of town and soil dispersed throughout Opportunity and the surrounding area. This assessment is supported by the affirmative response I obtained when asking "You feel like you haven't gotten a good picture from them (EPA) about where the contamination is?" and restating, "It sounds like they haven't really put it (information about the location of arsenic) together to show you what you need to see." As basic information, the locations of known contaminated areas was already slated for at least a brief inclusion in materials, but these omissions in focus group discussion augmented the degree of detail I included. Additionally, developed materials attempted to portray the distribution of high arsenic levels because most residents talked about high arsenic materials more as an assortment of contaminated locations than as a pattern of contamination throughout the area. Since most residents associated contaminated areas with particular properties or landscape features, it would be helpful to include some local landmarks, such as highways and nearby towns, for individuals to locate their own water source in the contamination pattern.

Movement of arsenic through the landscape and groundwater

In order to make sense of and evaluate threats to wells from arsenic, residents need information about the ways it can move through the landscape and end up in their well. The previous section described what was gleaned about resident views on the location of high arsenic areas. Another goal of the focus groups was to get a better sense of how residents conceive of arsenic moving around the local area and potentially posing threats to the groundwater feeding their domestic wells. Four of the protocol questions (#s 8 –11) asked about arsenic behavior and movement. The majority of responses addressing this topic occurred in response to those questions, but also came up when discussing the location of arsenic.

Most residents expressed concern about arsenic being mobilized from soil into groundwater. This was commonly explained as water pooling and “leaching down” through soil laden with contaminants. As one individual put it when talking about Yellow Ditch, “That doesn’t look too healthy…and it’s supposed to be dried up. But, who knows? When it rains, when it snows, how far it leaches back down?” There was, however, one resident who wasn’t so sure if soil arsenic would enter groundwater: “is it soluble…Does it just cling to the dirt wherever it’s at?”

Several residents also mentioned arsenic contamination entering groundwater via the transport of contaminated surface water. Gary and Steve portrayed this as happening in two ways: by seepage of water into the tops of wells when submerged by contaminated water during flood irrigation and by infiltration of water through irrigation ditch channels. In the larger group, Tim also expressed concern about water in these ditches possibly entering his well through the groundwater system, but wasn't sure how it would get from the ditch to his well.

Movement of contaminated groundwater was also brought up as a way that arsenic could threaten domestic wells. Half of the interviewed individuals (Steve, Gary, Tim, Maude and Earl), when directly asked with the assistance of a map, said they were concerned with contamination in the plume area moving into town wells. Earl referred to this as the "big, bad, stream coming from the west." Other comments also referred more generally to the threat of contaminated groundwater moving into Opportunity. However, these did not specify the identified plume as the origin of that contamination, but rather some unknown and unreported mass of contaminated water that is somewhere in the ground as a result of water moving down through contaminated soil for many years. As Earl explains, he's heard from "fellows who might know something…(that) that water's still there."

On a finer scale, in terms of movement of arsenic, it was clear from statements mentioned above that participants believed that arsenic could move from soil into water. When asked specifically if arsenic could ever be naturally removed from the water, only a few residents entertained various ideas about such a process. The most common idea was that it may somehow get "filtered" out. Dwayne, when responding to what another individual described as a "spotty" contamination pattern, suggested, "Clay especially would keep it up above. But gravel it might go right through and sand would filter it. I think it's the soil composition that works as a filter…" Another individual wondered, "Does the aquifer flow like the river at all? (Because) if it did, it'd be filtered out." One individual in the smaller group felt that "once the arsenic's there, it's there forever", but clarified that "there's different states it can be in, though." These comments suggested that residents might have difficulty conceptualizing of dissolved arsenic since filtering is a process that would affect suspended particles. Although one resident did ask “Is it soluble?”, he later asserted that it could be filtered.

In their discussions, residents did touch on many of the pathways and mechanisms of arsenic transport studied at the Superfund site. For example, saturation of contaminated soil, introduction of arsenic-laden water through flood irrigation, the infiltration of arsenic-laden water through leaky channels, submersion of well heads during flooding and movement of contaminated groundwater downgradient in the aquifer have all been assessed as potential pathways for arsenic to move into domestic well areas. It is clear, however, that residents are generally uncertain about the validity of some of these ideas. There was also a general lack of commentary and some potential confusion about arsenic movement on a smaller, atomic/molecular scale. Materials addressed this by discussing arsenic behavior and movement at smaller scales. Specifically, they addressed processes such as attenuation and discussed arsenic as part of suspended particles and dissolved substances.

Additional topics

Residents commented on other topics not specifically addressed by protocol questions. I offered an opportunity for this to happen by asking if residents had any other concerns or issues they would like to learn more about. Residents expressed a desire for information regarding arsenic health effects and arsenic cleanup levels.

Because my expertise positioned me to primarily contribute to the local discourse on hydrogeological issues related to groundwater contamination, none of the focus group questions addressed arsenic health issues. Of course, arsenic would be of little or no concern if it did not affect residents’ health and, naturally, it came up in discussion. Several residents mentioned directly seeing the effects that arsenic had on individuals or hearing about specific cases of illness in the area that were attributed to arsenic exposure. Most dramatically, one person who worked in the smelter years ago talked about seeing “guys who had their noses eaten out.” Two cases of terminal arsenic poisoning were mentioned. Most participants made comments showing that exposure to arsenic is viewed as a health risk, but there was no consensus about how much of a concern it was or what all the possible effects were. In one exchange, this understanding of arsenic as a dangerous, and possibly deadly, but somewhat mysterious toxin is illumined:

Jill: I don’t really know what arsenic does to you.

Bonny: It kills you.

Jill: …This lady come into the store…they said ‘She’s dying.’ And I said ‘Well, what’s *wrong* with her?’ No one could tell me. I don’t know.

Tim: Is her liver shot or is it her kidneys? What does it do?

Two individuals described arsenic as affecting skin tissue. Two residents also described it as a carcinogen. Steve and Gary both expressed that they are particularly concerned about the affect it may have on young children. Steve expounded on this, explaining that he wonders if it is linked to Attention Deficit Disorder and that it “affects them in the growing age…and the mothers…that’s the time the stuff can really hurt.” On the other hand, Earl talked about knowing two men who were chronically exposed to large amounts of arsenic at work and lived into their nineties. He concluded, “So I don’t know, how poisonous *is it*?”

It is not surprising that residents express uncertainty about what sort of health risk arsenic poses. While it is classified as a carcinogen, the toxicity and health effects of arsenic are debated amongst the medical community (Smith, Bates, Lopipero & Steinmaus, 2002) themselves. Even though there may not be a consensus among the medical community, additional information was provided to residents about known health effects and paths of exposure, including information about what body systems and symptoms are related to arsenic exposure. I also determined to provide contact information for resources that may be able to answer questions about arsenic health effects.

Based on comments from a few participants, some information about the current cleanup level goals for arsenic and the basis for these levels was included in the developed materials. One resident directly asked about the “maximum containment level” and the “regulatory limit”, which she understood as being “10 ppb” and “0.018” respectively. It was clear that she was referring to the EPA established MCL of 10 ppb that replaced the Montana standard of 18 ppb as the drinking water arsenic limit at the site. Her question pointed out a few aspects of the cleanup goal that would be important to share with residents: first of all, that 10 ppb and 0.010 mg/l are equivalent measurements (both are commonly used in reference to the arsenic limit); second, that the original cleanup goal was based on a Montana water standard of 18 ppb, but that this water standard had been changed to 10 ppb in 2001 and this was now the applicable standard for the cleanup; also, that this change may be the reason they see both levels referred to in Superfund related literature; and lastly, that a host of different terms (MCL, RAG, Montana human health standard) may be used to talk about this 10 ppb limit. A brief explanation for the arsenic levels being used at the site was necessary.

Two residents used the presence of fish in surface waters as a proxy for low levels of toxins. As one of these individuals put it, “…there’s fish in that creek…so it isn’t deadly at all.” The cleanup goals for streams that support aquatic life are at much higher arsenic levels than those for waters used for human consumption since fish are far less sensitive to arsenic than humans. These comments suggested that a discussion of the different cleanup goals would be important for residents to make sense of the cleanup activities in their environment.

Conclusion

The focus group interviews were helpful for adjusting my ideas about which topics and information should be included in order to respond to the needs and concerns of Opportunity residents. Some of the results reinforced my preliminary ideas about which concepts would be necessary to discuss in order to address the lack of competencies that residents may have concerning groundwater contamination. For example, results suggested that residents did not have well-developed ideas of surface and groundwater connections. Results also pointed out that many residents are familiar with certain aspects of the local groundwater context, such as the general direction of groundwater flow to the northeast and the location of drain tiles. Generally, the interviews affirmed that this project fills a gap and would address concerns and questions of Opportunity residents.

While helpful, my understanding of residents' comments would have been further developed by post-focus group phone calls. The use of an observer may have helped illuminate group dynamics which affected participation and which I did not notice in my review of audio and video recordings. I also believe that a question in the background questionnaire about residents' previous attempts at obtaining groundwater contamination-related information would have been informative for the project. Knowing which resources of information residents have used (meetings, websites, etc.) would provide an additional opportunity to assess what has been effective and ineffective.

5. THE PUBLIC PRESENTATION

The purpose of the presentation was to provide preliminary information to be included in the booklet to an audience in Opportunity and to receive feedback from residents. This feedback provided a way to incorporate resident views into choices on the content and design of the final booklet. I chose a presentation and feedback format because it provided a setting in which residents could comment on what was useful and relevant without feeling that they were being tested on their knowledge or understanding. The content and design of the presentation represents an integration of relevant literature, ARWWS site documents and the focus group results described in previous chapters.

This chapter begins by describing my preparation of the presentation. This first section discusses the presentation structure, the materials I developed (including a tool for collecting feedback), additional insights from literature that applied specifically to this step of the larger project, and, finally, my recruitment strategy. The next major section, "Description of Presentation Content", describes what I included in the presentation and provides brief explanations for the reason certain content was included. "Presentation Results" discusses how the presentation was delivered and participant response to it, including feedback data collected. A short "Conclusion" section provides reflection on the success of the presentation in fulfilling its purpose.

Planning the Presentation

I initially conceived of this stage in the project as more of an interactive workshop, but, after creating a preliminary draft, this format did not seem feasible given the amount of material to be covered. The presentation consisted of a set of discussion topics accompanied by a total of 80 slides and was designed to last for two hours (see presentation outline, Appendix H, and presentation slides, Appendix J). A number of the slides simply announced different parts or sections of the presentation. Many of the slides contained images found in Superfund site reports and documents. The presentation contained ten topical parts, divided into three sections of approximately 30 – 35 minutes. Intervals of five to ten minutes divided these sections, allowing a designated time for feedback, questions, and for residents to take breaks. Slides announced the end of each section, invited questions and reminded attendees to fill out the appropriate section of a feedback form that I developed for the presentation. I also prepared a handout for participants that listed sources for obtaining information not covered by the presentation.

The “Groundwater Presentation Feedback Form” (Appendix I) was designed to obtain feedback from participants. Its format was based on previous feedback forms given to residents by Silberberger and others (2006). The questions on the form assessed how well content in each of the sections of the workshop fulfilled their purpose, communicated information and addressed resident concerns. The form posed up to seven questions for each section.

Influences on presentation design

In forming content for the presentation I used insights that literature provided for generally communicating about groundwater, as discussed in Chapter 3. For example, the presentation limited the use of scientific language, relying more on visual representations and less technical descriptors. It only used and defined a few technical terms, such as “water table” and “aquifer” that are basic to and common enough in discussion of the ARWWS site to warrant specific attention. Other technical terms were either avoided completely or accompanied by alternate descriptors in more common language. For example, “non-point source”, a term familiar to less than 20% of the general population (Coyle, 2005), was also referred to as “dispersed over a large area.”

The presentation also attempted to present scientific information in the context of peoples' daily experiences by anchoring discussion of various concepts in residents' experiences with domestic wells. Because domestic wells provide a window, physical and conceptual, for residents into the local groundwater system, the presentation intentionally began at the scale in which this window is wrought: the sediments through which a well passes through and draws water from. From here the presentation moved into larger, smaller and, ultimately, more abstract scales, always referring back to some tangible or familiar aspect of the water system around them. I also included what may be familiar examples when discussing other topics such as types of pollution (see slide 60 in Appendix J) or substances often found in water (see slide 55 in Appendix J).

The development and use of images in the presentation deserves some brief discussion. While the use of simple, accurate, cross-sectional imagery and maps throughout the project was influenced by literature discussed earlier (p. 54), additional literature provided insight specifically for the medium of a verbally delivered slide presentation and is described here. The presentation included a large amount of slides (over 80) within two hours. However, this number was manageable due to the way they were designed and used. Observations and recommendations offered in a workshop by consultants to the National Science Foundation (May 16, 2012), informed the design and use of slides. Studies of human perception show that 83% of the information taken in by presentation audiences is visual. Additionally, the human brain retains little information when reading and listening to language at the same time. For this reason, I relied heavily on visuals that contained very little text to communicate information and concepts. They mostly fulfilled a "supplemental" purpose by illustrating concepts and aspects of the discussion difficult to relay verbally, thereby simplifying explanations and reducing the time spent on topics. They also provided emphasis for and deepened the meaning of verbal content, thereby "reinforcing" it. The slides also incorporated the suggestion to develop complex images in stages for audience comprehension. Many of the slides were actually repetitions of the same visual with a slightly different emphasis and text. The repetition of these images created a type of visual vocabulary for the presentation. (NSF, 2012)

As Gunckel and colleagues (2012) mention, literature on developing scientific understandings of groundwater suggest that the use of physical models is helpful for communicating concepts. I initially planned on including some physical models of groundwater system aspects into the presentation. However, based on my former experience[2] delivering scientific content in group settings, I determined that using such models was not practical given time constraints. The presentation did, however, take advantage of incorporating animations into projected slides. Through these I was able to visually represent movement when addressing such concepts as water table movement (see slide 47 in Appendix J) or movement of contaminants through an aquifer (slides 60 and 61 in Appendix J).

In preparation, I delivered the presentation to several adult non-experts. I made a few minor alterations and clarifications based on their feedback.

Recruiting for the presentation

I recruited participants in several ways. I mailed out an invitation letter and a total of 65 handbills to all participants in the focus group and to other residents on the initial focus group contact list (p. 59). This mailing went out approximately two weeks prior to the event. Each mailing included extra announcements and a request to share these with any neighbors, friends or

[2] I have several years of experience in programs that delivered scientific content to non-expert audiences. This includes over three years of work running and delivering programs which served individuals from elementary to college age and covered topics of basic physics, astronomy, biology and botany. Most recently, I volunteered with the Clark Fork Watershed Education Project in spring of 2012 to deliver content about the Clark Fork Superfund complex to local Missoula middle schools.

coworkers who may be interested. Two members of OCPA distributed 20 additional fliers. In the week preceding the presentation, I contacted the households from the mailing list to confirm receipt of materials and to inquire about their planned attendance at the presentation. Five individuals affirmed their attendance, three individuals declined to attend, one individual was tentative and the remaining individuals could not be directly contacted. Phone messages were left at these numbers. In addition, I arranged for a flier to be displayed at the local grocery store two weeks prior to the event. Advertisements for the presentation also ran in the *Anaconda Leader* newspaper on the preceding Wednesday and Friday.

Description of Presentation Content

The final presentation consisted of ten parts as follows:

1. Introduction: an orientation to the larger project and myself; an overview of what the presentation would cover; and an explanation of what would not be included and why.
2. Overview of arsenic in the Opportunity area: what is arsenic; where is arsenic generally found in the environment; health effects; regulatory limits; and a summary of arsenic levels in Opportunity area soils, surface water and groundwater.
3. What makes an aquifer?: where groundwater is found, defining the word "aquifer", and the effect of different ground materials on where aquifers are found in the groundwater system.
4. Groundwater and aquifers in the Opportunity area: the general distribution of ground materials (clay, gravel, sand, rock) in this basin fill system, the location of the local water table, the effect of the system's structure on the location of wells/aquifers in the Opportunity area.

5. Where groundwater comes from and goes: groundwater inputs, water movement between surface features and groundwater, and variation in groundwater levels due to seasonal changes and irrigation.
6. Tools that tell us what groundwater is doing: monitoring wells, water table elevations and lateral movement, nested wells, water chemistry and how it can be used, streamflow measurements showing interaction between streams and groundwater.
7. Contamination in aquifers: typical sources, types of sources and patterns of contamination, and what can happen to contaminants in the landscape.
8. Arsenic as a local groundwater contaminant: characteristics and forms of arsenic, current explanations for the existence and behavior of the nearby groundwater plume, current explanations for the pattern of arsenic contamination found in Opportunity, and pathways for arsenic to enter domestic wells.
9. Update: cleanup and monitoring: planned soil removal activities, what a TI waiver is and what areas/resources are receiving one, and the well monitoring plan
10. Wrap-up: next steps in this project, time for additional questions and comments, departing reminders; and thank you.

The following sections describe the purpose of each part and elaborate on some of the major content and design considerations for each part.

1. Presentation introduction (slides 1 – 13)

This part provided the audience with an orientation to the content and purpose of the presentation. A brief introduction of the larger project and myself was necessary since attendees included individuals who had not participated in the focus group. It was important to explain that the purpose of the project was to specifically address residents' knowledge needs and concerns regarding groundwater science in the area. This information helped explain why their experience of and feedback on the presentation were integral parts of the event.

2. Overview of arsenic in the Opportunity area (slides 14 – 28)

The purpose of this part was to provide contextual information about arsenic and the regulatory setting. Establishing that arsenic exposure has consequences for the health of residents and is a concern in the area provided incentive for participants to engage with the material presented. This included information about the origins of arsenic in the natural landscape and the two basic forms (organic and inorganic) in which it occurs. This distinction was useful because "inorganic" forms are the focus of remediation and would be discussed later. In order to set context for residents about the local magnitude of contamination levels, this part discussed typical background levels of arsenic found in soils and waters of Montana in addition to its prevalence in mined ores. Information about arsenic health effects and regulatory limits used to guide remediation at the site addressed questions and concerns brought up in focus group interviews (see Chapter 4, pp. 81, 82).

A summary of the arsenic concentrations in local soils, surface water and groundwater reported in Superfund related documents rounded out this part. In response to focus group results (pp. 75-77) this discussion used images that showed the range of contamination levels in general areas as well as the location and magnitude of particularly high test results in an effort to put isolated instances of arsenic exceedances into a landscape perspective (slide 23).

3. What makes an aquifer? (slides 29 – 33)

The goal of this part was to provide information about the structure of groundwater systems that would assist residents in conceptualizing the spatial occurrence of the water table, groundwater, and aquifers. This discussion was anchored in a distinction between the words "groundwater" and "aquifer." The focus group had suggested that most residents interface with the groundwater system through their well, and, therefore, through their experience with the local aquifers. As discussed, resident comments suggested that equating aquifer location with groundwater occurrence caused some dissonance in reasoning about the structure and behavior of water in the ground (see pp. 68, 69).

This part explained groundwater occurrence at a small scale that residents might relate to and be able to build more accurate scientific ideas on. Discussion and slides showed that groundwater saturates the pore spaces between all sediments below the water table. To show how the type of subsurface material affects the occurrence and movement of water in the ground, I developed very simple diagrams illustrating the comparative volume of water held by different materials (clay, sand, gravel), speed of water through these materials and water yields typical of them (slides 22, 23). Simple animation of these images reinforced statements about movement and comparative yield. Throughout the presentation, the words "ground", "water" and "aquifer" were very carefully and consistently used to reinforce the interaction and distinction between different parts of the groundwater system. This small-scale concept of how subsurface materials affect groundwater and aquifer occurrence was built upon in the next part.

4. Groundwater and aquifers in the Opportunity area (slides 34 - 39)

This part formally introduced the term "water table" and presented information about the larger structure of the local groundwater system. The goal of this part was to extend the idea that subsurface material distribution affects groundwater and aquifer occurrence to a larger landscape scale in which residents could conceptually place their own wells and think about movement of groundwater. As discussed earlier, the geology of the Deer Lodge Valley includes many layers of sedimentary material with varying porosity, resulting in a complex groundwater system (p. 22).

The sporadic nature of the location of aquifers in such a system fits easily into a perception of groundwater as occurring in isolated bodies or streams, a concept expressed in focus group interviews and noted as a common misunderstanding in educational literature (pp. 66, 67; Covitt et al., 2009).

The discussion of the local groundwater system relied heavily on the use of cross-sectional images of Deer Lodge Valley geology in the Opportunity area (Smith, 2009). It began by showing the distribution of subsurface materials and noting the location of fine clay-like sediments versus more coarse and gravelly sediments (slide 35). Building on the previous part, water was then visually introduced into this setting, showing the location of the regional "water table" underneath which all pore spaces are saturated (slide 36). An actual well drilling log for the area then provided an entry point for applying the previous part's discussion about aquifers to a larger scale (slide 38). It showed that, although a connected body of groundwater may saturate all materials, wells might draw water from aquifers existing far beneath the water table depending on the distribution of those materials. This example was followed by a cross-sectional illustration of the possible variation in well levels that may result from a system similar to that underneath Opportunity, in which wells are not fed by streams or isolated lakes, but from different water-yielding materials within a connected groundwater body (slide 39).

5. Where groundwater comes from and goes (slides 40 - 48)

Parts three and four established the physical setting for the movement of groundwater. The purpose of the fifth part was to show the multiple ways water moves between the land surface and the groundwater system. As discussed in chapter two, the movement of arsenic into and through the groundwater system is affected by how water flows between surface features (including streams and ditches) and the groundwater system. Familiarity with the ways water can move between surface and subsurface features is, then, important for residents to understand and interpret information they receive about arsenic threats to their domestic wells and to evaluate monitoring and cleanup activities. This comports with statements made in the reviewed literature (p. 50). Focus group results indicated that Opportunity residents might have difficulty conceptualizing these connections (pp. 72-74). This part discussed all of the connections noted as influential to arsenic and groundwater movement in the Opportunity area (pp. 25).

I also included discussion of seasonal water table variations in this part for two reasons: firstly, because of assertions that high water table periods are linked to high arsenic content in the plume to the southwest (p. 29); secondly, it provided a way to discuss the effects of surface and groundwater connections through a phenomenon observed by residents (p. 73). Another important aspect of this part, included as subtext, was constant reference to groundwater motion. This was built upon later in the presentation.

Cross-sectional diagrams accompanied all topics covered in this part. It began by briefly discussing the ultimate origin of groundwater, infiltration of precipitation (slide 40). The idea of infiltration through the soil would be important in discussions of contaminant mobilization later on. The presentation then addressed surface water and groundwater connections including: gaining (or effluent) streams and lakes (slide 43); springs (slide 44); wetlands (slide 45); and losing (or influent) streams (slide 46). Images of a cross-sectional diagram and map of the Opportunity area indicating the locations of these connections in the local landscape accompanied discussion of each. This part concluded by discussing the seasonal variation in water table levels. I produced a simple, animated cross-sectional diagram to show fluctuations in the water table (slide 47).

6. Tools that tell us what groundwater is doing (slides 50 - 58)

This part served two purposes: to demystify the process by which experts make statements about groundwater movement in the local aquifer system, and to show what tools, techniques and data interpretations have been used to make statements about groundwater conditions in the Opportunity area. As Steve mentioned during an interview, “They got the experts out there doing stuff…So you got to basically go with what they say, cause I don’t know how to do it” (p. 9). While it is unreasonable to expect residents to attain the same degree of technological understanding that trained hydrogeologists have of groundwater concepts and exploration techniques, it is a disservice to not offer some information about the bases for conclusions and offer that information in a way that is considerate of lay people’s familiarity with groundwater science.

Building resident knowledge about which data gathering methods and tools have been used can enable residents to direct their inquiries and requests about well water quality. If residents want more information about their aquifer, they need to know what kind of information they can ask for from the “experts.” For example, if residents are concerned about water flowing through an irrigation ditch potentially contaminating their private well, they could ask if streamflow readings have been collected for the reach near their home and what they indicated about flow between the stream and groundwater system.

This part described four tools commonly used to study groundwater at the ARWWS site (ARCO, 1996; CDM, 2009a, b, c, d; Coover, 2010; Myers, 2007; Pioneer, 2006a,b; USEPA, 20011b): water table wells, nested wells (a cluster of wells installed at different depths), water chemistry tests, and streamflow measurements. In each case, I discussed what sort of data the tool collected and how that information has been used to make statements about groundwater in the Opportunity area.

I first included discussion of water table wells. Based on comments made in focus group discussions (p. 71), I decided to use a cross-sectional image showing the spatial relationship between the ground surface and well level (slide 51) to aid my explanation. The presentation showed how a network of these wells can and has been used to obtain a set of water table readings in the Opportunity area (slide 52). I then shared a water table map based on these data (slide 53). This image showed the general groundwater movement indicated by the map. I expected that this would draw a connection between observable phenomena (water table levels) and landscape scale movement of groundwater. Because they are a similar tool used to assess vertical, rather than lateral, movement of groundwater, I also included brief information about nested wells. However, I only discussed the physical set-up of a nested well installation and what situations this tool is helpful in because sufficient background information on interpreting three-dimensional flow from nested well readings requires considerable time.[3]

Water chemistry analysis, another tool used to make statements about large-scale groundwater movement, was the next topic. Water chemistry is a far more abstract aspect of the local groundwater system and I took special care to use non-expert language and images that might be familiar. I also framed the topic in terms of the physical constituents that affect water quality (slide 55). The presentation centered around: constituents that play major roles in water chemistry (e.g., salts, elements like iron, bicarbonates, bacteria), what influences the presence and amount of these constituents in water (e.g., rain/snow chemistry, rocks and soil, time, temperature), and what sorts of water analyses measurements are influenced by these constituents (pH/acidity, hardness, dissolved solids etc.) (slide 56). I then discussed, while

[3] As a former student of hydrogeology, this is something I am familiar with.

showing a common graphical tool used to represent a set of basic water chemistry measurements, how this suite of measurements is often used to identify types of groundwater and make statements about the source and flow of groundwater (slide 56). A map of Opportunity identifying the areas of differing groundwater chemistry between Mill Creek area groundwater and Willow Creek area groundwater showed how this tool has been used to make statements about the source of water to domestic wells (slide 57). Important to note is that this part also introduced information about the chemical makeup of water that would be relevant for talking about arsenic behavior and movement in part eight.

The end of this part explained how streamflow measurements provide data about connections between surface and subsurface flows. Simple diagrams illustrated how measured water quantities in streams could be used to make inferences about the location of losing and gaining stream reaches. The slide also included cross-sectional diagrams used earlier. Examples of losing and gaining streams were mentioned again to point out that streamflow measurements provided the data for making statements about those local groundwater connections.

7. Contamination in aquifers (slides 59 - 65)

The essential context for understanding arsenic contamination was now set. The goal of part seven was to support the ability of residents to understand and respond to explanations for arsenic movement through their local environment by providing information about the movement of contaminants through groundwater systems. Acknowledging observations made in literature (Covitt et al., 2009), it discussed this movement on a large landscape scale as well as on a molecular scale. As noted in the focus group results, residents expressed a relatively complete understanding of the types of arsenic sources in the area (p. 75-77), but comments suggested that conceptualizations of movement might be undeveloped or incomplete (p. 78-80).

Within the SOAOC, identified sources of arsenic to groundwater include line sources, such as Mill Creek (p. 26), and non-point sources, such as widespread smelter dust deposition southwest of town (p. 29). Some of these sources are generally continuous, such as contaminated soils and Mill Creek, which contain arsenic and are present year-round. Some local sources, such as irrigation ditches that only flow for part of the year, share characteristics with one-time contaminant sources (p. 26). While these large-scale concepts play roles in explanations, small-scale behavior of arsenic is also used to explain how arsenic enters and moves through the groundwater system that feeds domestic wells (p. 29). In particular, explanations of "natural attenuation" involve concepts of the molecular behavior of arsenic.

This part opened by focusing on large, landscape scale groundwater contamination sources and patterns. Using simple animated diagrams and examples that may be familiar to residents, such as septic tanks, cow fields and the Alberton train wreck, the slides discussed point, non-point, continuous, and one-time sources, focusing on the patterns of contamination these types of sources would result in (slides 60, 61). The bulk of this part then covered the possible molecular behavior of a contaminant in the groundwater system, including processes that would result in natural attenuation. These included: dispersion (i.e., dilution), decomposition, chemical incorporation into other substances (suspended and dissolved), adsorption (i.e., attachment to sediments or soil), and uptake by life forms (slides 62 - 65). Because it is not relevant to arsenic, only brief mention that some contaminants maintain their initial form and either sink or float in the water system was made. I developed symbolic and somewhat naïve animated portrayals to illustrate each of these possibilities (slide 62). To encourage comparison between the different possibilities, the visuals used consistent imagery to represent contaminants, the movement of groundwater, and constituents found in the groundwater system. This was especially important because a discussion and portrayal of the multiple molecular paths that arsenic may take within the same groundwater system, and, therefore, where it may end up in that system (e.g., attached to sediments, dispersed in the water, etc.), concluded this part (slide 65).

8. Arsenic as a local groundwater contaminant (slides 67 - 74)

The purpose of this section was to communicate, based on the explanations available through Superfund site studies and documents, what the most current EPA understanding is of the arsenic risks that exist for Opportunity domestic wells and the residents who rely on them. It was also an attempt to illustrate how scientific concepts had been applied in official interpretations that drove decisions about the remediation. The degree of risk posed to resident health through drinking water depends on the amount of arsenic found in toxic forms and available through wells. As discussed earlier in the Superfund Context chapter, studies have examined several possible sources of arsenic to domestic wells in Opportunity and determined that the contaminated arsenic plume to the southwest and Mill Creek, along with associated irrigation ditches, are of most concern to the Opportunity area (pp. 26-29). Explanations for how these arsenic sources interact with the aquifer feeding Opportunity wells rely on varying types of data and analysis. This part described what studies say about the likelihood of these sources adding arsenic to Opportunity wells. It also applied the information and concepts discussed in earlier parts of the presentation by showing how they are being used to support these statements.

A discussion of the various forms of arsenic, their relative toxicity, and where they may be found (e.g., dissolved, suspended as particulate, attached to sediments in the aquifer system) began this part (slides 67, 68). The prime goal was to show that, as an element, arsenic cannot be removed from the system through decomposition, but can repeatedly change chemical structure, varying in toxicity, mobility, and location depending on conditions in the aquifer. The aspects of the groundwater system discussed as influential on arsenic and the images used to aid this discussion were previously introduced in the general discussion of water chemistry.

This part then progressed into a discussion of explanations accepted by the EPA for the pattern of contamination associated with the groundwater plume and Mill Creek surface waters. Throughout the discussion, I did not endorse or critique these interpretations, but simply showed what they were based on. Before moving into this topic, it was necessary to set the scene by reviewing a map showing the location of contaminated surface and groundwater bodies that play pivotal roles in site interpretations, namely, the groundwater plume and contaminated surface streams (slide 69).

I first addressed the groundwater plume and the reasons given for why it is not considered a source of arsenic to wells in town. This included discussion of accepted ideas about the source and location of arsenic in the plume, the role of large groundwater influxes associated with the Mill Creek watershed, and the role of the tile drain system. In presenting information about the source of arsenic to the plume, I used animated visuals to illustrate the molecular pathways that are suspected of mobilizing arsenic into groundwater (slide 70). These were consistent with visuals used earlier in part seven. I then described how groundwater chemistry information has been used to claim that this plume is not threatening Opportunity wells because it is diluted by a large influx of water from the Mill Creek drainage area (slide 71). In concluding my discussion about the groundwater plume, I used a map of the tile drain system and cross-sectional image to discuss what has been said about how the drains affect the movement of arsenic through the local groundwater (slide 72).

Part eight concluded by discussing the explanation that losing streams (Mill Creek, Brundy Creek, and irrigation ditches) are the most likely source of domestic well contamination within Opportunity. A map showing the suspected location of losing streams within and near Opportunity, alongside diagrams shared earlier of this type of connection accompanied discussion of this interpretation (slide 73). The presentation explained that observations of contamination occurring in shallow wells near contaminated surface streams have been used to bolster the validity of this interpretation. To support a more developed understanding to help residents assess statements about contamination sources within Opportunity, this part concluded by discussing how and when contamination of wells would happen according to this explanation. A simple animated cross-sectional diagram of a subsurface environment similar to Opportunity illustrated the paths that arsenic might take into domestic wells if the local source of contamination did originate from infiltration of contaminated water in streams and irrigation ditches (slide 74). With this mental picture, residents would be able to evaluate whether information they received about contamination in town wells comported with the explanation given for how it was happening.

9. Update: cleanup and monitoring (slides 75 – 81)

The purpose of this final substantive part of the presentation was to fulfill possible resident needs for current information and provide residents with an understanding of what to expect from groundwater conditions and Superfund activities in the future. Based on my interaction with residents during the focus group, I anticipated that more information about the cleanup would be desired. This part focused on information about current cleanup and monitoring plans relevant to groundwater conditions in the Opportunity area. Since the presentation essentially started by asking "Where are we now?" it ended by asking, "Where are we going?" Information included the location of materials within the SOAOC slated for removal, details about adopted TI waivers, and aspects of the long-term groundwater monitoring plan for the Opportunity area

Maps showing the location of cleanup activities, TI waiver zones and groundwater monitoring wells accompanied this part (slides 76 - 81). Discussion of TI waivers included information about the justification used to employ this strategy at CERCLA sites, the standards waived by their use and their effect on future cleanup activities. Information about long-term well monitoring included the purpose and testing frequency for monitoring well types, what sorts of results would trigger a contingency plan and what sorts of actions might be taken under a contingency plan. These cleanup designations, removals and monitoring efforts represent the final stages of remediation and have lasting implications for the future safety of domestic wells in town.

10. Wrap-up

The presentation concluded by explaining the next steps of my project. I wanted to alert residents that a resource about groundwater contamination would be available in the future and that I planned on delivering comments about the informational needs and concerns of Opportunity residents to individuals working on the cleanup. The presentation design allowed more time for questions and the completion of evaluation forms. This part also reminded residents of the "more information" handout available to them. This handout, developed specifically for distribution at the presentation, listed sources for additional information on topics that may be of concern for residents, but were not thoroughly addressed during the presentation, such as health effects of arsenic.

<u>Presentation Results</u>

I delivered the presentation to 11 residents at the Opportunity Community Club on Saturday, October 13th from 1 to 3 pm. Three of the individuals had participated in focus group discussions. Unlike the focus group, attendees did not submit any demographic data because the intent was for participation to be as anonymous as possible. Neither did they receive any compensation. A visual survey indicated an even gender balance, but a skew towards older individuals. Each attendee was provided a presentation evaluation form and pen. In order to document the event, an assistant accompanied me to take photographs and make notes on any questions that residents posed during the presentation.

Each individual was provided with a feedback form and pen upon arrival. The presentation began approximately ten minutes later than planned. Before the presentation began, I invited participants to ask me questions if anything on the slide or in my discussion was unclear. I set out the structure of the presentation and explained that there would be time specifically allotted for any other questions the discussion brought up. By setting time points for the beginning and ending of each part, I was able to deliver all parts of the presentation within two hours and allow at least five minutes for discussion, feedback and break time between the three major sections.

Resident response

Residents appeared to have varying interest in the presentation. All but two individuals remained for the entire two hours. These two individuals left approximately ten minutes before the end of the presentation. I observed three individuals taking notes. Several members of OCPA attended. After the meeting they thanked me for the "helpful" presentation and expressed a wish that more residents had attended.

Several residents asked questions during the presentation. A couple of these questions were posed during discussion of topics and asked for clarification of what was shown on images. Other individuals posed questions before the presentation began or during breaks. Before the presentation began, one resident showed me a report of a well test conducted at their home and wanted to know "how it looked." This report listed the results of different water quality measurements, including arsenic levels. After examining it, I explained that the arsenic level readings fell below the cleanup level, but still showed the presence of arsenic in their well. I explained that this meant the EPA considered the water acceptable for drinking, but that, since arsenic levels can change over time, they may want to get tests done in the future. Another attendee wondered where information about water table fluctuation and arsenic included in the presentation originated. I told him which document it came from and how he may be able to obtain it. A third individual posed a question about the effect of adding material to the waste repository on groundwater flow. They had a concern that this addition of material would cause a constriction in the flow of water through the aquifer. We engaged in conversation about this and he went on to mention his concerns about the possible removal of trees in the area releasing soil-borne arsenic and allowing contaminated dust to blow into town.

Presentation Feedback

Disappointingly, I received only five evaluation forms. One of these was only partially filled out. Most questions on the form asked residents to rate the success of different aspects of the presentation on a scale from 1 to 5, with five indicating the highest degree of success (see Appendix I). Average scores for each question ranged from 3.6 to 4.75. The least successful parts of the presentation were the following:

- Has the presentation increased your understanding of where groundwater exists underneath Opportunity? Average score = 3.8
- Has the presentation increased your understanding of what a water table elevation map is and what it can show about groundwater in the area? Average score = 3.8
- Did this section increase your understanding of how different tools are used to explore what groundwater is doing? Average score = 3.8
- Did this section increase your understanding of arsenic as a groundwater contaminant? Average score = 3.6

Average scores for all other questions were at least four. Importantly, all respondents indicated that the presentation was helpful for understanding the safety of their well water (average = 4.75). Although the average rating for the presentation's success at addressing things residents wanted to know about groundwater in and around Opportunity was also high (4.4), one individual responded to this question with a low rating (2). Notably, this individual provided low scores for almost all questions.

The feedback form, in addition to these rating questions, also contained questions in each section requesting more substantive feedback about the effectiveness of visuals used. The completed forms contained few responses to these questions. Many of these comments indicated that all the images were "helpful" or "interesting." Only one slide was mentioned by more than one individual as helpful. This contained a map of known drain tile locations and a cross-sectional diagram illustrating the effect of drain tiles on the flow of groundwater. Only one respondent indicated which images were not helpful. They mentioned a slide including a tertiary water quality diagram. Such a diagram is a specialized and abstract graph used by hydrogeologists. I anticipated that this visual would be ill fit for a lay audience. Negative comments were useful because any developed materials would seek to avoid alienating residents. More comments were needed, however, to intimate which images should be included.

Conclusion

Although residents' participation and responses during the presentation were helpful, the general paucity of feedback about the presentation provided little guidance for developing the booklet. The major benefit of conducting the presentation was reaped from the process of putting together and composing a preliminary set of information and images that attempted to address the needs of Opportunity residents. Because I intended to obtain feedback about the presentation anonymously, I did not include the option to contact participants afterwards in my original IRB application, nor did I collect contact information to enable this. However, given the amount of feedback obtained, individual follow-up discussions over the phone or in person would have provided valuable additional feedback. Also, including a question on the feedback form that asked residents to rate their prior level of familiarity with the topics covered would have provided helpful context for interpreting responses.

A different approach for obtaining feedback from residents may have been more appropriate. Since my goal was to obtain feedback useful for constructing the written booklet, providing residents with preliminary written material, rather than an audio-visual presentation, would have provided feedback that spoke more directly to the format I planned on using. As a narrative medium that included animations, the presentation discussed groundwater information and concepts in ways not possible within the booklet. For example, I used animations to visually represent such concepts as a dropping water level or molecular scale movement of contaminants through an aquifer. Also, the printed pamphlet would not be large enough to accommodate all the presentation images.

Despite these considerations, the presentation did shape the booklet. Feedback provided some insight about which content and design choices to incorporate into the booklet. Positive feedback about cross-sectional images reinforced literature asserting that they are helpful for explaining groundwater concepts or structure. Negative feedback about other images reinforced my inclination to avoid abstract graphical representations. The lower scoring questions on the feedback form also led me to adjust the images and language with which I discussed groundwater occurrence and water table elevation maps. They also reinforced that discussion on an atomic/molecular level about the nature of arsenic would be one of the more challenging aspects of the booklet, requiring very concise and clear material that focused on the most relevant aspects of this contaminant. The questions and comments offered by residents during the presentation also reinforced my decision to include information about the 10 ppb arsenic limit and discuss groundwater system structure on the scale of sediments. Overall, it was instructive that there was little negative feedback about the presentation and that OCPA members found it helpful.

6. THE BOOKLET

The culmination of all the previous steps in this project is the "What's going on down there? A Citizen's Guide to Understanding Groundwater, Wells and Arsenic in the Opportunity Area" booklet (Appendix K). This booklet fulfills the project's end goal of responding to the needs and desires of Opportunity residents. By providing information that supports a better understanding of the current and future threats posed by arsenic to domestic wells, it addresses concerns about well safety repeatedly expressed by Opportunity residents. It also serves the larger environmental justice purpose of this project by reducing barriers to the meaningful participation of Opportunity residents in decisions affecting their environmental health. Offering contextual and educational information that supports the ability of residents to understand and use technical information about arsenic contamination of groundwater in the local area reduces these barriers. The booklet provides information about the local regulatory and hydrogeological context. It also supports the development of technical or scientific competencies by presenting and discussing relevant groundwater concepts. This information is important for understanding, assessing, and engaging with expert statements about groundwater contamination and the risk it poses to domestic wells.

This chapter describes how the booklet was produced, and the final content. The content section includes some brief discussion that elaborates on or clarifies how the literature review, focus group, and presentation influenced my decisions in instances where this may not be evident from previous chapters.

Creating the booklet

The booklet is a refinement of material in the presentation. As in the presentation, I applied relevant literature discussed earlier to communicate technical information about the

Opportunity groundwater setting to a lay audience. After reviewing the presentation and focus group results, I decided upon the general structure and content of the booklet. Before drafting the booklet, I consulted a graphic designer. This consultation provided information about topics such as adequate image resolution, appropriate text size and font, general printing costs, printable document characteristics, and working with printing contractors. This information was necessary for formatting the booklet.

General design

While covering the same general topics and using the same guidelines about communicating complex technical information to residents, the booklet reorganized and condensed or cut much of the presentation material. In some cases this action removed information peripheral to the relevant scientific literacies or competencies that the booklet intends to strengthen. The removed material included such things as details about different groundwater research tools (see Appendix J, slides 50 - 58) or very general information about groundwater contamination patterns (see Appendix J, slides 60, 61). In other cases, I reduced material due to considerations of space. The booklet contains 19 half-sized pages of actual technical content. After laying out a preliminary draft of the planned material, I determined that this length was enough to cover the essential material without being cost-prohibitive.

Booklet graphics

I used Adobe Photoshop and Microsoft Word software to create or modify a total of 20 images for the booklet. Outside sources provided 12 of these images. Map-based graphics are based on images from Superfund site documents and other local studies. Because these source images were from documents developed for technical experts, they required modification to show the desired information and portray it clearly to a lay audience. This included modifications such as extracting visual elements from complex maps containing irrelevant elements and few recognizable landscape features and placing those visual elements on simpler, more recognizable maps. Some informational graphics (Appendix K, p. 4) are slightly modified images from outside sources. Each image is attributed and source information for all images is included on the references page of the booklet.

I also created eight images after searching for illustrations of relevant groundwater concepts in various groundwater information sources available in print and online. I concluded that these images, for issues of clarity and relevance, should be specifically developed for the booklet. My design of these images was informed by my academic study of water sciences and by the various citizen-oriented educational materials I viewed during my search, such as those on the Colorado Foundation for Water Education website (http://www.cfwe.org). The images I created stressed simplicity, clarity and relevance. Some of the graphics created for the booklet were refined versions of those created for the presentation. In general, the booklet graphics each contain more visual information than individual graphics in the presentation. As mentioned earlier the presentation included 80 slides that were primarily graphic and incorporated animation. The booklet contains much fewer. Necessarily, images in the booklet communicate more information.

Content and Organization

As mentioned in the chapter introduction, the booklet fulfills two main goals of providing necessary context and supporting the development of technical or scientific competencies. Necessary context is given by providing information about the Superfund cleanup and analyses of groundwater contamination risks in the Opportunity area. The content supports development of competencies and literacies by explaining groundwater and contamination concepts relevant to Opportunity well water conditions and then discussing how these concepts have been applied to explain the local pattern of contamination. This content is divided into ten major headed sections in the booklet. The title and content of each booklet section are briefly described below.

1. Well water: information about a resource at risk (p. 1): a brief introduction explaining the purpose and content of the booklet.
2. The big picture: arsenic and the Anaconda Smelter Superfund site (pp. 2-3): background information on the site, how the site is organized, who is involved, why arsenic is a concern and what arsenic limits are informing work in the site.
3. Arsenic and Opportunity (pp. 4-5): ore processing wastes that introduce arsenic into the local environment; how arsenic contamination is distributed in area soils, surface waters and groundwater.
4. What do groundwater and aquifers look like? (pp. 6-8): groundwater occurrence, aquifer occurrence, types of aquifers, groundwater and aquifers of the Opportunity area.
5. Groundwater moves (pp. 8-9): how groundwater moves in landscapes and in the local area, and how groundwater movement can be determined.
6. Above and below: connections between the surface and groundwater (p. 10): how water in streams, wetlands and springs can be connected to groundwater.
7. Up and Down: water tables, well levels, and irrigation (pp. 10-11): seasonal movement of water table, effect of irrigation on water table, possible effects of water table change on flow of water above and below ground, correlation between water table levels and arsenic levels in groundwater plume.

8. Chemistry of a contaminant: arsenic (pp. 12-13): basic information about how arsenic commonly occurs on the environment, forms of arsenic, conditions that affect arsenic behavior, how arsenic may move in groundwater, how arsenic in groundwater may "naturally attenuate."
9. Sources of arsenic to Opportunity wells (pp. 14-17): discusses explanations given in Superfund documents. Covers the following topics: does the contaminated groundwater plume reach Opportunity, structure and function of the drain tile system and their inferred effects on local groundwater flow and contamination, streams as the source of arsenic contamination, protective steps available to residents, questions to help evaluate the official explanation.
10. What's going on with the cleanup? (pp. 18-19): planned material removal activities, what TI waivers are and where they are being used, planned monitoring activities, planned institutional controls.

The content, to address the two main goals, addresses three general topics in the booklet. Sections 1-3 and 10 focus mainly on contextual information about the Superfund site and groundwater contamination setting. Sections 4-8 focus on explaining groundwater and contamination concepts and the ways these concepts apply to the Opportunity area. Section 9 describes the EPA-accepted explanations for the pattern of groundwater contamination and shows how the discussed concepts have been applied to these explanations. The booklet also provides contact information for local individuals and institutions that may be able to provide services or answer further questions related to arsenic and well water contamination.

The order of content and the reasoning is also refined from the presentation. The initial three sections provide the context for the rest of the booklet. They illustrate how this material will address issues that affect residents of Opportunity. The next five sections (4-8) focus on addressing groundwater competency needs relevant to the Opportunity context while presenting more detailed hydrogeological information about the SOAOC. Based upon the work of Covitt and others (2009) these sections focus upon the structure and movement of groundwater before discussing more complex and abstract elements of arsenic movement through the area. The information and concepts in these sections is necessary for understanding the explanations for groundwater contamination detailed in section 9. All of these earlier sections frame the future cleanup plans discussed in section 10 within the local risk context.

Below, I provide a brief discussion of how material in each section was adapted from the presentation for the booklet and what influenced those decisions.

1. Well water: information about a resource at risk (p. 1)

This section makes a case for why issues of well safety and, therefore, groundwater conditions are relevant to Opportunity residents and explains how the booklet can help Opportunity residents better understand and assess what they hear about arsenic contamination of groundwater.

2. The big picture: arsenic and the Anaconda Smelter Superfund site (pp. 2-3)

This section provides information about the larger ARWWS site context. Earlier studies showed that most residents are unaware that cleanup activities are part of the Superfund program (p. 42). General information about how the Superfund site is structured, terminology commonly used, why the cleanup is being conducted, who is involved, why arsenic warrants a cleanup, and what goals exist for protecting residents from arsenic contamination is helpful for making sense of cleanup activities and communicating about them with local Superfund site experts. For example, residents must know they live within the "South Opportunity Area of Concern" to obtain relevant information from experts working on the larger site and to locate relevant documents available to the public through the Superfund document repository or Montana Bureau of Mines and Geology. Additionally, because the map used to show the structure of the ARWWS OU shows the location of Opportunity in relation to Smelter Hill and the Opportunity Ponds, it provides a useful spatial orientation to similar maps used in latter pages of the booklet.

As in the presentation, it is important to present information about the health risks of arsenic exposure early on in the booklet. This is necessary context as well as an argument for why residents should spend their time reading this information. Information included about arsenic limits used at the site provides important context and addresses confusion over arsenic limits expressed during the focus group (p. 82). For example, the booklet explains that the presence of fish in streams is not a good indicator of drinking water quality.

3. Arsenic and Opportunity (pp. 4-5)

Section three discusses how ore processing introduced arsenic into the area, and the local pattern of contamination in soil, surface water and groundwater. It is included for the reasons described in the presentation chapter (p. 76, 77). Information about the location of soil and water contamination is represented in a map. Unlike the presentation, this map represents all of the contamination in one image, providing a better sense of the pattern of contamination. This is also a consideration of available space. For issues of clarity, I omitted more detailed information about arsenic levels in specific locations (such as the soil in yellow ditch, or water in specific stream sections). However, the accompanying text acknowledges that arsenic levels vary within these larger areas and describes the location of notable high arsenic areas. These areas are labeled and visible on the map. The one exception to this is the representation of contaminated well locations within Opportunity. Because their location is of particular relevance to the topic of this booklet, they are pinpointed on the map.

4. What do groundwater and aquifers look like? (pp. 6-8)

This section marks the point of the booklet where presentation and explanation of groundwater concepts begins. It is essentially a condensed version of parts three and four of the presentation. As in those parts, it explains and illustrates concepts central to "understand(ing) the structure of systems through which water flows" (Covitt et al., 2009, p. 38). As discussed in the focus group results (p. 68, 69), attempting to understand the structure and behavior of water in the complex local groundwater system through observations of domestic wells can be challenging. Some resident comments indicated that individuals might have misconceptions about where groundwater occurs and what affects its occurrence (68, 69). This section begins with a discussion of groundwater system structure at a scale relevant to domestic wells and builds up to a larger landscape scale. It focuses on three key concepts and vocabulary items: "groundwater", "aquifers", and the "water table" that are basic to understanding where groundwater exists in a landscape, where aquifers occur within a groundwater system, and, therefore, how contaminants may enter and flow through groundwater towards domestic wells.

The three graphics used in this section collectively illustrate how subsurface structure affects the occurrence of aquifers in the Opportunity area. The first graphic, which was developed for the booklet, shows groundwater underneath a valley surface similar to Opportunity and focuses on depicting the occurrence of groundwater within the pore space of soil and rock particles. The second graphic reflects a minor change between the presentation and the booklet. Because wells in Opportunity do not tap perched aquifers (aquifers that are suspended above larger regional water tables), they are not depicted in the booklet. Because well water levels between adjacent properties in Opportunity can vary due to confining layers, this illustration may be helpful for residents in making sense of observations made from their domestic wells. As noted in the presentation chapter (p. 104), an illustration showing how variation in ground structure affects well levels was specifically identified as helpful by an attendee. The last illustration is a slightly modified version of a graphic used in the presentation and depicts the results of ground sampling by the Montana Bureau of Mines and Geology. It shows how the concepts of groundwater and aquifer occurrence apply to the Opportunity area and how this affects the location of wells in town.

5. Groundwater moves (pp. 8-9)

In section five of the booklet, I modified the treatment and attention given in the presentation to describing large-scale groundwater movement. In the presentation, landscape scale groundwater movement was alluded to repeatedly, but not explicitly discussed until section five. In that section, I embedded discussion of groundwater movement into an explanation of how different tools are used to analyze and describe groundwater. Upon reflection, this topic merited more attention. Education literature identifies the idea that groundwater does not move as a common misconception (Covitt et al., 2009; Gunckel et al., 2012). Understanding large-scale movement is part of the scientific literacy described by Covitt and colleagues. (2009). Also, upon revisiting comments made during the focus group, I realized that resident comments about where groundwater "goes" may be comments about the location of groundwater and not, necessarily, about how groundwater is moving (p. 66). In Opportunity, understanding large-scale movement of groundwater is important for understanding where arsenic contamination of wells may originate. It is essential, for example, for understanding that the South Opportunity plume poses more of a risk than water associated with the waste ponds north of town. For these reasons, I devoted an entire section of the booklet to this topic and included an illustration of general groundwater movement in the area.

Similar to the presentation, however, is my choice to explain how groundwater movement is determined by the use of water table elevation readings in water table wells (wells that penetrate just below the water level). As explained in the presentation chapter (p. 86), this provides a link between observable phenomena and a larger, less tangible aspect of the groundwater system. Explaining this link demystifies the process by which experts make statements about groundwater movement.

Illustrations in this section incorporate focus group comments about the helpfulness of seeing cross sections that depict the relative elevation of the land and water table (p. 71). Additionally, the booklet diagram illustrating how water table elevations are measured and used to determine groundwater movement (Appendix K, p. 9) carefully reflects water table elevations on the accompanying map of general groundwater movement in the Opportunity area.

6. Above and below: connections between the surface and groundwater (p. 10-11)

This section incorporates most of the groundwater concepts in part four of the presentation. As discussed earlier (pp. 26 & 28) connections between surface and groundwater features, such as the loss of water from Mill Creek to the ground or the gain of water in the drain tiles, inform official explanations for the distribution of arsenic in local aquifers and it was not evident from focus group comments that residents understand or recognize the relevance of those connections. This scientific literacy need has implications for the ability of residents to "trace matter through natural and human-engineered systems" (Covitt et al., 2009, p. 38). The booklet retains this necessary discussion of connections, but, instead of using many diagrams to show these connections, uses a single diagram that depicts several types of connections (e.g. losing streams, gaining streams, springs) in a single landscape. This is more representative of the groundwater context in and around Opportunity than images used in the presentation.

7. Up and Down: water tables, well levels and irrigation (pp. 10 - 11)

Discussion of water table fluctuations was part of the presentation (part four) and is retained in the booklet. The location of the water table affects how surface water and groundwater connects. Losing streams are part of the official explanation for the pattern of groundwater contamination. Therefore, the link between water table location and flow between the surface and ground is important. Irrigation ditches affect these fluctuations and, therefore, this link is also important to make. Understanding the role that water table fluctuations play in the local landscape is necessary for Opportunity residents to understand explanations for the movement of arsenic through the local groundwater system. In order to show the relationship between these different elements of the local system more clearly than it was depicted in the presentation, I developed a diagram showing groundwater and surface water behavior during irrigation and non-irrigation seasons.

Additionally, as the Superfund Background chapter explained (p. 29) groundwater fluctuations are linked to periods of high arsenic content in the South Opportunity groundwater plume. Because water table fluctuations are used to explain arsenic concentrations within the groundwater plume, I describe that reasoning here rather than in the later section that deals exclusively with explanations for arsenic contamination patterns within Opportunity.

8. Chemistry of a contaminant: arsenic (pp. 12-13)

This part of the booklet focuses on supporting the ability of residents to trace arsenic through the environment at the “atomic-molecular scale” (Covitt et al., 2009, p. 38). It also contains some basic information about arsenic that is important for interpreting information provided about the site. For example, this section explains the terms arsenic "3" and arsenic "5." As science education literature reviewed for this project indicates (Covitt et al., 2009), students have difficulty conceptualizing how molecular scale mechanisms affect surface contaminant mobilization into groundwater and conceptualizing the difference between dissolved and solid states of a contaminant. Focus group results (p. 80) revealed a lack of resident familiarity and certainty with the behavior of arsenic in the groundwater system.

Information about the atomic-molecular behavior and nature of arsenic was spread throughout different parts of the presentation (1, 6, 7, 8). This booklet section draws together information that is specific to arsenic from these disparate parts in order to more directly address resident competencies with this scale of contaminant movement. It omits some presentation information that was either irrelevant to arsenic or provided more technical detail than necessary for interpreting information provided about the cleanup. For example, a discussion about the factors influencing basic groundwater chemistry was cut.

Other topics covered in the presentation are clarified in the booklet. Textual and graphical information on p. 13 more explicitly discusses and illustrates how behavior of water in the landscape affects the mobility of arsenic. Also, processes (including at an atomic-molecular scale) that result in reduction of arsenic levels in groundwater are more explicitly discussed as "natural attenuation."

9. Sources of arsenic to Opportunity wells (pp. 14-17)

This section explains the reasoning behind official explanations for local groundwater contamination patterns and shows how concepts described in the booklet, such as surface water and groundwater connections, are part of this reasoning. As the literature review pointed out, previous attempts to explain how experts reached conclusions about the pattern of local groundwater contamination have been unclear to residents (pp. 45, 46). This section of the booklet, while not endorsing these explanations, is an attempt to more clearly convey the reasoning behind those explanations to a lay audience. As in the presentation, this section of the booklet includes a cross-sectional diagram illustrating how arsenic contamination may reach domestic wells according to the officially sanctioned explanation.

The booklet includes two other additional elements that show how information in the booklet can be applied to assist residents to take actions that address arsenic contamination of wells in their community. As recommended in risk communication literature (NRC, 1989), I include a list of concrete actions that residents can take to limit their exposure to contaminated groundwater. This list is based on the officially sanctioned contamination explanation. I also include a list of questions that residents can use to assess whether this official explanation comports with information shared about the site and with their own observations. Residents can answer some of these questions and some are better suited for conversations with Superfund site personnel. They are included as examples of how information in the booklet can be applied to form focused questions that provide Opportunity residents the chance to receive more relevant and satisfactory information about groundwater contamination.

10. What's going on with the cleanup? (pp. 18 -19)

The final section of the booklet summarizes the recent Superfund site decisions and plans that relate to groundwater quality and well safety. This content originated in part nine of the presentation and underwent few changes. I included this content as a service to residents who may not be familiar with the current status of Superfund activities. This information is also helpful for residents who may have questions about what to expect in the future. It does not provide a *concrete* answer to resident questions about future safety of their individual domestic wells, which Hasenbank (2006) identified as an informational desire of participants. Because I could find no source with a clear statement about this, providing such information would be disingenuous and dangerous. This section does, however, provide residents with a better picture of the future risk setting by illustrating where arsenic sources will remain (such as in surface water) and what safeguards will be in place to identify future threats.

Closing remarks about the booklet

The overall purpose of the booklet was to integrate the previous steps of the project into material that supports meaningful participation, procedural justice and, ultimately, environmental justice for the residents of Opportunity. By addressing informational needs and desires of residents, it sought to increase access to and understanding of the current and future risks faced by Opportunity residents regarding groundwater contamination with arsenic. The last chapter of this paper offers an personal and professional assessment of the project.

7. CONCLUSION

This chapter offers a reflection and assessment of the project. I first reflect upon whether the project, as conceived, did serve the purpose of advancing environmental justice for the community of Opportunity and its residents. I then discuss successes, limitations and areas of improvement in the project's achievement of the three original stated goals. Because the booklet must be available to Opportunity residents in order to serve the purpose of EJ, the next section describes further plans for producing and distributing a refined version of the booklet to residents of Opportunity. In conclusion, I briefly discuss how similar projects addressing groundwater are useful for attaining the ultimate EJ goal of a clean and healthful environment for all outside of the local context of Opportunity.

Serving the purpose of environmental justice

The overarching purpose of this project was to support the attainment of environmental justice for residents of Opportunity. I approached this by focusing on the procedural justice aspect of EJ and the role that access to and use of technical information plays in meaningful participation. While this approach was appropriate for supporting the attainment of meaningful participation, I was aware from the beginning that it does not ensure procedural justice, or EJ, for Opportunity residents.

As Teske (2000) pointed out in his study of two communities engaged in the Superfund process who did have the assistance of TAGs, access to expertise does not equate with access to power. Having a certain degree of competency with technical information does enable residents to engage more fully in the local discourse about groundwater contamination and remediation. However, unless the decision-making process also provides opportunities for resident contributions in that discourse to influence decisions, it does not meet the requirements of a fair and democratic process (Kuehn, 2000). In essence, the project helps get the voice of Opportunity residents a seat at the table, by providing access to a specialized discourse (risk assessment and remediation), but it does not ensure that this voice will be heard.

Meeting project goals

Within the larger purpose, the project set three goals: to identify informational needs and desires of Opportunity residents; to identify ways of appropriately communicating that information to the intended audience of Opportunity residents; and to create accessible informational materials about groundwater and groundwater contamination that respond to the needs and desires of Opportunity residents. This section offers a reflection on how well these goals were met.

In my attempt to identify the informational needs and desires of Opportunity residents, I focused largely on identifying needs associated with developing scientific competencies with groundwater. I concentrated less on identifying needs and desires for specific information or data. For example, the focus group did not contain questions such as "Which streams do you want more information about?" or "What groundwater test results do you want to have access to?" In this respect, the originally stated goal may be broader than the goal I actually met. My approach did, however, engage with the desire expressed repeatedly by residents to know more about the current and future safety of their domestic well water supply. By addressing competencies implicit in understanding explanations for the current and future groundwater risk setting and communicating those explanations in ways more appropriate for a lay audience, the project did provide Opportunity residents with more comprehensive information about the risks they face now and in the future.

However, the set of competencies that informed focus group questions was largely based upon literature and on my assessment of relevant competencies based on my knowledge of site studies. This limited opportunity for resident experience to speak to what sorts of technical information presented difficulty for them. This, in hindsight, limited the project and may not have captured the real range of competencies that Opportunity residents would like supported.

Additionally, I identified competencies that needed to be supported based largely on literature concerning non-adult individuals. While, as discussed in the literature review chapter, this literature does have applicability to adults, data about adult understandings of groundwater would provide a more accurate and informative basis upon which to build projects addressing competencies.

To address the second goal, I relied mostly on science education and risk communication literature. The materials I developed heeded the recommendations I found in this literature, such as the appropriate use of images and language. However, because this project is neither part of an educational curriculum nor solely a risk communication, additional literature would be informative for composing more effective material and identifying more specific guidance.

Because the project supported lay competencies in a non-formal setting, I explored science communication literature. Much of this literature, however, only provided very general guidance, such as speaking to the audiences experience level and avoiding technical terms. On the whole, the science communication literature that I found dealt more with how to effectively work with media outlets and not how to communicate scientific concepts unfamiliar to lay people. Although I did seek out literature on lay understandings of groundwater and public communication about hydrogeology or other related sciences (hydrology, geology, chemistry), I did not consult literature on adult education, which may have provided important insight into communicating unfamiliar scientific concepts to my identified audience. I also suspect that there may be more literature in the fields of science education, communication studies and journalism that does not specifically address communication issues about groundwater, but does address relevant topics, for example, literature about effective types of graphical elements for communicating abstract scientific concepts.

Another aspect of whether or not I identified appropriate ways of communicating deals with the question of whether the focus group, public presentation and booklet are effective media for reaching Opportunity residents. While I received suggestions that a web or computer-based medium may be appropriate, research conducted in another Montana town dealing with a Superfund cleanup provided support for my approach. Blata-Pennock's study (2010) of the informational preferences of residents living in Libby, Montana concluded that individuals preferred public presentations and printed materials over computer based communications to obtain information about the local cleanup site. She pointed out that her finding regarding preferences for public presentation comports with "rural theory", which examines the social and cultural norms of rural communities. Rural theory has asserted that personal relationships and face-to-face communication are highly valued in less densely populated areas. Using methods in which I personally engaged with residents, then, used communication channels appropriate for the rural town of Opportunity.

The third goal of this project: to create accessible informational materials about groundwater and groundwater contamination that respond to the needs and desires of Opportunity residents is an integration of the two other goals. It is possible to argue that the project achieved this goal by fulfilling the prior two goals. Feedback to the presentation indicated that material did generally address residents' desire to develop a better understanding of well water safety in Opportunity. However, based on the amount and quality of feedback, as well as the level of attendance at the presentation, I believe that the best way to test the project's success in meeting this goal would be to obtain formal feedback from Opportunity residents about their satisfaction with the booklet and to measure the change in resident competency with groundwater contamination concepts.

Future plans

The booklet needs to get into the hands of Opportunity residents in order for it to serve the purpose of EJ. At the outset of this project, I communicated with members of OCPA (S. Myers, personal communication, April 23, 2011; G. Niland, personal communication, March 12, 2011), CFRTAC (D. Barton, personal communication, January 31, 2011) and the Clark Fork Coalition (CFC) (C. Brick, April 7, 2011). All individuals expressed a general support for an informational product to better address the needs of Opportunity residents and expressed a willingness to somehow help distribute it. Since then, Chris Brick, Science Director with the CFC, has reviewed the booklet and indicated that the CFC and CFRTAC, which whom she is also affiliated, may be willing to provide graphic design, production, and funding support (C. Brick, June 7, 2013). In addition to this expert feedback, I plan on obtaining and incorporating resident feedback into future revisions of the booklet. If any copyrighted images are retained in the final version intended for public distribution, I will obtain permissions at that time.

I plan on exploring several opportunities for distributing the final booklet. Both the CFC and CFRTAC do work to engage citizens in Superfund remediation activities along the Clark Fork River Superfund complex, which contains Opportunity. As such, they are appropriate partners for refining the booklet and making it available to all Opportunity residents. Based on the population of Opportunity (Census Bureau, 2011), a run of approximately 260 booklets would provide a copy for every household in Opportunity. I intend to formally ask the CFC and CFRTAC if they are willing to support and endorse an effort to bring this booklet to production. Ideally, I would be able to provide all Opportunity households with a copy of the booklet, but will also propose the option of printing a smaller run to be distributed by OCPA. With the endorsement of the CFC or CFRTAC as an existing non-profit, I may seek grant or donor funding to support refinement, production and distribution of the project. If this option is unlikely, I will explore the prospect of the CFC, CFRTAC, OCPA and possibly the Arrowhead Foundation providing access to the booklet through their website.

Further applications

This project has argued that developing scientific understandings of groundwater contamination is important for facilitating the ability of Opportunity residents to participate in remediation decisions that pose risks to their health. Opportunity is not the only community whose health is tied to groundwater resources. According to the most recent report of water conditions and quality in the state (MTDEQ, 2012), 61% of Montanans obtain drinking water from aquifers. More importantly, this report indicates that 32% of Montana residents obtain their drinking water from private wells.

The Safe Drinking Water Act does not provide a mechanism for protecting this 32% from contamination through their private wells. Water provided through public water systems is regularly monitored and tested by the operators of those systems. For residents receiving water through these public systems, knowledge of groundwater systems is not necessary for assessing whether the water flowing through their tap is safe. For private well owners, however, there is little structure in place to ensure that drinking water remains suitable for drinking. Governing bodies are able to provide some protection for private well owners through the use of well permitting requirements and institutional controls. Aside from these administrative tools, the responsibility for assessing risks to private drinking water falls largely on residents. Without a more developed scientific understanding of groundwater contamination, the ability of individuals to make these assessments is impaired. For example, it may be difficult for residents to assess whether waste disposal methods occurring on neighboring property may pose a risk to their wells. Efforts to increase understanding of groundwater systems would provide this large portion of Montana residents a better ability to assess possible threats to their private wells and make decisions about how to protect themselves from water contamination. For example, in rural areas with little government oversight, better understanding of groundwater systems can help landowners determine what sorts of activities in the local landscape should trigger them to perform tests of their private well water quality. Also, in areas with available structures for monitoring and protecting groundwater, better understanding should improve the ability of residents to participate in public processes and advocate for protection of groundwater. By empowering residents in actions that reduce their exposure to contaminated drinking water, such efforts work towards the ultimate goal of protecting all individuals from environmental harm.

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APPENDICES

Appendix A: Focus group protocol

Bring

- This protocol!
- Computer, cables, extension cord and projector
- Camcorder w/tripod and the person who will run it
- A "whiteboard" and dry-erase markers
- Documents: consent form, background questionnaire, check-in form
- Refreshments and dinnerware
- Confidence, empathy and quick thinking!
- Funds: reimbursement for participation and payment for Community Club

<u>Before folks arrive</u>:

- Set up 10 chairs and three tables (refreshments, documents, projector)
- Set up and test projector and screen. To set up computer: System preferences/
- turn on heat

After people start arriving

- Give each person a consent form and questionnaire: show them which pages to keep and where to return the other ones, Give them an envelope with the reimbursement payment.
- Check them in to make sure everyone is there.

Interview Introduction:

Hi and thanks for coming. We've spoken on the phone, but let me refresh you about why I wanted to meet. My name is Yvonne Sorovacu. I'm a graduate student working with professor Robin Saha at UM. I organized this meeting to hear from you about groundwater conditions in and around Opportunity. This is part of a project for my graduate work and I 'm not an employee of any organization or agency working on the Anaconda site cleanup.

The goal of my project is to provide information about arsenic and groundwater that is relevant and useful for Opportunity residents. Information on local groundwater conditions provided by agencies and individuals working on the Superfund site are based on water science. The language and concepts of groundwater science or hydrogeology aren't common knowledge, but folks in Opportunity need this information in order to evaluate and weigh in on how they think the monitoring and cleanup are going. Information about groundwater conditions should be presented in a way that's useful and makes sense to the average citizen.

That's why I want to hear from you, Opportunity residents, about your understanding of and concerns with local groundwater and the presence of arsenic.

I have a list of questions that I'd like to hear your responses to. There are no right or wrong answers to them, because the goal of this meeting is to hear from you. I'll also be projecting some maps and pictures up here and asking you to comment on them by drawing on the whiteboard. We'll finish by four, but if you have questions you'd like to ask me, I'm happy to stay after the discussion is over and talk. What I hear from you today will help me incorporate the needs and concerns of Opportunity residents into a public workshop and some written informational materials. I'll offer that workshop and material to residents in the next couple months. My hope is that these will be useful tools for residents when they are *evaluating the cleanup and talking about it with family, friends, and neighbors or with agency or other personnel involved in the cleanup.*

Like I said on the phone, I'm recording this conversation so I can pay full attention to what you have to say and remember it accurately. If, at any point, this makes you uncomfortable, let me know. All of your comments will be confidential. I won't identify you personally as the source of any comments and the recording will be erased after I review and make notes on it. So you won't be able to find a copy of this video at the library or on Youtube, but I will include a summary of what we talk about in my final report of this project.

Your participation is voluntary. If, at any point, you don't want to respond to a question or continue in the discussion, that's fine.

Does anyone have questions, comments or requests before we begin?

I'll be projecting images and diagrams on this white board and asking you to draw on it to help our discussion. Dry erase markers are right here when you need them. Distribute printouts of images to participants. *Here are copies of the images. You can use them if you prefer not to share your drawn responses with the group. Also, in case you didn't get a chance to share a drawing or comment, you can write it on this paper and I'll collect it at the end.*

Before we start I want to explain that when I say "groundwater", I'm talking about any water that exists underground, such as the water that your wells tap into.

1. Today we're talking about groundwater in and around Opportunity. Do you have any concerns about groundwater and why or why not?
    - Are you concerned about the possibility of arsenic contamination in your wells?
    - Can you tell me what makes you feel that way about groundwater in and around Opportunity?

Project cross-section diagram of well

2. Okay. Now I'd like to hear about the groundwater that you use in your houses. Here is house over an aquifer similar to the one under Opportunity (refer to white board). There are layers of different materials - clay, gravel, cobble, sand - some are thinner, some are thicker. This is a simple well with an open bottom going down into the aquifer. Can you talk about and show me on this picture how you think water flows into your well from the aquifer? What I mean is when your well is pulling water, how do you think the water in the aquifer around your well is flowing?
    - Can you draw arrows on this diagram to help me see how water flows into your well from the aquifer?
    - Can you talk about where the water drawn by your well is replenished from?

Project aerial map of Opportunity area with water table elevations on it.

3. Okay, so your well is getting water from this aquifer. Let's talk about the larger picture of this aquifer and the water in it. Here's an aerial map of the Opportunity area (refer to white board*)*. Can you talk about how you think the water underground moves – things like direction and speed. You can draw arrows on this big map to show its path.
    - Where does the groundwater under Opportunity come from?
    - In which direction does it flow?
    - Where does it flow to?
    - How far do you think groundwater under Opportunity moves in one day?

4. Do you think that water from the surface, such as in soil, streams or ditches can get into the aquifer? Where and how do you think that might happen?

5. I've heard about the drain tiles underneath Opportunity. From what you know, where does the water in these tiles come from and where does it go? If anyone wants to draw pictures to help explain, you're welcome to.
   - How do you think the water gets in the tiles?
   - Could you tell me a little bit more about what you mean by that?

Okay, let's look at a similar picture, but with some things added in.
Erase lines drawn on whiteboard.

6. Pictures like this have been used in public presentations or documents about groundwater in Opportunity. These blue lines on the map (that aren't streams) are called water elevation lines. Do they mean anything to you? What do they mean to or show you?
   - What do you think the numbers on each line indicate?
   - Do these help show you anything about the aquifer? What?
   - Have you seen these before?

Project image of Opportunity with good illustration of streams and ditches.

7. Okay, now I'd like to hear about arsenic. Investigations of the Anaconda Smelter cleanup site have identified high arsenic amounts in some areas around Opportunity. This contamination can be in soil, surface waters or it can be underground in groundwater. If you have heard about any, can you show on this map where you have heard that there is a high amount of arsenic and talk about how much contamination is in those areas?
   - From what you've heard, at what depth does the water contamination in this area begin? (refer to areas they've ided)
   - From what you've heard, at what depth does the water stop being contaminated in this area? (refer to areas they've ided)
   - Could you tell me more about how contaminated this stream is??
   - Do any of the irrigation ditches have high arsenic levels?

Time check – is there at least an hour left?

8. Where do you think the arsenic in these contaminated areas came from?
   - Can you say more about where it came from, maybe identify places on the map?
   - How do you think the arsenic got from the source to the contaminated areas?

9. Do you think arsenic in these areas (gestures towards areas ided on map) can get into the water under Opportunity?
   - How do you think arsenic in these areas could get into Opportunity well water?
   - Do you think contaminated water in streams or ditches can get into the groundwater? If so, how do you think that could happen?
   - Do you think the contamination in groundwater from these areas can travel to other places? If so, how do you think that could happen?

10. Let's talk about how arsenic acts in water. Once arsenic is in the water, do you think it stays in the water or does it naturally get removed from the water? How do you think that could happen?
    - If it's removed from the water where do you think it goes?
    - Do you think soil, or some other material can permanently remove arsenic from water?
    - Can arsenic become nontoxic by moving through the environment?

11. Do you think arsenic can get into the water from soil?

- How do you think that happens?

12. Do you think arsenic can occur in any other places beside in water and in soil, and, if so, where?
    - How can arsenic get to these other places besides water and soil?

13. There have been numerous tests of wells in Opportunity and only a few of them have tested as having more arsenic than Montana water quality standards. Why do you think that arsenic levels in most Opportunity wells are lower than the water quality standards?

14. I'm interested in any explanations you've heard for the groundwater quality in Opportunity. Could you talk about any scientific explanations you've heard that were used to explain groundwater conditions in and around Opportunity?
    - Who provided these?
    - Do you remember when and where this was?
    - What issues did these explanations address?

15. Did these scientific explanations make sense?
    - What didn't make sense?
    - What was unclear about them?
    - Did the science behind it make sense to you?

Did the images or graphs make sense to you?

Time check – are there at least 10 minutes left?

16. What about groundwater conditions in and around Opportunity would you like to know more about?

    - Anything else?
    - Anything about the soils or how arsenic can move from water to soil or from soil to water or through the water?
    - Anything about the waste repository or Mill Creek?
    - Anything about the yellow ditch or the drain tiles?

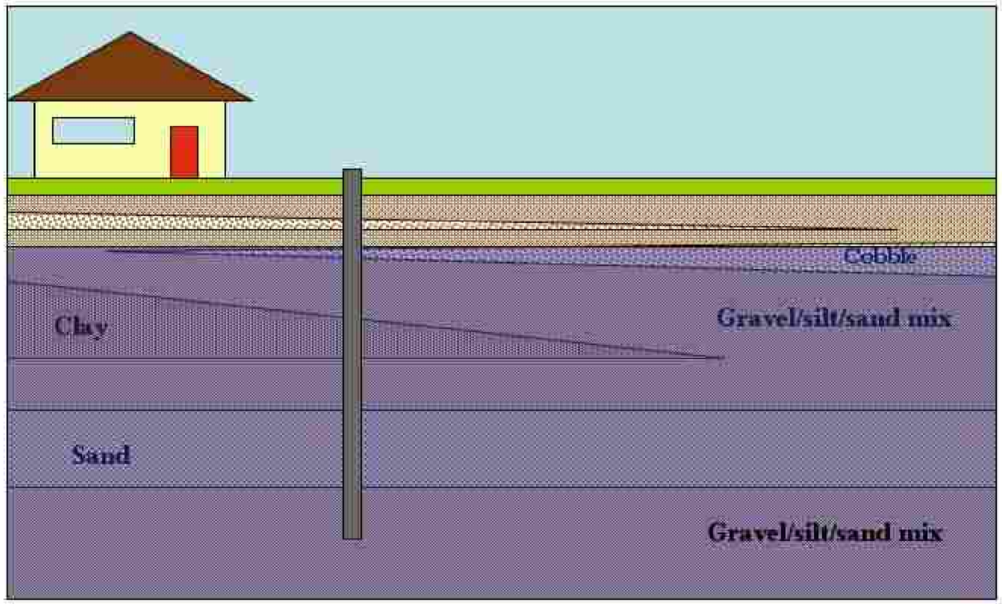
17. Is there anything you would like to add before we finish?

Outro

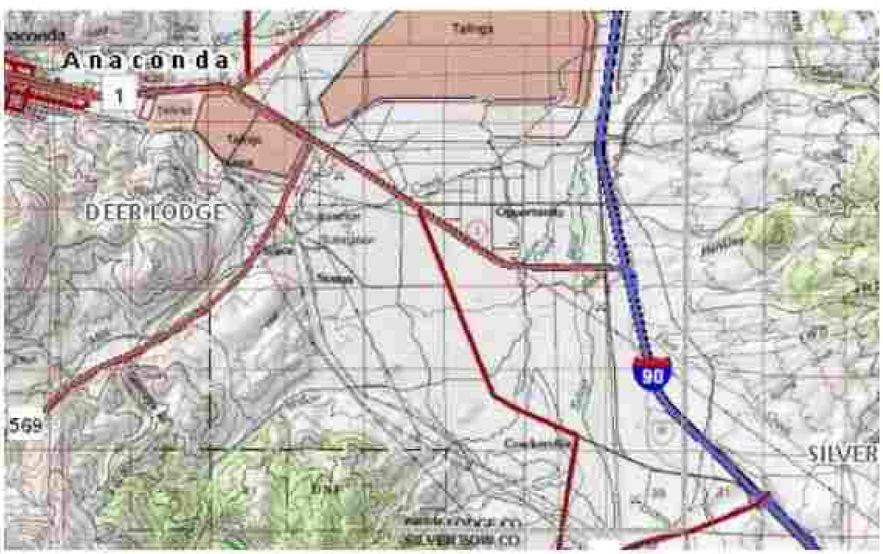
Thank you all, once again, for participating in this discussion. If I have more questions for those of you who said I could contact you with a follow-up call, I'll give you a call sometime in the next week. Could I have the handouts I gave you at the beginning?

Thanks. If there's anything else you'd like to share with me in the next few days about the things we talked about tonight, my contact info is on the copy of the consent form that you got at the beginning of our meeting. I'll be announcing my public presentation on groundwater and arsenic by flier at the market. If any of you have asked to get a personal announcement, I'll make sure to do that about two weeks before the presentation. Please contact me with any questions or comments about the project or discussion. My contact information is on your copy of the consent form.

Appendix B: Focus group image handout



How do you think the water in the aquifer around your well is flowing?



Do the blue water elevation lines mean anything to you?

Do they explain anything about the aquifer to you?

Figure 4-15
Water Table Elevations
South Opportunity Characterization Report
Anaconda Regional Water, Waste, and Soils OU
Anaconda Smelter NPL Site, Montana

Figure 1-2
Site Map
South Opportunity Technical Impracticability Evaluation
Anaconda Regional Water and Waste OU
Anaconda Smelter NPL Site, Montana

Appendix C: Background Questionnaire

All information given here is anonymous and will be kept confidential. The purpose of this questionnaire is to gather general background information from participants to see how the focus group represents the community. If you have any questions, please feel free to ask me.

1. For how many years have you lived in Opportunity? ____________________
2. What is your gender? (please circle one) Male Female
3. What street do you live on? ______________________________

   What is the nearest cross-street? ________________________________
4. What is your marital status? (circle one) Single Married Widowed Other
5. What is your age group? (please circle one)

   18-29 30-39 40-49 50-59 60-69 70+
6. What is your current occupation? ______________________________________

   If you are retired, what was your former occupation? _____________________________
7. Do you have children that live in Opportunity? (circle one) Yes No

   If yes, please list their ages: __________________________
8. Do you have grandchildren that live in Opportunity? (circle one) Yes No

   If yes, please list their ages: __________________________
9. Are you a homeowner, or do you rent your home? (circle one) Rent Own

Thank you!

Appendix D: Recruitment letter

Dear

I am writing to you and other residents of Opportunity who may have questions or concerns about the condition of groundwater in and around Opportunity. I am a graduate student at the University of Montana and am working with Professor Robin Saha. I've been learning about groundwater contamination issues related to the Anaconda Superfund site and understand that residents of Opportunity get their water from private wells. Through news articles, student papers and talks with residents of Opportunity and other folks involved in the Superfund cleanup I've learned that there is concern about how arsenic in groundwater may affect Opportunity and that many residents want more information and to stay informed.

This letter was sent to you and other residents of Opportunity to announce a groundwater awareness project that I am doing. The goal of my project is to provide information on groundwater and arsenic that responds to the needs, concerns and questions of Opportunity residents.

I would like to meet with a small group of Opportunity residents within a few weeks from now to discuss their understanding of, concerns with, and questions about groundwater and arsenic in the area. I'll be contacting folks by telephone within the next week to explain more about the project and to see who might be interested in being part of this discussion.

Thank you and I look forward to speaking with you!
Sincerely,

Yvonne Sorovacu
University of Montana
(406) 274-0641
yvonne.sorovacu@umontana.edu

*Please feel free to leave me a message or e-mail if you would prefer that I not contact you about the meeting. Also, if you *do* want me to contact you and the phone number I have for you below is incorrect, please feel free to email or phone me.

Appendix E: Phone script for recruitment of focus group participants

Hello, my name is Yvonne Sorovacu. I am a graduate student at the University of Montana working with Robin Saha. I'm contacting people in Opportunity to see if they might be interested in sharing their thoughts on groundwater conditions in the area for a service-research project I'm doing. Is -_____________ (name) available to speak with me?

Re-introduce self if phone is passed on.

I'm calling today because I know that the Opportunity community has been concerned with groundwater quality in the area. I'm interested in hearing from Opportunity residents about how they think of and are concerned with groundwater and arsenic within the Anaconda Superfund site. If you have time right now, I'd like to speak with you for a few minutes, tell you a little bit about what I'm doing and see if you'd be interested in coming to a meeting I'm having soon with other residents of Opportunity. Do you have a few minutes to hear about what I'm doing and see if you'd like to participate?

No - *Thanks for your time. I'll be making a presentation in Opportunity about groundwater and arsenic within the next few months. Do you want me to let you know when it happens?*

No –*Okay. I'll be putting up a flyer about it at the Opportunity market if you'd like to check it out. Thanks again for your time.*

Yes – *Okay. What's the best way to let you know about it?*

Yes - Continue

Great. So, as I mentioned, I'm a graduate student at the University of Montana. I've been studying groundwater contamination issues in and around the Anaconda Superfund site and I've learned that there are residents in Opportunity who are concerned about arsenic in the groundwater. From the things I've read and discussions that I've had with some individuals who live and work in the area, it seems that better information about arsenic and groundwater could help residents address their concerns about this part of the cleanup work. The ultimate goal of my project is to give information on groundwater and arsenic that responds to the needs and concerns of Opportunity residents. To do that I would like to meet with a group of Opportunity residents to talk about their understanding of and concerns about groundwater and arsenic in the area.

I'm interested in getting an idea of what the typical resident has to say. Since people who work directly on or closely with the Anaconda Superfund cleanup have extra knowledge and specific interests in the subject, their participation would not provide me with an accurate idea. May I ask if you are involved somehow in the Anaconda cleanup?

The group will meet at the community center roughly two weeks from now for about 2 hours of discussion at a time that interested people say will work for them. I'll show some maps and images and introduce discussion topics for the group to talk about groundwater, arsenic and wells in the area. The point of this meeting is to hear your thoughts and find out what questions you have about groundwater and arsenic in the area. I am interested in hearing what information you would like to know about groundwater issues in Opportunity. This talk will be videotaped to make sure that my memory of it is accurate. All participants will receive $20 as compensation and thanks for their time and effort. I'll provide some snacks and drinks during the meeting.

I want to explain what I'll be doing with what I hear in this discussion, but do you have any questions about what I've said so far?

I'll be using what people say in the meeting to make a workshop about arsenic and groundwater. In late March or early April I'll present that workshop at the community center for any residents interested in coming. What I hear from participants in our group discussion will help me make sure that this workshop addresses the needs and concerns of the community. After the workshop I will put together some written materials about groundwater and arsenic that will be available to Opportunity residents. I may also make some web-based materials. All of this work will be part of a paper that I am writing as a graduate student at UM.

*I have some university training in groundwater science, but am not an expert. I am not working for any of the local organizations or government agencies, but I have been talking with folks at OCPA, the Clark Fork Coalition and CFRTAC (*explain if necessary) *and will be coordinating parts of my work with them.*

I will not disclose your participation to anyone. I will keep the identity of participants anonymous and will not associate comments with any identifying information in my work.

Do you have any questions about what I'm doing or asking you about?

Respond to any questions.

Can I consider you a possible participant and contact you about when would be a good time to meet?

*N*o - *Thank you for your time. I will be making the presentation in Opportunity about groundwater and arsenic within the next few months. Would you like me to let you know when it happens?*

No –*Okay. I'll be posting an announcement about it at the Opportunity market if you'd like to check it out. Thanks again for your time.*

Yes – Okay. What is the best way to let you know about it?

Yes - *Thank you so much for your time. I look forward to meeting you and hearing what you have to share. Is this the best way to contact you?* Make note of what is. *I'll be back in touch soon to set up a time. Would you like my contact info in case you want to reach me before that?*

Appendix F: Recruitment flier

Want better information about groundwater in the Opportunity area?

Do you have questions or concerns about the aquifer your well taps into?

My name is Yvonne Sorovacu. I'm a student at the University of Montana doing a groundwater information and awareness project. My goal is to provide relevant and useful information to Opportunity residents on groundwater and arsenic in the area. Tests have been conducted for years around the Anaconda Superfund site and cleanup decisions have been based on them. What do the reports and their charts, maps and numbers show about groundwater in the Opportunity area?

I'd like to talk with interested residents about their ideas, questions and concerns about groundwater and arsenic in and around Opportunity.

Interested residents are invited to a two-hour small group discussion where we will talk about groundwater and arsenic. *This is not a well sampling project and I will not be testing wells*.

All participants will receive $20 for their time. Light refreshments will be provided. The discussion will be at the Community Club on April 7th, from 2-4 pm.

If you would to participate or have questions, please share your contact info below and I'll call you with details.

Name	Phone Number	Best time to call

Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641	Groundwater project yvonne.sorovacu@umontana.edu 406-274-0641

Appendix G: Participant Information and Consent Form

Focus Group Interviews in Opportunity, MT

Researcher Contact Information:
Yvonne Sorovacu
Environmental Studies Graduate Program
University of Montana
Phone: (406) 274-0641
email: yvonne.sorovacu@umontana.edu

Faculty Supervisor:
Dr. Robin Saha
Assistant Professor, Environmental Studies
University of Montana
Phone: (406) 243-6285

PROJECT: A Modest Effort to Democratize Groundwater Remediation in Opportunity, Montana

PROJECT DIRECTOR:
Yvonne Sorovacu
University of Montana
Environmental Studies Program, RH 18
Missoula, MT 59812-4320

Special instructions to the potential participant:

- This consent form may contain expressions unfamiliar to you. If you read anything unclear to you, please ask the person who gave you this form to explain them to you.

Purpose of the study:

- This study is a professional paper for the project director's master's degree in Environmental Studies at the University of Montana.

- The purpose of this study is to use a focus/discussion group to explore Opportunity residents' understandings of arsenic and groundwater as well as their concerns related to local groundwater contamination associated with the Anaconda Smelter Superfund Site. Specific topics to be discussed include the source, occurrence and movement of groundwater and arsenic in the local area and the concerns or questions that residents have regarding these subjects.

- The information gathered during this study will be used by the project director to develop a public presentation about groundwater and arsenic which will be offered to Opportunity residents in the coming months. It will also be used to prepare written and possibly web-based informational materials about groundwater and arsenic.

Procedures:

- If you agree to take part in this research study you will be participating in a focus/discussion group. Participants will be interviewed as a group of six to eight individuals to discuss their technical understanding of and concerns about groundwater and arsenic, especially as it relates to domestic well sources. The project director will be serving as the moderator, or interviewer.

- You will be asked to participate in the discussions during the focus group by expressing your ideas and concerns.

- You will be asked (participation is voluntary) to fill out a background questionnaire at the beginning of the focus group session.

- To ensure that participants' comments are accurately noted, the discussion will be audio and videotaped. A professional with experience leading discussion groups will also be present to observe and provide guidance on the principal investigator's technique.

The group discussion will take place at the Opportunity Community Club in Opportunity, Montana and last for two hours. Refreshments will be provided.

Risks/Discomforts:
- Answering the questions may cause you to think about issues or share ideas that are stressful or upsetting. If you are uncomfortable with participating in discussion or it causes unmanageable stress, you can leave the group at any time and/or may want to consult a physician or a counseling professional.

Benefits:
- There is no guarantee that you will receive any benefit from taking part in this study.

- Your help with this study may assist the project director create a public presentation, as well as written and/or web-based materials that better meet the informational needs and concerns of Opportunity residents concerning arsenic and groundwater.

Confidentiality:
- Your identity will be kept confidential at all times and will not be used during the analysis of comments or in any written or web-based documents that result from this project.

- All participants in the focus group are asked to keep the comments and identities of other participants confidential.

- Only the project director and her faculty supervisor will have access to files associating your identity to the collected focus group data.

- All video, audio and written files will be stored in a password protected computer. Printed copies will be stored in a locked container.

- Your signed consent form will be stored in a locked cabinet separate from the data.

- Audio and video recordings of the group discussion will be transcribed and noted without any information that could identify you. Files will be erased from recording equipment directly after transfer to a password protected computer. After completion of the project audio and video files will be erased from the computer.

Compensation for Injury

Although we believe that the risk of taking part in this study is minimal, the following liability statement is required in all University of Montana consent forms:

"In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Claims representative or University Legal Counsel." (Reviewed by University Legal Counsel, July 6, 1993)

Voluntary Participation/Withdrawal:
- Your decision to take part in this research study is entirely voluntary.

- You may leave the study for any reason.

Questions:
- If you have any questions about the research now or at any time, please contact: Yvonne Sorovacu at (406) 274-0641 or yvonne.sorovacu@umontana.edu
- You may also contact the faculty advisor, Robin Saha, at (406) 243-6285.
- If you have questions regarding your rights as a research participant, you may contact the Chair of the IRB through the University of Montana Research Office at (406) 243-6670.

Participant's Statement of Consent:

I have read the above description of this research study. I understand that audio/video recordings may be taken during the study. I consent to being audio/video recorded. I understand that audio/video recordings will be destroyed following transcription, and that no identifying information will be included in the transcription. I have been informed of the risks and benefits involved in the study, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study. I understand I will receive a copy of this consent form.

Name of Participant: ____

____ ________________

Participant's Signature Date

❑ YES, it is okay to contact me with follow-up questions about today's discussion.

❑ YES, please send me an announcement about the public workshop which today's discussion is informing

Appendix H: Workshop Outline

*NOTE: The structure of the workshop and order of topics is an attempt to start from concepts and scales that are familiar to Opportunity residents and build form there to larger scales and more complex or abstract concepts. Where possible, all graphics and diagrams will be based on groundwater or geologic data from Opportunity.

There is also lots of Opportunity specific information that I plan on including in the final written informational pamphlet, but that I think may distract a workshop group from focusing on the hydrogeology concepts this workshop is attempting to present and assess. I do plan on providing a handout at the workshop that contains my contact info and lists sources for additional information on the topics of:

- well testing
- public health info about arsenic
- community involvement opportunities
- the Superfund document repository
- Institutional controls and Superfund site related regulations

I. Introduction
   a. Who I am and what I'm doing here
      i. Yvonne Sorovacu; grad student at UM working with Robin Saha; independent researcher not working for any organization involved in the Anaconda Superfund site; studying water science, environmental justice and groundwater issues related to the Anaconda Smelter Superfund site.
      ii. Folks in Opp (YOU!) have questions and concerns about well water. You deserve to have some basic science about how groundwater works shared with you so you can understand and ask questions about what's gong on in the cleanup. Knowledge is a tool that can help make sure the cleanup is done in a way that satisfies you.
   b. What I'm going to cover today: groundwater science info and concepts helpful for understanding the aquifer under Opportunity and how arsenic contamination may affect it.
      i. Overview of arsenic and arsenic contamination in the Opp. area
      ii. What makes an aquifer
      iii. What kind of aquifer is under Opportunity and how that affects where we find water
      iv. Where groundwater comes from and goes
      v. Tools scientists use to understand what's going on down there
      vi. Contamination in aquifers: some basics
      vii. Arsenic as a contaminant of aquifers
      viii. What's going on in the cleanup related to groundwater and arsenic?
      ix. What's next in my project?
   c. What is not part of the workshop and why
      i. What exactly does the whole aquifer system look like from house to house underneath Opportunity? – hasn't been looked at in this detail by anyone – need more data.

ii. Will wells in Opportunity become contaminated? – this is a question better suited for an experienced hydrogeologist and there may not be enough data to answer this question yet. I haven't found anything definitive
iii. What's up with rules and regulations covering wells and water rights? – not my area of expertise and other folks can give you better info
iv. Handout on table by door with resources that may be able to answer questions I'm not addressing.

II. Overview of As contamination in the Opportunity area
 a. what is arsenic?
  i. a naturally occurring element that, in pure form, is gray and can't be smelled or tasted.
  ii. rarely found in pure form; usually mixed with other elements such as oxygen, iron and sulfur. (arsenopyrite)
  iii. these forms fall into two general groups
   1. "organic" = combined with carbon and hydrogen (the kind you find in most life forms)
   2. "inorganic" = not combined with carbon (arsenic trioxide)
    a. currently known to be more toxic than "organic" As, so is the focus of regulation
 b. where do we find Arsenic?
  i. naturally occurs in soil and different rocks
  ii. As levels throughout MT
   1. Soil: 40 ppb in 95% of MT surface soil (per DEQ position paper)
   2. Groundwater *naturally occurring and otherwise
    a. According to a study by the USGS: 11% of wells in dry areas have arsenic levels above 10 ppb
    b. Deer Lodge, Silver Bow, Powell and Granite County
     i. from an MBMG study of 238 well samples
     ii. Arsenic detected in 65% of well samples
     iii. 15% of wells above the regulated limit of 10ppb
    c. Missoula and Mineral County
     i. from a MBMG study of 149 well samples
     ii. arsenic detected in 50% of wells
     iii. 4% exceeded regulatory limit
    d. high levels were found in shallow and deep wells
  iii. commonly found in rocks that contain copper, gold and lead
  iv. during smelting processes, enters air as fine dust from smelter, also found in tailings and slag
 c. health effects
  i. vary depending on how exposed, size of dose, and length of exposure
   1. swallowing, breathing or skin contact
   2. larger short-term doses or chronic exposure to lower doses
    a. At highest levels (60,000 ppb): death, pregnancy complications, sore throat, irritated lungs, skin discoloration and disfiguration.

        b. lower levels: stomachache, nausea, vomiting, diarrhea, fatigue, abnormal heart rhythm, bruising,
        c. chronic exposure to low levels: skin changes such as dark patches, corns and warts on hands, feet and torso; cancer of the skin, lung, and bladder, circulatory and nervous system disorders, possible effect on fetal and child development.

d. regulatory limits
    i. Montana human health standard for groundwater is based on EPA Clean Water Act standard (the one that matters for your private well) is this for filtered or unfiltered samples!?
        1. 10 parts per billion = roughly, few drops in an Olympic pool
        2. in cleanup site talk also called the "maximum contaminant level (MCL)", a federal limit; "groundwater human health standard" , "groundwater ARAR (applicable or relevant and appropriate requirement)", and groundwater "RAG" (remedial Action Goal).
            a. "human health standards" apply to public drinking water
            b. old groundwater standard
                i. 18 ppb when original cleanup plan made:1998. Was state standard and, at time, more stringent than EPA one (50 ppb)
                ii. changed to 10 ppb after Jan. 2001 per new EPA standard
    ii. other water-based limits (different than drinking water one!)
        1. aquatic life standards apply to surface water *not* used for human consumption: what is "safe" for fish in streams. Notice fish are not as sensitive to arsenic
            a. short-term exposure (acute) = 340 ppb
            b. long-term exposure (chronic) = 150 ppb

e. Arsenic levels in Opportunity area
    i. soil: limit is 250 mg/kg residential, 1000 mg/kg open space *opp diar*
        1. areal extent
            a. all soil contaminated
        2. range of levels in/outside of town *note to self, the standard deviation indicates that there is possibility for serious hot spots within soil levels
            a. in: 7.6 – 1000 mg/kg
            b. out: 2 – 1080 mg/kg
        3. Average of levels
            a. in: 174 mg/kg
            b. out: 250 mg/kg
        4. depth
            a. Arsenic seems to be lower below 10 inches *statistically analyzed though?
        5. known hot spots
            a. *tailings* in Willow Creek floodplain – 709 mg/kg
            b. Yellow ditch (esp. above 6 inches) – 290 mg/kg

c. *railroad ballast* in Blue Lagoon (south of upper willow where yellow ditch approaches rail line)– 1010-2220 mg/kg

ii. surface waters exceeding 10 ppb: basically all in area from SO Char. report and Opp DIAR *note: data poorly organized, hard to get sense of range and averages.

1. Willow, Mill and Brundy Creek, ACM and Yellow ditch, Willow Glen Gulch
   a. amount of arsenic varies by location and time of year

iii. groundwater

1. Opportunity well water/groundwater
   a. in monthly tests from 2007 - June 2009(most recent found), 1 well in town exceeded 10ppb (17 ppb), 3 had detectable arsenic *curious to me because seems not to have shown up as a "detect" before that.
   b. lower levels than other nearby groundwater – what's going on here? no one REALLY knows.
2. South Opportunity plume
   a. areal extent *fig. 4-16 from Sogw character* *boundaries are NOT exact.
   b. depth - upper 10 feet: as of report from 2006 *p. 7 in SO DIAR*

iv. what we will look at closer today/ reinforcing "what to expect"

1. how do soil, surface water and groundwater connect? What is an aquifer and how do water and contaminants act in it?
2. My goal: give you helpful info, help you translate the technical speak, give you tools to evaluate info and the cleanup

III. What makes an "aquifer"?

a. aquifer is part of the groundwater system: at a certain depth under the ground surface, water fills all the space inbetween particles of ground material.

b. What is an "aquifer"?
   i. Clay vs. sand vs. silt vs. rock: What is your well drilled into?
   ii. define: saturated soil and rock that yields water in amounts and at speeds useful to people. Sooo, an aquifer is just *part of* a larger groundwater system – the part humans try to get water out of.

c. The ground we find water in: how different soils affect how much groundwater there is and how it moves.
   i. Groundwater = the water that *fills* the space between soil and rock material.
   ii. How much water can we get out of these spaces? The kind of material affects: how much water there is to begin with; how quickly it moves; how much of it we can pull out with a typical well.
      1. How much is in there? "storage capacity" rock vs. clay vs. sand vs. gravel
         a. examples of pore space in different materials - point out: clay holds most water; sand and gravel hold less; can have a mix of materials

2. How fast can it move? Kind of like "hydraulic conductivity"
    a. Depends on how large spaces are and how circuitous the route is! Examples: clay is slowest; sand and gravel MUCH faster
3. How much can we pull out? a tug of war between us and the ground
    a. Greedy/generous materials: water sticks to particle surfaces – we get more out of sand and gravel than out of clay
    b. Point: it's all wet under a certain level, but sand and gravel materials are where we find our "aquifers." Clay acts more as a barrier to water movement, just like solid rock.

IV. Groundwater and aquifers in the Opportunity area: the Deer Lodge "basin and range" groundwater system
- a. typical of Rocky Mountains: basin or valley of sediment flanked by mountains of rock.
- b. The ground down there: distribution of soil material in the Opp. area of the Deer Lodge valley
    - i. Many layers as small as clay to big as cobbles: a legacy of old streams
    - ii. no continuous layers across Opportunity: many small layers of different material
    - iii. One pattern: more fine material towards river. Hm, what means for drilling wells?
- c. The water "table": the level below which the soil is saturated
    - i. Depth to water table in Opp. varies from ground to 29.4 feet below
    - ii. Deeper to west, shallower as approach rivers and creeks to the east
- d. Wells in Opp. reflect the variation in the ground below
    - i. 195 on record with MBMG
    - ii. Drilled into coarser grained sediments
    - iii. Average well depth about 50 feet. Deepest 258 feet.
    - iv. Wells tend to get deeper, but water table gets shallower close to river. Why?
        1. Deep layers of clay. Remember earlier? Saturation doesn't equal "aquifer."
- e. Punching a well into lasagna: how layers can affect where we drill for water.
    - i. layers that water doesn't move through or moves through SLOWLY(aquitard, aquifuge, aquiclude, confining layer) affect where we find water and how it acts
        1. perched water tables sit above the main water table, can cause springs
        2. confined aquifers/"artesian" wells
            a. under pressure, forced up well shaft. sometimes above ground surface.
        3. Sooo…because material varies so much there can be different "aquifers" or sources of well water within the town limits. And it can be hard to tell how the water under there is connected. It isn't mapped well

5 minute break: evaluation part I

V. Where groundwater comes from and goes: groundwater inputs, outputs and seasonal variation
  a. Where it begins: rain, snow, connections to other groundwater systems
    i. What actually makes it into the basin: what doesn't runoff, evaporate, get used by plants, or stick to soil particles (soil water), infiltrates down to the water table
  b. Where it goes: moves through ground, or feeds surface waters (sometimes moves back and forth)
    i. can move in any direction (up, down, sideways)
  c. Water above and below is connected: surface water and groundwater interactions
    i. Water in the ground may resurface as stream or lake water – "effluent" or "gaining"
    ii. Groundwater can flow to the surface as springs (contact spring)
    iii. Sometimes it just passes through such as in wetlands where the water table is *at* ground level (like Opp. before the drains). Can also happen in streams and lakes
    iv. Water that ran off might eventually sink into the ground through leaky streams or lakes – AKA "influent" or "losing"
    v. Ponds and puddles: could be water waiting to "leach down" to the water table or could be where the ground intercepts the water table.
  d. The depth of the water table rises and falls seasonally since it is fed by rain and snow…and since farmers irrigate
    i. highest during spring runoff (late May/June)
    ii. lower levels August through March (lowest often in Jan./Feb)
    iii. effect not immediate
      1. response time depends on rate of water movement into, through soil, and out of soil
    iv. Irrigation season creates local seasonal effects around Opportunity
      1. moving water to areas it normally isn't at that time (growing season is dry!)
        a. areas affected by irrigation have a higher water table than other areas during the season
      2. irrigation ditches act like streams: usually are leaky and lose water to ground along path
      3. if water in irrigated land doesn't evaporate, runoff, or get used by plants, it infiltrates into the ground
    v. knowing where the water table is helps us see how groundwater is moving

VI. Tools that tell us what groundwater is doing
  a. Common tools
    i. monitoring wells/piezometers
    ii. water quality tests
    iii. streamflow measurements
  b. Elevation and water table in a monitoring well: the short version
    i. well is perforated all the way down and not pumped

    - ii. water has had time to fill well to maximum height (minutes to days)
    - iii. level of water is given as height above sea level – similar to topography
        1. this may also be referred to as the “head” measurement
- c. With a system of wells we can build water elevation maps.
    - i. well locations must have a good distribution
    - ii. water table readings should be taken within days of each other
- d. Looking at a water elevation map: Opportunity
    - i. contour lines connect areas of the water table at the same height above sea level, like a topo map
    - ii. red lines = low water/winter, blue lines = high water/spring
    - iii. like surface water on a topo map, groundwater moves from high elevations to low elevations
        1. just as on a topo map the steepest path and the one water travels is at right angles to the elevation lines.
    - iv. what does the Opportunity map show?
        1. groundwater moves from west to east and slightly north
        2. doesn’t show movement into Opportunity from the ponds
        3. not much difference in general flow path from high to low conditions
- e. “Nested wells”
    - i. several wells in the same area. some not finished at the water table, open at a point deeper in the aquifer.
    - ii. in simplest explanation: they show us how much pressure water at a certain depth in the aquifer is under.
    - iii. can show us more details about how water is moving up or down in the system.
- f. Water chemistry in an aquifer
    - i. What else is in the water besides H2O?
        1. found in larger amounts - examples
            - a. bicarbonates, elements like calcium and magnesium, salts, acids
        2. found in lesser amounts - examples
            - a. iron, bacteria (coliform), contaminants (arsenic)
    - ii. What affects the chemistry?
        1. original chemistry of rain or snow
        2. what’s in the rock and soil that gw moves through
            - a. rock and soil can add, change, or remove things that affect water chemistry.
        3. how long the water has been in the ground
        4. temperature
    - iii. The chemistry changes results for various types of measurements: pH, dissolved solids(including calcium, iron, magnesium etc.), hardness, electric conductivity, redox potential
        1. all are basically a measure of what is in the water besides H2O (water)
        2. these measurements are like a fingerprint for groundwater sources

3. can help show: where it came from, what it passed through, how long it has been in the ground.
4. like a chemical tracer that can identify which waters are connected and what direction they flow (similar to ARCO putting dye in septic tanks to detect ones leaking into tiledrains)
5. example: tests of dissolved solids used to identify which type of water different wells were drawing from
6. has been used to make statements about water in Opp area (remember where plume is?)

g. Streamflow measurements
   i. can show if streams and groundwater are connected
   ii. groundwater flows into streams (gaining streams), increases their cfs
   iii. there is no net gain or loss of water from ground, no real change in cfs
   iv. stream water flows into ground (losing stream), decreases their cfs

5 minute break: evaluation part 2

VII. Contamination in groundwater

a. Example of some sources
   i. livestock waste, agricultural chemicals, household waste, septic tanks, landfills (include. waste depositories if poorly designed) underground storage tanks*, local industry*
      1. some of these are surface and some are underground sources

b. Whether surface or underground, the type of source affects the pattern of contamination in an aquifer
   i. type based on location: point (concentrated in a small area) or non-point (dispersed)
      1. point: concentration high close to source and decreases with distance
      2. non-point (like widespread arsenic contamination of soil): concentration relatively even over a large area, but above what you would normally find in the area
   ii. type based on time: continuous or one-time
      1. continuous (like the smelter until it closed): high levels sustained in one area over long period of time; concentrations decrease with distance.
      2. one-time: the area of high concentration moves through the aquifer

c. What can happen to groundwater contaminants over time without intervention? Natural processes that may be part of a "natural attenuation" approach to groundwater remediation.
   i. depends on characteristics of the contaminant and the aquifer
   ii. remains dissolved in water and is carried out of area with flow of groundwater
      1. speed affected by how fast groundwater moves through aquifer
      2. shows up "downstream" of pollution site in lower concentrations
   iii. chemically breaks down/decomposes into different substances
      1. will not re-form into the initial contaminant
      2. often break down into something non-toxic

iv. becomes incorporated into other chemical compounds of the water or soil
    1. carbon-based (“organic”) ones where they are “bound”
    2. also into non-carbon based ones: salts, metalloids etc.
v. attaches or “adsorbs” to soil particles
    1. doesn’t leave area, but is removed from water source
vi. taken up by life form (plant, animal, bacteria, fungus)
    1. may become “bound” into organic molecules or could cycle back into the environment
vii. floats or sinks and tends to stick around at a certain depth (like some petroleum products)
viii. In reality it can be complex… like arsenic: cycles through being attached/released and through different chemical forms depending on surrounding conditions …attached to soil, can detach, some disperses/dilutes, some incorporated into soil and water molecules, some re attaches to soil etc…
ix. “Natural Attenuation” refers to natural processes that reduce the concentration of a contaminant

VIII. A specific contaminant: Arsenic in the groundwater system

a. Refer to section II: Arsenic is a naturally occurring gray, odorless, tasteless element. It is often found with mined ores, and released into the environment by mining processes as arsenic trioxide (ash or dust), tailings, and slag. It is now found in local soils, streams, and groundwater.
b. Can not be broken down into something besides arsenic (it’s an element), but can be incorporated into many different chemical compounds. It often combines with oxygen, carbon, sulfur, iron and aluminum. Some forms are more toxic than others.
c. Two basic forms: As 3 (arsen*ites*) and As 5 (arsen*ates*)
    i. 3 or 5 basically refers to the “charge” of the arsenic in whatever chemical compound it’s in
    ii. As 3 (arsen*ite*)
        1. associated with low oxygen conditions
        2. arsenite forms currently thought to be more toxic
    iii. As 5 (arsen*ate*)
        1. associated with oxygen rich conditions
        2. arsenate forms currently thought to be less toxic
    iv. Within this diversity of forms, it can be dissolved in the water (in a liquid form), suspended as particulate in the water or attached to soil particles.
    v. Some things that affect how much arsenic is in the water vs. the soil and how much of it is arsenic 3 versus arsenic 5
        1. ph of water
        2. oxygen content of water
        3. presence of other elements/compounds (iron, salts, calcium-magnesium, sulfur, nitrates)
        4. structure of soil (clay, sand, lots of organics)
        5. what sorts of bacteria and other microorganisms are there

vi. The 10 ppb limit applies to the total amount of arsenic in a sample (As 3 and As 5)
    1. Water tests can and have been done to break down what part of As in a sample is 3 or 5 form

d. Arsenic around Opportunity: most current official explanation found
    i. High levels of contamination in area waters
        1. Groundwater plume upgradient in the aquifer
        2. All surface streams have elevated arsenic levels
        3. Leads to questions
            a. where is this arsenic from?
            b. why are the As levels lower in Opp. wells
    ii. Pattern of arsenic levels related to groundwater plume
        1. Note: Arsenic throughout area is high, but area around Willow Glen Ranch is *really* high (up to 249 ppb) (see MW232 discussion in gwcharso)
            a. Yellow Ditch not considered a source b/c high levels show up in well upgradient of yellow ditch also
        2. Triggered by: infiltration of irrigation water through contaminated soils/saturation of contaminated soils. But *how* does it happen?
            a. As introduced by irrigation water? ruled out because As in irrigation water much lower than As in groundwater. (p. 7-2/89 of gwcharso)
            b. As released from soil as water saturates it? Considered more likely because As levels possible this way AND because same situation occurs with saturated soils in "North Opportunity" where there is no irrigation water applied.
        3. Where does it go? i.e. why does it not show up downgradient in Opp?
            a. water chemistry indicates Opp. groundwater is "Mill Creek type" which is below 10ppb. Large volume of water "dilutes" potential addition from soil. p. 7-6 gwcharso
            b. tile drains
                i. in southern Opp: create vertical flow that pulls up "clean" water
                ii. creates low pressure flow path at shallow depths for high As water
    iii. Influent streams thought to be main source in Opp.
        1. High arsenic waters enter groundwater through losing streams
        2. Mill, Brundy and irrigation ditches considered the way arsenic enters the aquifer in Opportunity see the Opp DIAR

e. How Arsenic can get into private wells
    i. Through the aquifer system
        1. water drawn from area of contaminated water
        2. depth of well may result in different As levels
    ii. From contaminated surface water

1. cracked casings
2. well heads at ground level

5 minute break: evaluation part 3

IX. Update: cleanup and monitoring
   a. Contaminated soil hot spots that may add arsenic to groundwater being physically removed and relocated to a WMA
      i. Yellow ditch
      ii. Blue Lagoon
      iii. Railroad embankments
   b. Other soils in the GWA (considered a contributor of As to groundwater)
      i. widespread area
      ii. average arsenic levels lower than areas mentioned above
      iii. previous sampling detected no "hotspots" and no finescale sampling to find any is planned
      iv. no widespread removal planned
   c. TI (Technical Impracticability) waivers for surface water and groundwater
      i. TI waiver: a waiver of a specific ARAR (in this case 10 ppb, the arsenic human health standard) for certain areas/materials
      ii. Other ARARs/standards not waived (lead, for example) are still applicable
      iii. TI waiver adopted by the EPA when they accept an analysis that achieving reduction of contaminants to the ARAR in an area is technically impracticable "from an engineering perspective." Which means any possible solutions have problems with
         1. engineering infeasibility: current engineering methods can't be "reasonably implemented"
         2. unreliability: the possible solution can't be expected to remain effective into the future
      iv. Not permanent, can be reversed but none have been so far and no clear process exists to do this
      v. TI zones and the current standards of cleanup there
         1. Groundwater
            a. South Opportunity TI zone: across Highway one to the west and south; foothills of the mountains in the west, north to Mill Creek, south to county line
            b. Bedrock Aquifer TI zone: in Mount Haggin area
            c. Human health standard of 10 ppb for arsenic waived
            d. no other arsenic standards apply
         2. Surface water
            a. All streams from their origin in the Bedrock TI zone to where Mill and Willow Creek meet
               i. not clear if this covers Brundy Creek or any irrigation ditches
            b. Human health standard waived
            c. Aquatic life standards still apply to streams in TI zone
               i. 150 ppb chronic and 340 ppb acute
   d. Monitoring

    i. results will be reported twice a year in electronic format (to whom? where would this info be available?)
    ii. results and sampling locations will be discussed during each official 5 year review
    iii. if statistical analysis of monitoring well arsenic levels show that arsenic is at less than 10 ppb, then AOCs and TIs will be delisted and no more monitoring done
  e. Domestic wells
    i. Frequency of testing under the official plan
    ii. Actions taken when arsenic tests above 10 ppb
      1. retesting to confirm exceedance
        a. if resample is below 10 ppb, then no action
        b. if resample is above 10 ppb, then contingency plan takes affect
          i. bottled water supply
          ii. installation of a reverse osmosis system
          iii. drilling a deeper well
          iv. replacement of well
          v. connecting house to an alternate water supply

X. Wrap-up
  a. What comes next in this project
    i. Writing a groundwater science pamphlet for use by residents of Opportunity.
      1. Comments in your evaluation forms will help me write and design it.
      2. Will distribute copies to Solan's grocery and can mail directly to people if they add name to mailing list.
      3. May be available as a digital file on the OCPA, CFRTAC or Clark Fork Coalition website.
    ii. Letter to officials and experts involved in the Superfund site
      1. Observations and suggestions about how to better communicate technical info to the residents of Opportunity
        a. informational needs and wants (what subjects should you have more info about?)
        b. informational successes (What do you have enough of?)
        c. communication methods that are effective/not effective
  b. Time for additional questions
  c. Time to finish evaluation form
    i. Please leave on the table as you exit
  d. Thank you and reminder of informational handout.
    i. My focus was talking with you about groundwater science subjects that are helpful in understanding what's going on at the site. I am sure you have many other questions about parts of the cleanup. Also on the table by the door is a handout with contact info for local and official sources with info on the Superfund site cleanup.

Appendix I: Groundwater Presentation Feedback

Most of the following questions ask you to rank your responses on a scale of 1 to 5

Section 1: Arsenic in the area; What's an aquifer?; and the local aquifer

1. Has the presentation increased your understanding about why Arsenic is a health concern in the area?

Not at all				Very Much
1	2	3	4	5

2. Did this section increase your knowledge about where arsenic contamination exists in the area?

Not at all				Very Much
1	2	3	4	5

3. Has the presentation increased your understanding of where groundwater exists underneath Opportunity?

Not at all				Very Much
1	2	3	4	5

4. Has the presentation increased your understanding of what an aquifer is?

Not at all				Very Much
1	2	3	4	5

5. Did this section increase your understanding of how the pattern of ground materials affects well locations and levels?

Not at all				Very Much
1	2	3	4	5

6. Which diagrams, pictures or images most increased your understanding of where groundwater and/or aquifers are found in the Opportunity area?

….the least?

Section 2: Where groundwater comes from and goes; tools to look at groundwater; and groundwater contamination

7. Has the presentation increased your understanding of how surface water (streams, wetlands, ponds) and groundwater are related/connected?

Not at all				Very Much
1	2	3	4	5

8. Has the presentation increased your understanding of what a water table elevation map is and what it can show us about groundwater in an area?

Not at all				Very Much
1	2	3	4	5

9. Did this section increase your understanding of how different tools are used to explore what groundwater is doing?

Not at all				Very Much
1	2	3	4	5

10. Has the presentation increased your understanding of how groundwater moves?

Not at all				Very Much
1	2	3	4	5

11. Did this section increase your understanding of how groundwater contaminants may act in the local aquifer?

Not at all				Very Much
1	2	3	4	5

12. Which diagrams, pictures or images most increased your understanding of how groundwater moves through the Opportunity area?

….the least?

13. Which diagrams, pictures or images were most helpful at increasing your understanding of groundwater contaminants?

….the least?

Section 3: Arsenic as a local groundwater contaminant; update on cleanup activity

14. Did this section increase your understanding of Arsenic as a groundwater contaminant?

Not at all				Very Much
1	2	3	4	5

15. Did this section help explain where Arsenic, as a specific groundwater contaminant may come from in the Opportunity area?

Not at all				Very Much
1	2	3	4	5

16. Was this section effective at explaining the official concept for the pattern of groundwater contamination in Opportunity?

Not at all				Very Much
1	2	3	4	5

Not at all				Very Much
1	2	3	4	5

17. Did this section increase your understanding of what a "TI" waiver is and how it affects the cleanup?

18. Which diagrams, pictures or images most increased your understanding of where groundwater contamination comes from and how it acts?

….the least?

19. Overall, how helpful was this presentation at addressing things you wanted to know about groundwater in and around Opportunity?

Not at all				Very Much
1	2	3	4	5

20. Overall how helpful was this presentation to your understanding of the safety of your well water?

Not at all				Very Much
1	2	3	4	5

21. What questions do you still have about groundwater?