4.0 IMPACTS OF PROGRAM TECHNOLOGIES

4.1 INTRODUCTION

This chapter describes the potential environmental impacts resulting from implementing Program technologies. For each environmental resource, the following topics are addressed in this chapter:

- **Impact Considerations** – Describes the thresholds, features or outcomes that were considered when assessing the potential of a technology to cause impacts. The severity of an impact relates to the value of affected resources, as well as the magnitude and frequency of the potential impact. Section 4.1.1 discusses the methodology in further detail.

- **Generalized Siting and Operational Impacts of Technologies** – Describes the potential impacts of each respective technology. The discussions are intended to provide the reader with a sense of the typical issues, concerns, and potential impacts that may be expected from siting and operation of a project involving a particular technology.

- **Mitigation of Potential Adverse Impacts** – Provides guidance with respect to significant impacts that should be avoided during site selection for future projects and recommends Best Management Practices (BMPs) and other measures that should be followed to mitigate potential adverse impacts during project planning, design, construction, and operation.

- **Regional Considerations** – Describes factors related to general environmental conditions in states that may create special concerns for the siting and operation of various technologies. Such conditions may relate to climate factors and other constraints that impose critical limitations or increased sensitivity for specific resources. The basis for environmental impacts includes the settings for all 50 states.

- **Summary of Potential Impacts** – Provides a graphic representation to summarize the potential impacts of each model project with respect to the considerations presented at the beginning of each section.

4.1.1 Impact Assessment Methodology

In this chapter, impact levels or ranges were assigned to each resource criteria for each individual technology. The following impact levels and their definitions were used:

- **Negligible Impact** – The impact is neither noticeable nor perceptible. Little or no change to environmental conditions is expected. For example, operations of new systems or technologies would have negligible impacts if they operate within industry and regulatory standards, meet BMPs, and conform to relevant environmental permit conditions. Processes where environmental degradation would be strictly controlled or fully mitigated, or would not interact with environmental resources could also result in negligible impacts.
- **Minor Adverse Impact** - The impact would be short-term and/or localized. The impact would fall within acceptable permit or regulatory limits, or would occur very infrequently, as in the case of a mishap. The duration of short-term impacts may include the timeframe for construction of a system, such as in the case of land disturbance for the installation of pipeline systems. Localized impacts would generally be those that fall within 1 mile of the footprint of the associated action. Exceptions to the definition of localized impacts will be discussed in the subsequent resource sections.

- **Moderate Adverse Impact** – The impact would be short-term and widespread or long-term and localized. The impact would result in discharges within acceptable permit limits, could be mitigated through BMPs or operational controls, or would occur very infrequently as in the case of a mishap. Widespread impacts are defined as occurring beyond limits defined for localized impacts. Long-term impacts are defined as exceeding the duration of short-term impacts.
- **Significant Adverse Impact** – The impact would be long-term and widespread. The impact would result in violation of environmental statutes and regulations, despite mitigation measures.
- **Beneficial Impact** – The impact would enhance or protect environmental resources, by the prevention of discharges that would normally occur otherwise, restoration of previously degraded environments or by creating a socio-economic benefit.

4.2 ATMOSPHERIC RESOURCES

This section describes the potential impacts to atmospheric resources (air quality and GHG reduction) that could occur during the implementation of carbon sequestration technologies. The atmospheric resources that could be affected by sequestration technologies are described in Section 3.2. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.2.1 Impact Considerations

Potential impacts on air quality have been assessed using the considerations outlined below and the definitions found in Section 4.1.1. Short-term impacts for atmospheric resources are defined as impacts occurring during the construction timeframe. Localized impacts for atmospheric resources are defined as those occurring within 25 miles of the relevant source.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- violate a NAAQS primary standard or contribute substantially to existing or projected violations.
- degrade air quality locally, regionally, nationally.
- cause air pollution that would increase the hazard quotient or cancer risk to the public.
- conflict with or obstruct implementation of a local or regional air quality management plan.
- create objectionable odors affecting site personnel or neighborhoods beyond the site boundary.
- substantially increase greenhouse gas emissions.

4.2.2 Regulatory Framework

Geologic sequestration technology is targeted at the large-scale reduction of CO_2 emitted into the atmosphere from anthropogenic sources. There are currently no regulatory limits on CO_2 emissions from point sources under the federal Clean Air Act, although some states are imposing their own CO_2 reduction goals as described in Appendix A. There are also no air permit regulations at the state or federal level regarding the transport of compressed CO_2 or the injection of CO_2 underground. As carbon sequestration technologies advance, a regulatory framework could be required for permitting and monitoring potential air emissions or releases attributable to CO_2 storage, transmission and injection.

CO_2 releases or leaks from geologic formations are unlikely to occur if proper project planning and formation characterization are conducted. Catastrophic releases of naturally occurring CO_2 are usually associated with areas of volcanic activity. In such cases, CO_2 finds its way to the land surface where, due to its heavier-than-air density, it pools near the ground in high concentrations. Near these volcanic areas, wildlife, plant life and humans have died from asphyxiation when CO_2 displaces oxygen. Asphyxiation can occur when the atmospheric oxygen is less than 16 percent (Rice, 2004). Because the sudden release of a large quantity of CO_2 can have ground-level impacts on nearby flora, fauna and humans, monitoring for leaks in and around pipelines and around injection points is an important consideration of any system design. Identifying and properly abandoning obsolete wells in the area of influence for geologic sequestration projects is also an important step to prevent unintentional CO_2 leaks. Transmission piping and wells should be located to allow for adequate dispersion of CO_2 (away from populated areas and environmentally sensitive areas) in the event of an accidental release.

In general, impacts on atmospheric resources or air quality from the implementation of carbon sequestration technologies would be related to the types of technologies used, intensity of construction activities that could increase airborne dust and tailpipe emissions, the potential release of chemicals used to convert or capture CO_2, the potential release of CO_2 or other gases during transfer or transportation via truck or pipeline, emissions from compressors and other equipment that are needed to transport and inject CO_2 underground, and the overall effectiveness and potential of technologies to reduce GHGs and other air pollutants.

Overall, carbon sequestration projects would need to consider applicable air quality laws and regulations at the federal, state and local levels to determine applicable permitting requirements. A list of federal air quality laws and regulations is provided in Table 4-1. For example, stationary sources of air pollution, such as generators, compressors and heating units used in the distribution and injection of CO_2 in geologic formations, would need to conform to applicable New Source Performance Standards. While most carbon sequestration programs may be implemented by the private sector, projects that receive federal funding in whole or in part would be required to conduct a clean air act conformity analysis under 40 CFR 51 Subpart W.

Table 4-1. Major Laws, Regulatory Requirements and Plans for Air Quality

Law/Regulation	Key Elements and Thresholds
National Ambient Air Quality Standards (NAAQS) 40 CFR 50	Primary and secondary standards designed to protect the public health and welfare. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. The EPA Office of Air Quality Planning and Standards (OAQPS) has set NAAQS for six principal pollutants, which are called "criteria" pollutants: carbon monoxide, lead, nitrogen oxides (NO_X), particulate matter, ozone and sulfur oxides (SO_X). Areas that experience ambient air levels of one or more of these criteria pollutants above the NAAQS are deemed to be in "non-attainment" and Regional Air Quality Conformity rules must be evaluated for new projects within the area.
Prevention of Significant Deterioration (PSD) 40 CFR 52.21	Prevent major sources in "unclassified" or "attainment" areas from creating large ambient impacts in excess of PSD increment standard and impaired visibility. Divide the U.S. into two classification categories: Class I (public lands that have special protection under the CAA) and Class II (remainder of the U.S.) Triggered if emissions of a single regulated pollutant equals or exceeds 250 tons per year, or 100 tons per year for each of the 28 major source categories.
New Source Review (NSR)	Federal preconstruction permitting program incorporating both NSR (applicable to sources of pollutants for which the area is nonattainment) and PSD (for major sources in other areas) to prevent new sources of emissions from deteriorating air quality beyond acceptable levels.
National Emission Standards for Hazardous Air Pollutants (NESHAPs) 40 CFR 61 and 63	Regulated emissions of 188 hazardous air pollutants (HAPs).
New Source Performance Standards (NSPS) 40 CFR 60	New source performance standards apply to new sources in designated source categories.
Title V Operating Permit 40 CFR 70 and 71	Operating permit program assures compliance with standards, recordkeeping, testing, and compliance at major sources of criteria and HAP emissions. Requires a Federal Operating Permit for major sources of regulated pollutants and a compliance plan for meeting each regulatory requirement. Designation of a major source is contingent on the attainment status of the air basin.

Law/Regulation	Key Elements and Thresholds
Determining Conformity of General Federal Actions to State or Federal Implementation Plans 40 CFR 51 Subpart W	All federal actions must conform to the applicable State Implementation Plan (SIP). Only pollutants for which the area is classified as nonattainment are included in the conformity determination. All construction related and non-permitted sources of emissions must be included in the conformity determination. If annual emissions exceed the significance threshold, a full conformity analysis is performed to ensure the project would not contribute to violation of the SIP. Modeling, offsets, and/or additional mitigation measures can be used to help the project conform.

4.2.3 Generalized Siting and Operational Impacts of Technologies

4.2.3.1 Post-Combustion Capture

Post-combustion capture projects would be retrofitted to existing, or added to proposed, fossil fuel combustion facilities. Combustion of fossil fuel results in emissions of CO_2 at a rate of 5 to 15 percent of the exhaust stream (Benson, 2004). Section 2.5 provides example model project descriptions that indicated the potential capture rate for small and moderately sized projects.

The ability to capture CO_2 at its point source would result in improved air quality and a reduction in GHGs. Some other pollutants, such as SO_x, NO_x, and PM, would be captured in the CO_2 stream. However, according to model project estimations, other pollutants from the post-combustion capture process would account for less than 0.5 percent of the total composition of the captured gas. Because the side reactions of SO_x and NO_x with amines tend to form soluble salts, thus consuming expensive reagent solvent and potentially creating additional waste streams, an optimal site selection criterion for application of these technologies would be for the existing coal-fired power plant to already be equipped with flue gas desulfurization (FGD) and selective catalytic reduction (SCR) systems for SO_2 and NO_x control, respectively.

This technology could potentially be used throughout the country; however, regional differences are difficult to predict. Therefore, the location of probable sinks for CO_2 and their proximity to existing sources would likely result in regional differences in the degree of implementation.

Another consideration is that the need to transport solvent (amine solution) in large quantities to the project site and to remove process related wastes (sludge and spent carbon) would result in increased traffic related emissions. These emission increases could potentially be reduced by transporting raw materials and wastes by rail wherever feasible.

The post-combustion capture process could cause minor adverse impacts in the form of increasing the emissions of regulated air pollutants, associated with the expected compression and transport operations that would follow the capture process. The capture process would have negligible impacts in terms of toxic and hazardous air pollutants, air quality management plans, and objectionable odors, as the process would not cause new air pollutants to be emitted. The process is designed to capture CO_2, resulting in a beneficial impact in the category of unregulated air pollutants.

4.2.3.1.1 Comparison of Power Plant Emissions with and without Carbon Sequestration

To illustrate the difference in air emissions between a conventional coal-fired power plant and one with CO_2 capture and sequestration, baseline air emissions from four conventional coal-fired power plants ranging from 299 to 358 MW were analyzed (see Table 4-2). Then the emissions anticipated from a similar plant with CO_2 capture, compression, transport and injection into a geologic formation were estimated (see Table 4-3). It is estimated that the CO_2 capture process removes 90 percent of the plants emissions. However, the equipment used to compress, transport and inject the CO_2 (which could be fossil-fueled) may emit additional air pollutants. The net emissions from the entire CO_2 sequestration process were then compared with the emissions from the plant without CO_2 capture. In this example, it is estimated that 83 percent of CO_2 emissions would be avoided under the sequestration process. However, NOx emissions would be 12 times greater overall under the sequestration option (assuming model project parameters for coal seam sequestration) when compared to the emissions of the power plant alone. Under this CO_2 sequestration example, the approximately 1,800,000 tons/year of CO_2 releases are avoided, while NOx releases would increase by approximately 40,000 tons/year. The amount of NOx released could be reduced through use of electric-powered equipment or low-NOx fossil-fueled equipment.

Table 4-2. Air Emissions from Coal-Fired Power Plants

Representative Power Plant (EIA, 2005, EPA, 2005)	**Nameplate Capacity** (MW)	**Coal Type**	**CO_2 Emissions** (tons CO_2 per year)	**NO_x Emissions**(tons per year)	**SO_2 Emissions** (tons per year)
Will County, IL Unit 3	299	Sub bituminous	1,246,847	1,180	2,575
HL Spurlock, KY Unit 1	305	Bituminous	2,253,244	4,632	18,589
Naughton, WY Unit 3	326	Bituminous	2,546,225	4,595	4,462
Colstrip, MT Unit 1	358	Bituminous	2,763,954	5,370	7,089
Average	322		2,202,568	3,944	8,179

Table 4-3. Comparison of Power Plant Emissions, With and Without Carbon Sequestration

Case (nominal 300 MW plant)	**CO_2 Emissions From Power Generation And Carbon Capture** (tons CO_2 per year)	**Other Air Emissions From Power Generation** (tons per year)	**Air Emissions From CO_2 Compression And Transport** (tons per year)	**Air Emissions from CO_2 Injection at a Coal Bed Methane Site** (tons per year)	**Total Emissions (tons per year)**
Example Coal Fired Power Plant with Carbon Capture	220,257	NOx 3,944 SO_2 8,179	CO_2 150,584 NO_x 44,336 SO_2 (NC)	CO_2 5,052 NOx < 1 SOx (NC)	CO_2 375,893 NOx 44,336 SOx 8,179
Example Coal Fired Power Plant without Carbon Capture	2,202,568 (see Table 4-2)	NOx 3,944 SO_2 8,179	None	None	CO_2 2,202,568 NOx 3,944 SOx 8,179

Note: NC means "not calculated"

4.2.3.2 CO_2 Compression and Transport

Compression and transport of CO_2 are well-established technologies that are used routinely for sequestration, beverage carbonation, and fire suppression (Benson, 2004). Uncontrolled releases of CO_2 from tanks and pipelines can be prevented through safety procedures, pressure testing of vessels and lines automated shut-off valves. Detection of releases can be improved by adding chemical odorants, like those added to natural gas, which would be especially beneficial around more populous areas (Heinrich, et. al, 2003).

The transport of CO_2 both by truck and by pipeline would contribute somewhat to air pollution and would generate additional CO_2 over the life of the project. Internal-combustion engine compressors would generate the majority of air pollutants including CO_2. It is likely that equipment to compress and pump CO_2 would require air permits. Other components of pipeline transport would include intercoolers, dehydrators, and water knockouts. Collectively, these stationary sources of air emissions for each pipeline project may meet the definition of a major source under the Prevention of Significant Deterioration (PSD) standard. Although trucks are considered mobile sources and their emissions do not fall under New Source Review regulations, their emissions would be counted in any Clean Air Act conformity analysis performed for federally funded projects. The decision to truck CO_2 or to construct a pipeline would likely be dictated by project quantities and economics. For small field validation-scale projects, trucking CO_2 to underground injection sites is expected to be the simplest and least expensive transport option. However, a larger-scale project justifies the construction of pipelines.

> Highest risk areas for leakage of CO_2 back to the atmosphere are associated with the injection wells, abandoned wells that could provide short-circuits to the surface, and inadequate characterization of the storage site (e.g., undetected faults).

The use of gas-fired compressors and heaters would introduce new sources of criteria pollutant emissions. However, impacts to air quality would be minor because it is assumed that equipment would conform to applicable air quality regulations and BACT. The compression and transport process would not introduce toxic or other hazardous air pollutants, nor create objectionable odors. Assuming all relevant air permits would be obtained, the process would not impact air quality management plans. The compression and transport process is a key element of geologic sequestration of CO_2. Subsequently, the process would have a beneficial impact towards reducing greenhouse gas emissions.

4.2.3.3 Sequestration in Coal Seams

Air impacts from sequestration in coal seams are associated with both construction and operation aspects of the project. Construction activities that may contribute to short-term air emissions include land clearing, providing access roads to the project site, drilling wells, installing CO_2 pipeline to wells, installing equipment, and running utilities to the site. To operate the system, gas-fired heaters would be employed at the well head.

The highest probability risk areas for leakage of CO_2 back to the atmosphere are associated with the injection wells, abandoned wells that provide short-circuits to the surface, and inadequate characterization of the storage site, such as not detecting faults (Benson, 2004). Leaks can be detected through monitoring systems at the wells and by deploying surface-flux monitoring of CO_2. See Section 2.2.3 on monitoring, mitigation and verification (MM&V) techniques.

For the reasons cited under the compression and transport process (4.2.3.2), the process of sequestering CO_2 in coal seams would have:

- a minor adverse impact with regard to increases in regulated air pollutants (due to use of gas-fired compressors and heaters);
- a negligible impact with regard to release of toxic and hazardous air pollutants;
- a negligible impact on air quality management plans;
- a negligible impact with regard to causing objectionable odors; and
- an overall beneficial impact by reducing greenhouse gas emissions.

4.2.3.3.1 Air Permitting for Coal Bed Methane (CBM) Projects

Carbon sequestration in coal seams would utilize similar equipment to that used in traditional CBM recovery projects. Therefore, air permitting requirements for carbon sequestration in coal seams (with or without CBM production) should be similar to those at existing CBM project sites. Stationary air emission sources associated with general CO_2 transport and compression (prior to injection) that are found under Section 4.2.3.2 "CO_2 Compression and Transport" would be included in the permitting of coal seam sequestration projects.

The process of CBM extraction requires the construction and operation of wells to access the gas and compressor stations to extract the gas. The compressor stations consist of various pieces of equipment with the potential to emit pollutants at varying levels depending on equipment capacities. In addition, the facility may incorporate a CBM powered generator (well-head generator) located on top of the well to generate electricity. In these cases, the generator would also be a source of pollutant emissions. A typical compressor station harvesting CBM will incorporate from 1 to 3 compressor engines varying in power from 100 to 500 hp. Operation of these natural gas fired engines results in the emission of regulated air pollutants including CO, NO_x, VOCs, SO_x, and PM-10 (Montana DEQ, 2005).

As an indicator of the types of air permit conditions that may be required for coal seam carbon sequestration projects, the Record of Decision for the Montana Statewide CBM EIS outlined the following conditions and mitigation procedures (Montana DEQ, 2003):

- *"Natural gas-fired field compressors, serving groups of wells, are generally permitted as minor sources. Best Available Control Technology (BACT) emission limits are established at the time of permit issuance and are established on a case-by-case basis.*
- *The larger scale compressors, serving several field compressors, will likely be permitted as major sources. BACT emission limits will be established for each compressor on a case-by-case basis.*
- *By administrative rule and, typically, by permit, reasonable precautions must be taken to control fugitive dust. Generally, opacity of emissions of airborne particulate matter is limited to less than 20 percent. Operators are required to keep fresh water and/or chemical dust suppressant available for the purpose of controlling fugitive dust.*
- *In addition, at least one regional-scale ambient monitoring station will be established and maintained. Criteria pollutants that will be monitored are NO_x, O_3, and PM-10. Data gathered by the monitoring program will be used to model cumulative impacts."*

Similarly, in Wyoming, CBM recovery projects require NAAQS analysis for compliance with NO_x standards. This analysis requires using the ISCST3 model and 7.5 minute Complex Terrain Data, using at least one year of on-site meteorological data (Wyoming, 2000). In addition, permits for generators operating at CBM well sites are required. New generators must also meet Best Available Control Technology (BACT), which at a minimum meets EPA/California certified emissions. However temporary diesel- or gas-fired generators may operate for up to 6 months under a waiver issued by the state (Wyoming, 2001).

The implementation of coal seam sequestration projects would require permitting of applicable source equipment in accordance with local, state and federal clean air requirements. To minimize air pollution associated with this technology, equipment should conform to the BACT.

> Projects would require permitting of applicable source equipment, such as compressors and generators, in accordance with local, state and federal clean air requirements. To minimize air pollution, equipment should conform to the Best Available Control Technology (BACT).

4.2.3.4 Sequestration in Depleted Oil and Gas Reserves

Air impacts and permitting associated with sequestration in depleted oil and gas reserves would be similar to those for coal seams. However, due to the potential for a larger number of wells and abandoned wells at existing oil and gas reserves, the possibility for leakage of CO_2 is somewhat greater. Careful site selection and review of all wells or other surface conduits in the area must be conducted when designing a sequestration system at an oil or gas reserve.

The impacts to air resources for EOR would be similar to those for the compression and transport process.

4.2.3.5 Sequestration in Saline Formations

The impacts to air resources for saline formation sequestration would be similar to those for the compression and transport process.

4.2.3.6 Sequestration in Basalt Formations

Air impacts and permitting associated with sequestration in basalt formation would be similar to those for coal seams, and operational air impacts would generally relate to emissions from compression, transport and injection equipment. However, as CO_2 may react with the basalt causing mineralization, the long-term potential for leakage of CO_2 would be less than other geologic sequestration methods.

> It is possible that the dissolved CO_2 would undergo a mineralization reaction with the calcium, magnesium, and iron silicates within a basalt formation producing carbonate minerals and amorphous quartz.

The impacts to air resources for basalt formation sequestration would be similar to those for the compression and transport process.

4.2.3.7 Terrestrial Sequestration-Reforestation

Many terrestrial sequestration projects involve planting of trees on a large scale. Terrestrial sequestration generally will not have air permitting issues, unlike the other CO_2 transport and geologic sequestration technologies.

Planting of trees or other plant material may involve use of heavy machinery for land clearing, grading, tilling, fertilizing, spreading of seed or other mechanized planting methods. The air emissions associated with these activities would be short-term and within existing air regulations.

As discussed below, the ability of forests to sequester carbon would be greatly dependent on a variety of factors, such as adverse weather events (drought, hurricanes), forest fires, air pollution, global warming, insect damage and/or tree-disease. Discussion of the potential rates of sequestration possible per acre of planting is discussed in Section 2.5. Under adverse conditions or as trees reach the end of their natural lifespan, some or all of the carbon captured by forests could be reversed (released) back into the atmosphere.

Terrestrial reforestation projects would have negligible impacts in terms of regulated air pollutants, toxic and hazardous air pollutants, air quality management plans, and objectionable odors. Reforestation would have a beneficial impact on unregulated air pollutants by taking up additional CO_2 from the air.

4.2.3.7.1 Effects of Climate Change and Natural Events on Sequestration in Vegetation

Climatic conditions can greatly influence the ability of vegetation to grow and perform photosynthesis, which directly affects the amount of carbon that plants can sequester (Watson et al., 2000). Plants do not grow in the winter in non-tropical regions; therefore, carbon uptake occurs from spring through fall in these areas (Ramanujan, 2002). Also, during the winter there is a loss of carbon back to the atmosphere as shed leaves and other plant material decomposes (ScienceDaily, 2002). Relatively warm early-spring temperatures can cause earlier leaf emergences by plants, which allows a longer growing season and an increased amount of carbon sequestered (Chen et al., 1999). Any climatic conditions, such as drought and cloud cover, that restrain elements necessary for plant growth during the growing season (water, light, etc.) will inhibit the amount of carbon that can be sequestered in vegetation (Hanson, 2001). Hurricanes and other major storm events in forested areas can have a major negative effect on carbon sequestration because they leave large amounts of dead trees in their wake that decompose and subsequently release the carbon that was stored in them back into the atmosphere (ScienceDaily, 2002). Other natural events, such as forest fires, can also reverse carbon sequestration in soils and trees by releasing stored carbon back into the atmosphere (EPA, 2005).

4.2.3.7.2 Effects of Air Pollutants on Tree Health

Trees sequester many pollutants from the atmosphere, including NO_2, SO_2, O_3, CO, and PM-10 (American Forests, 2005). However, high levels of air pollution are known to cause stress in trees and other plants, markedly decreasing their ability to ward off disease and pests and can limit their rate of growth.

Nitrogen deposition can degrade forest ecosystems by increasing sensitivity to frost, reducing net primary production, and leaching of nutrients, especially in areas where soil nitrogen levels are high and have reached, or are approaching, saturation. In a study of 4 areas of the northeastern U.S., the areas with the greatest frequency of problems from forest insects and disease also receive the highest deposition of sulfur and nitrogen and/or have the highest annual exposure to ground-level ozone (EMAN, 2003).

Forests have been predicted to grow faster under increased levels of CO_2 and so fix more carbon than possible under ambient conditions. However, along with the increasing concentrations of CO_2 in the atmosphere are increasing concentrations of tropospheric ozone. O_3 damages plant foliage and reproductive systems and adversely affects the growth processes. The impact of the interaction between increased concentrations of both atmospheric CO_2 and O_3 on forests can be varied, but is relatively unknown. Current research suggests that the presence of elevated concentrations of ozone will likely negate the potential for increased growth and carbon sequestration from higher concentrations of CO_2 (EMAN, 2003).

Further evidence of the uncertain effects of global climate change on carbon sequestration is found in a study of the interaction of forests exposed to SO_2 emissions. Boreal forest sites (northern forests generally dominated by coniferous trees) exposed to SO_2 captured drastically less CO_2 than control forests. It was found that SO_2 pollution affected trees even in remote regions, suggesting that an extensive region of the boreal forest may be impacted. Given that the boreal forest composes a large proportion of the estimated global forest carbon sink, the lowered carbon sequestration capacity related to SO_2 pollution may be globally significant (EMAN, 2003).

The interaction of elevated CO_2 and O_3 levels also can also affect forest pest feeding and larval growth as well as the chemical composition and defensive qualities of foliage. As a result, the incidence and severity of insect attack and disease outbreak may increase. One study showed sap-feeding aphids were five times more abundant on aspen species under high O_3 conditions than control plots, while natural number of enemies of the aphids where halved (Percy et al. 2002). Under both high ozone and CO_2, the aphids tripled in numbers while their enemies increased just slightly. In addition, trees may also be under considerably more stress in a changed climate leaving them more susceptible to insects and diseases, than they are currently, thus reducing any net benefit of increased temperature on carbon sequestration in forests (EMAN, 2003).

> Trees can sequester many pollutants from the atmosphere. However, high levels of air pollution are known to cause stress in trees, markedly decreasing their ability to ward off disease and pests, and can limit their rate of growth.

As forest health and growth is a key component of a successful carbon sequestration project, localized atmospheric pollution may be a consideration in the siting of these projects. Trees planted should be disease and pest resistant, and appropriate to the local climate. To be effective, monitoring programs for terrestrial sequestration projects should also include parameters to evaluate general tree health and identify the presence of new or increased pest populations.

4.2.3.7.3 Forest Maintenance

To maintain forest health, prescribed burning of understory material is an accepted industry practice for mature stands. The primary purpose of prescribed burning is to reduce the hazardous accumulations of forest fuels. This aids in the prevention of wildfires, reduces the intensity of the fires, and also provides a foundation for safer, more effective fire suppression and protection operations. This burning is usually limited in scope and actively monitored by fire officials. Although prescribed burning would generate particulate matter and CO_2 on a routine basis, it would significantly reduce the chances of a larger forest fire that would not only generate more and lasting particulate pollution, but would eliminate the benefits of the forest to sequester carbon. Prescribed burning plans need to be submitted to the applicable state forest fire service for approval.

Management of smoke from prescribed burning is a critical issue. It can affect air quality, highway traffic, and nearby properties, and is subject to federal and state air pollution laws. Recent changes in the NAAQS require reduced emissions of particular matter, as well as gaseous emissions. All adjacent smoke-sensitive areas must be identified in the burning plan. Wind direction and speed, and smoke dispersal are some of the atmospheric characteristics that should be considered before conducting a burn. Firing techniques also affect smoke emissions. Hot summer burns, usually called backfires (i.e., moves in the direction of the wind), burn slowly and consume a large amount of fuel. Backfires produce considerably less emissions than other firing techniques (NJDEP, 2004). Mechanical removal of fuels may reduce emissions from controlled burning substantially. Methods of removing fuels from a forest include onsite chipping of woody material, or even allowing grazing of grassy and bushy fuels by sheep, cattle or goats.

4.2.3.8 Co-Sequestration of H_2S and CO_2

In the case of sequestering CO_2 from sour gas fields or IGCC plants, H_2S gas would also be captured and sequestered. The concentration of H_2S is assumed to be 2 percent for a typical IGCC gas stream and 25 percent on average for a typical sour gas processing plant waste gas stream.

Air impacts and permitting associated with co-sequestration of H_2S (compression and transport) would be similar to those for coal seams. The gas streams would typically contain between 2 and 25 percent H_2S, and subsequently would require pipelines and ancillary equipment to be able to withstand the corrosive properties of H_2S. Transport piping and injection wells may require additional safeguards to prevent catastrophic releases of the gas.

Gas streams that contain H_2S would generally be sequestered by injecting it into oil and gas reserves or into deep saline formations. This cost-effective method of disposal of H_2S would provide incentives for operators of IGCC and sour gas plants to sequester CO_2 that would normally be released into the atmosphere.

The impacts to air resources for co-sequestration of H_2S and CO_2 would include the minor adverse (localized) impacts associated with the release of minor amounts of criteria pollutants associated with the operation of compression and injection equipment. While it is expected that equipment and processes would meet all safety regulations to prevent the inadvertent release of gases, an inadvertent release could cause minor adverse impacts (localized and short-term), causing the release of toxic and hazardous air pollutants and causing objectionable odors. The process overall would result in a beneficial impact (long-term emissions reductions) to atmospheric resources in terms of unregulated air pollutants.

4.2.4 Mitigation of Potential Adverse Impacts

Based on possible impacts of technologies identified in Section 4.2.3, this section outlines measures recommended to mitigate potential adverse impacts of carbon sequestration projects on air quality.

4.2.4.1 Project Planning and Design

- Determine the air impacts associated with operation of CO_2 compression and injection equipment as applicable. Consult state air permitting officials to determine if the project will meet emission standards as designed.

- If the project is sponsored by the federal government and located in a non-attainment area for one or more criteria pollutant, conduct a clean air applicability analysis of the project to determine conformance to the applicable SIP.

- Locate pipelines and injection areas away from populated areas.

- For terrestrial sequestration projects, ensure local air quality will not significantly limit tree growth or health.

4.2.4.2 Construction

Before beginning a construction project, a construction permit from the state or local air permitting agency is generally required. Because most major air impacts of construction projects are local and temporary, many states do not require modeling of air quality impacts. Instead, agencies may require that certain mitigation practices are utilized, such as watering areas of soil disturbance to control fugitive dust.

Table 4-4 lists types of pollutants that can be generated during construction and site preparation activities.

Table 4-4. Pollutants and Factors Influencing Emissions from Construction of Carbon Sequestration Projects

Activity	Pollutants	Factors
Vehicular Traffic	CO, NOx, VOCs, particulates, SO_2, air toxics	Vehicle- miles traveled, travel speed
Vehicle Fugitive dust from paved and unpaved roads	Particulate	Vehicle-miles traveled, road conditions (e.g., silt loading, silt content, moisture content, vehicle weight)
Construction fugitive dust from earthmoving activities	Particulate	Acres disturbed
Construction equipment exhaust	CO, NOx, VOCs, particulates, SO_2, air toxics	Volume of fuel used
Emergency or permanent[1] generators	CO, NOx, VOCs, particulates, SO_2, air toxics	Volume of fuel used or hours of operation

[1] (Definition of emergency and permanent use of generators may vary according to state air rules)
Source: DOE, 2004.

The following BMPs can be employed to mitigate air emissions associated with construction activities.

- Dust abatement techniques should be used on unpaved, unvegetated surfaces to reduce airborne dust.
- Unpaved access roads should be surfaced with stone whenever appropriate.
- Construction materials and stockpiled soils should be covered to reduce fugitive dust.
- Disturbed areas should be minimized.
- Land should be watered prior to disturbance (excavation, grading, backfilling, or compacting).
- Disturbed areas should be revegetated as soon as possible after disturbance.
- Soil should be moist while being loaded into dump trucks.
- Dump trucks should be covered before traveling on public roads.
- Use of diesel or gasoline generators for operating construction equipment should be minimized.

4.2.4.3 Operation

The operation of carbon sequestration technologies may include the use of generators for compression and transport of CO_2 and vehicle travel that may generate fugitive dust and vehicular exhaust. Each project should evaluate where electricity lines can be run to equipment to avoid the use of internal combustion generators wherever feasible. Where utility lines are not practical, use of the BACT for compressors, pumps and heaters should be employed. The use of freight trains to transport raw materials where economically feasible may reduce air emissions associated with frequent truck traffic.

To reduce the possibility of accidental release of captured CO_2 from geologic sequestration projects, the following guidelines should be followed:

- Pressure test all pipelines and wells before placing them into service.
- Install automatic shut-off valves along pipelines and at the well-points.
- Install monitoring equipment to measure releases of CO_2 from the surface above geologic formations (MM&V).

4.2.5 Regional Considerations

Air permitting and regulations would vary depending on state requirements and the presence or absence of non-attainment areas. Geologic sequestration projects proposed in states that have non-attainment areas for CO and/or O_3 may find it difficult to permit a multitude of gas-fired compressors and pumps. These difficulties can be overcome by using equipment with BACT, extending electric utility lines to equipment and/or buying air emission credits. Construction activities for all sequestration technologies produce emissions associated with earth moving, equipment operation and vehicle traffic. However, these air impacts are usually short term and particulate matter emissions can be reduced significantly through dust-control strategies.

4.2.6 Summary of Potential Impacts

Table 4-5 provides an overall qualitative assessment of potential impacts to atmospheric resources for each sequestration technology.

All program technologies (other than terrestrial sequestration) would emit regulated pollutants on a recurring basis for the operation of compressors, pumps and heaters to transport gas streams. Assuming all project components would be properly permitted under applicable local, state and federal air emission guidelines, these emissions would pose minor to negligible impacts to air quality. These technologies are not expected to affect air quality management plans assuming that the BACT are used.

Co-sequestration projects have the potential to accidentally release varying amounts of H_2S with CO_2 to the atmosphere. Therefore, while impacts are not expected to be significant under this generally proven safe technology, there may be rare and minor (short term and localized) adverse impacts in the realm of accidental release of toxic pollutants and/or objectionable odors.

All carbon sequestration technologies are designed to remove CO_2 from the atmosphere or avoid its release into the atmosphere. Therefore all Program technologies would result in a net benefit in terms or reducing greenhouse gas emissions or atmospheric concentrations.

Table 4-5. Potential Impacts of Program Technologies on Atmospheric Resources

Impact Considerations	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Regulated air pollutants	○	○	○	○	○	○	·	○
Toxic and hazardous air pollutants	·	·	·	·	·	·	·	○
Air quality management plans	·	·	·	·	·	·	·	·
Objectionable odors	·	·	·	·	·	·	·	○
Greenhouse gases	+	+	+	+	+	+	+	+

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

4.3 GEOLOGIC RESOURCES

This section describes the potential impacts to geologic resources (which includes soils, geology, and groundwater) that could occur during the implementation of carbon sequestration technologies. The geologic resources that could be affected by sequestration technologies are described in Section 3.3. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.3.1 Impact Considerations

The impacts to geologic resources as a result of implementing carbon sequestration technologies would be dependent on the specific location of the proposed project. Geologic resources that could be impacted include soils, mineral resources, and groundwater sources (especially sole source aquifers, but also including all sources of drinking water).

Impacts of sequestration projects must be evaluated on a site-specific basis and would depend on a multitude of site conditions, the surrounding environment, and the technology implemented. Although the construction and site preparation could impact the geologic resources of an area, the majority of impacts would be related to the operational and post-operational periods of the project.

Potential impacts on geologic resources have been assessed using the considerations outlined below and the definitions found in Section 4.1.1. Short-term impacts for geologic resources are defined as impacts occurring for less than 1 year. Localized impacts for geologic resources are defined as those occurring within 25 miles of the project.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- cause potential for local seismic destabilization and damage to structures.
- potentially destroy high-value mineral resources or unique geologic formations, or render them inaccessible.
- cause excessive soil erosion that cannot be mitigated in site planning and design.
- require the conversion of active prime or unique farmlands to nonagricultural use.
- degrade or adversely alter the quantity or quality of groundwater within a sole source aquifer.
- deplete groundwater supplies or interference with groundwater recharge affecting available capacity of a public water source.
- conflict with established water rights or regulations protecting groundwater for future beneficial uses.
- contaminate a public water supply aquifer, causing violations of water quality criteria or standards established in accordance with the Safe Drinking Water Act, state regulations, or permits.
- conflict with aquifer management plans or goals of governmental water authorities.

4.3.2 Regulatory Framework

Carbon sequestration projects must comply with applicable Federal, State, and local laws and regulations concerned with geologic resources. The principal federal laws and regulations pertaining to these resources are listed in Table 4-6.

Table 4-6. Major Federal Laws and Regulatory Requirements for Geologic Resources

Law/Regulation	Key Elements
Safe Drinking Water Act of 1974 (42 USC § 300(f))	The SDWA specified a system for the protection of drinking water supplies, including underground sources of drinking water, through the establishment of contaminant limitations and enforcement procedures. Part C of the Act established the UIC Program to provide safeguards so that injection wells do not endanger current and future USDW.
40 CFR 144 - 149, Underground Injection Control Program.	The regulations establish minimum requirements for UIC programs, technical criteria and standards, and the construction, operation, monitoring, and reporting requirements of the program. Wells used to inject fluids for enhanced recovery of oil or natural gas are regulated as Class II wells under the program.
Soil Conservation and Domestic Allotment Act (16 USC § 5901)	This Act authorized the Secretary of Agriculture to conduct soil erosion surveys and prevention measures, and it established the Natural Resources Conservation Service to conduct these activities. Emphasis was given to engineering operations, methods of cultivation, growing of vegetation and other land uses as preventative measures.
Farmland Protection Policy Act of 1981 (7 USC § 4201)	The FPPA is intended to minimize the impact Federal programs have on the unnecessary and irreversible conversion of farmland to nonagricultural uses. It assures that—to the extent possible—Federal programs are administered to be compatible with state, local units of government, and private programs and policies to protect farmland.

4.3.3 Generalized Siting and Operational Impacts of Technologies

This section discusses the potential impacts to geologic resources based on the description of the various capture, transportation, and sequestration technologies in Section 2.5 and the geologic resources in Section 3.3. When applicable, monitoring, mitigation and verification (MM&V) methods are described with regard to mitigating or avoiding potential impacts. Employing BMPs (e.g., such as those described in the "GEO-SEQ Best Practices Manual" dated September 30, 2004 and the "Handbook on Best Management Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin" prepared by ALI Consulting dated April 2002) during all phases of a geologic sequestration project would help protect the groundwater resources of the project area. These BMPs focus on eliminating the potential for leakage and contamination of the surrounding environment, and include proper injection well design with safety features (e.g., similar to a Class I or Class II injection well).

4.3.3.1 Post-combustion Capture

Post-combustion CO_2 capture technologies are expected to be retro-fitted to existing facilities or included in new facilities where the CO_2 is formed as a product of the combustion of fossil fuel. The construction of the capture facility, including the addition of access roads, would necessitate the clearing of native ground cover and grading of the land surface. These actions could increase the potential for soil erosion at the site; however, significant soil erosion and sedimentation of surface waters can be mitigated through the use of BMPs for erosion control. As the capture facility would be co-located with an existing or proposed new plant, soil resources (e.g., farmland) would only be impacted to the extent that the existing plant were to be expanded, or as an incremental impact resulting from new plant construction, which is anticipated to be insignificant.

Waste products from the post-combustion capture process could include heat-stable amine salts and other degradation products, which would be transported to the wastewater tank at the facility for off-site disposal. Spent carbon from the amine filter beds would require transport to and disposal in an appropriately permitted waste management facility. It is anticipated that waste from the oil and grease used for maintenance at the facility would not significantly add to the quantity already generated at the plant. These waste products would not impact the surface soils or groundwater quality unless an accidental spill occurs.

The capture technology requires cooling water to wash the flue gas as it exits the absorber (see model project description in Section 2.5). It has been assumed that cooling water would be supplied from the cooling water recirculation system of the existing or proposed new fossil fueled plant. Although cooling water is re-circulated in the process, losses to the system would require potentially millions of gallons of additional water per year. This water would be obtained locally, either from aquifers or existing surface water reservoirs, and proper permits would be required for these water withdrawals. The permitting processes for water resources usage include mechanisms for protecting existing water rights and local groundwater users. Also, the effect of the increased need for water on surrounding communities and users would be evaluated during the permitting process and site-specific NEPA review.

As cooling water is re-circulated, it becomes saline and may contain elevated levels of biocides, such as bromide, due to evaporation during the blow-down process. Typically, saline water is removed from the cooling water system of a fossil-fueled plant and managed in a lined reservoir (or an above-ground tank) specifically designed to prevent seepage to underlying soil and groundwater resources.

4.3.3.2 CO_2 Compression and Transport

Compression facilities are expected to be co-located with an existing power plant facility or comparable facility where the CO_2 is captured. Transport of the CO_2 from the capture location to the sequestration site can be accomplished using one of two methods, tank truck or pipeline, as described in Section 2.5.

Compression facilities and equipment for CO_2 pipelines would require land to be cleared of vegetation and potentially graded to accommodate the facilities necessary. These activities could increase soil erosion in the affected area, but appropriate use of BMPs would minimize impacts. Additionally, access roads would be created for pipeline maintenance. The pipeline corridor must remain clear of vegetation growth, other than groundcover, for pipeline access. Significant soil erosion and sedimentation of surface waters can be mitigated through the use of BMPs for erosion control.

Maintenance of transmission equipment would require use of lubricating oil. Spent lubricating oil could be stored in a waste oil tank for periodic off-site disposal in an appropriately permitted waste management facility. Under proper handling, this waste product would not impact geologic resources at the site except in the event of an accidental spill. Potential wastes from the transportation of CO_2 via a pipeline include the condensate from the compressed gas stream, which could be transferred to a wastewater tank for off-site disposal.

Compression and transportation activities would not affect the potential for geologic hazards. Valuable mineral deposits and soil resources (e.g., prime farmland) would not be significantly affected by these activities as these resources would be protected by existing mineral rights and soil conservation programs. It is also assumed that any increase in oil and grease waste would not add a significant amount to the current waste from the source facility. The waste products from the compression and transportation of CO_2 via either pipeline or tank truck would not impact the geologic resources of an area except in the event of an accidental release.

4.3.3.3 Sequestration in Coal Seams

Sequestration of CO_2 in unmineable coal seams, principally involving ECBM recovery projects, would require detailed planning to avoid or mitigate impacts to the geologic resources of an area. A detailed evaluation to address the following topics would be a prerequisite for selecting an appropriate site.

- The construction of sequestration facilities at the injection site, including excavation for foundations, may cause new or renewed movement on landslide-prone slopes in the area. These areas would be mapped and avoided during the construction phase of the project. Although the buildup and sudden release of pressure in the injection zone could theoretically induce a seismic response in the subsurface near the injection site, federal regulations and state permitting processes for injection wells include provisions to control the injection pressures, thereby minimizing this potential hazard.

- The sequestration of CO_2 in a coal seam would preclude the mining of that coal seam in the future, as the CO_2 would be released during the mining process. Therefore, to avoid the loss of a valuable mineral resource, the coal seam must be determined to be unmineable before initiation of sequestration. Sequestration associated with ECBM production, which is the most economically feasible method currently envisioned, would have a net beneficial impact on mineral resource recovery. Other nonrenewable resources that could be impacted during the sequestration of CO_2 in coal seams include groundwater quantity and quality (e.g., impacts to a water supply aquifer or geothermal springs) and mineable surface resources (e.g., sand, gravel, or aggregate deposits). Naturally occurring outcrops and surface deposits could be altered due to excavation during construction of the sequestration facilities.

- Potentially hundreds of acres of land would be required to install the required wells and equipment (see Section 2.5). Much of the land associated with the sequestration process, however, would remain in the original, natural state. Surface preparation for drill rigs and equipment, access roads, pipelines, and related facilities would require clearing of the native vegetation and potential grading of the land surface, which could increase soil erosion. The increase in soil erosion could also increase the amount of sediment in nearby water bodies. Significant soil erosion and sedimentation of surface waters can be mitigated through the use of BMPs for erosion control. With proper planning, disturbance or loss of soil resources (e.g., farmland) would be minimized.

- Useable groundwater along the outcrop of the coal seam could be affected as water levels are lowered due to pumping at the injection site. Prior to selecting an injection site, evaluations would be performed to ensure that the shallower, usable aquifers are hydrogeologically isolated from the production and sequestration zones. If the injection reservoir is not completely sealed by very low permeable formations overlying it, leakage or migration of the sequestered CO_2 could impact the groundwater quality in the area. For instance, the addition of CO_2 to the coal water-bearing formation can decrease the water pH and alter the oxidation potential (Eh) of the water causing the mobilization of trace elements (e.g., arsenic, selenium, lead).

- For projects involving methane recovery, the produced water may be of poor quality (e.g., elevated total dissolved solids and inorganic or organic parameters) and would be disposed of properly to avoid contamination of useable water sources. BMPs and facilities that are properly constructed and operated would preserve both the quality and quantity of groundwater in the area of the sequestration process.

4.3.3.4 Sequestration in Depleted Oil and Gas Reserves

Impacts to geologic resources associated with applying EOR for the sequestration of CO_2 would be similar to those described above for coal seam sequestration. However, the mere presence of petroleum is clear evidence of long-term hydrogeologic isolation of fluids within this type of subsurface reservoir. Many of the technologies that would be utilized for this sequestration process are currently in use by oil and gas production companies. Therefore, the implementation of the sequestration method is well documented and potential problems that could arise from the continued use of these technologies being investigated. With proper planning and the use BMPs, many of the impacts can be mitigated or avoided. The impact criteria with respect to the sequestration of CO_2 for EOR are discussed below.

- Damage to sequestration facility structures due to geologic hazards induced by sequestration processes can be avoided. The geologic setting and petrophysical characteristics of the oil and gas reservoir would be well studied as part of the previous planning process for the development of the petroleum resource. These details would enable proper design of sequestration facilities to avoid the potential for landslides, seismic activity, or other localized hazards.

- The sequestration process may have a favorable effect on the development of oil and gas reservoirs in the area of the injection sites. Producing oil and gas from adjoining or nearby reservoirs could stimulate the migration of sequestered CO_2 toward the petroleum extraction points, which may have a net beneficial effect, because it would increase petroleum reservoir pressures and recovery. However, without proper project planning, the sequestration process could impact other non-renewable resources, such as groundwater and mineable surface resources. In some cases, underground mines in the area of the injection site could affect the integrity of the natural, geologic seals of the reservoir.

- The land area necessary for the sequestration of CO_2 in oil and gas reservoirs depends on the number of injection wells planned and the distance between the wells. In the areas of roads, facilities, and drill pads, the land surface would need to be cleared and potentially graded. These estimates of area disturbed do not include major pipelines that may be installed to transport CO_2 to the site. Pipelines would be buried to avoid temperature fluctuations due to weather conditions. Clearing of the natural vegetation for these purposes could increase the amount and rate of soil erosion. Significant soil erosion and sedimentation of surface waters can be mitigated through the use of BMPs for erosion control. The project site would be located and operated to minimize impacts to valuable soil resources (e.g., prime farmland); however, many producing oil and gas fields are already located within or near farmland. The small incremental increase in disturbed land should not restrict the location of an EOR-sequestration site.

- In existing oil and gas fields, there are many exploration and production wells, some operating wells and some shut-in or abandoned wells. Prior to the initiation of CO_2 injection for sequestration and EOR, all such wells in the vicinity would be evaluated for proper completion to protect potable groundwater resources. Casing and annular seal integrity are particularly important. If the casing is damaged or severely corroded, or if the annulus between the casing and the drill hole is not effectively sealed with cement bentonite grout, the well may leak formation fluids. Impacts to local groundwater systems could occur as contaminants (e.g., formation fluid, CO_2, poor quality groundwater) migrate from the injection zone through the poorly completed or damaged wells in the field. Properly sealing such wells prior to CO_2 injection would preclude this contaminant migration mechanism.

- Produced fluid (i.e., non-potable water that is separated from the recovered oil as part of the EOR process) can be disposed of on-site in a properly designed, constructed, and permitted waste disposal well. The injection of CO_2 or produced water at excessive pressure may cause hydrofracturing, allowing the CO_2 to escape the naturally formed petroleum trap. The addition of CO_2 to the water-bearing oil reservoir can decrease the water pH and alter the Eh of the water, which are key factors in the solubility and mobility of trace elements (e.g., arsenic, selenium, lead). If fluids escape from the petroleum reservoir, the impacts to water quality in the shallow aquifers would depend on the quality and rate of leakage from the reservoir, and geochemical reactions between the rocks and groundwater along the migration paths. The proper design, construction and operation of facilities and implementation of BMPs would protect both the quality and quantity of groundwater in the area of the sequestration process.

4.3.3.5 Sequestration in Saline Formations

Utilizing saline water-bearing formations for the sequestration of CO_2 involves many technologies that are currently in use in several carbon sequestration sites worldwide. Thus, the equipment, processes, and potential impacts of CO_2 injection are currently being studied and evaluated. Proper planning and BMPs can help avoid or mitigate potential impacts to the geologic resources of an area due to the sequestration process. The impact criteria with respect to the sequestration of CO_2 in saline formations are discussed below.

- The potential for induced seismic responses due to the injection of CO_2 into the subsurface is low if proper injection pressures are maintained. State and federal agencies regulate the injection pressures that can be utilized during the sequestration process, and monitoring of the formation pressure would help detect potential over-pressurization. Some saline formations are located in geologic traps that also serve as petroleum reservoirs. Therefore, prior to the sequestration of CO_2 in a saline formation, the surrounding area would be studied to determine if the sequestration would affect any oil and gas resources. As with the other geologic sequestration technologies, surface and underground mining in the area of the injected CO_2 could affect the integrity of the hydrogeologic features that cap and isolate the reservoir, thus may allow undesirable migration of the CO_2.

- Land would need to be cleared for wells and equipment. Disturbances of the natural vegetation could cause increased soil erosion, but applying BMPs for protection of soils can minimize these impacts. Effective project siting and planning would avoid areas where soils are used as a resource (e.g., prime farmland). If farmland were proximal to the project site, erosion-control and groundwater-protection measures would be incorporated in the project design.

- It is essential to protect the water supply aquifers that are stratigraphically above the injection zone. The addition of CO_2 to the saline water-bearing formation can decrease the water pH and alter the Eh of the water causing the mobilization of trace elements (e.g., arsenic, selenium, lead). However, selecting sites with competent, extremely tight caprock above the injection zone and other favorable geologic features that restrict both vertical and lateral flow would isolate the sequestered CO_2 from any aquifer that could be used as a potable water supply source. Utilizing BMPs for design, construction, operation, and monitoring can control the subsurface leakage of formation fluids. Injection pressures would be carefully monitored and controlled to avoid hydrofracturing of the formation or caprock that could allow formation fluids to migrate to shallower aquifers.

4.3.3.6 Sequestration in Basalt Formations

Sequestration of CO_2 in basalt formations has not been tested in pilot-scale field projects. Therefore, much of the data needed for the successful design of a basalt sequestration program are not available, including injectivity, storage capacity, and rate of conversion (NETL, 2004). Nonetheless, it is reasonable to assume that the technologies currently available and in use for other sequestration projects would be utilized for CO_2 sequestration in basalt formations. For example, the equipment used for sequestration in saline water-bearing formations would be similar to that employed for sequestration in basalt. The differences, however, are the response of the natural system to the injected CO_2 and the potential impacts to the surrounding environment. These responses can only be ascertained following site-specific studies of CO_2 injection into basalt formations.

Proper planning and BMPs can help mitigate or avoid potential impacts to the geologic resources of an area due to the sequestration process.

- The potential for inducing seismic disturbances by injection of CO_2 into basalt formations is low if proper injection pressures are maintained and a complete and thorough site investigation is conducted prior to project initiation. Additionally, monitoring formation pressures in the sequestration zone and surrounding formations will help identify any potential over-pressurization that could generate a seismic response.
- The location of any basalt sequestration project should be investigated to determine if any valuable mineral deposits could be adversely affected. With proper planning and design of the sequestration project, valuable mineral deposits can be protected.
- Land would need to be cleared for wells and equipment. Disturbances of the natural vegetation could cause increased soil erosion; however, applying BMPs for protection of soils can minimize these impacts. Proper project siting and planning would avoid areas where soils are being used as a resource (e.g. valuable farmland), if negative impacts were predicted. Farmland or other natural resources surrounding a project site would be protected through use of erosion-control, spill prevention and groundwater-protection measures.
- A competent, extremely tight caprock and geologic features that trap the injected CO_2 in the basalt formation are essential to protect water supply aquifers located stratigraphically above the injection formation. Injection pressures would be monitored and controlled to avoid excessive pressures that could breach the integrity of the low permeability formations above the injection formation. This monitoring, along with implementing BMPs and the other proper MM&V protocols, should protect the groundwater availability, use, and quality above the target injection formation.
- Based on initial studies, the Big Sky Regional Carbon Sequestration Partnership (BSRCSP) expects favorable geochemical reactions to occur between the basalt and the injected CO_2 (BSRCSP, 2005). While such geochemical reactions may further reduce the potential for impacts of CO_2 injection on overlying groundwater aquifers, the *in-situ* kinetics of these geochemical reactions are not yet clearly established, but may require a period of several hundred years to reach the reaction end points (BSRCSP, 2005). Moreover, the available data are insufficient to evaluate the degree to which these reactions may create adverse plugging effects in the fractured basalt reservoir due to precipitation of clay minerals.

4.3.3.7 Terrestrial Sequestration – Reforestation

Forests provide natural carbon sinks, and utilizing this natural process by implementing a reforestation program on mined lands, as described in the model project presented in Section 3, provides an additional option to geologic sequestration of CO_2. Currently, many mined lands are reclaimed as grasslands rather than reforested. The capacity of grasslands to sequester CO_2 is lower than the demonstrated capacity of forestland. The site climate and other environmental conditions must be evaluated prior to the initiation of a reforestation project, and it may take as many as 20 to 70 years for the forest biomass to be adequate to reach peak sequestration rates, depending on the management practices, species of trees utilized, and environmental setting. The impact criteria with respect to the sequestration of CO_2 utilizing the natural processes associated with reforestation are discussed below.

- The reforestation process would not increase the potential for geologic hazards in the area of a terrestrial sequestration project. Reforestation may in fact have a net beneficial effect on soil structure and land stability. Since reforestation would initially be implemented on abandoned and reclaimed mine lands, mineral and energy resources would not be impacted adversely. Soil amendments and erosion control measures implemented as part of the reforestation project could beneficially affect surrounding active farmland. Any pesticides or herbicides used in the project to control weeds and other competition to the newly planted trees could percolate into the shallow groundwater or runoff to surface water bodies if not properly applied. However, the establishment of newly forested areas on lands damaged by prior mining activities would likely have a net beneficial impact on groundwater resources.

- The improvement of damaged soils is a key element for successful reforestation of mined lands, and the productivity of the terrestrial ecosystem can be enhanced through the application of soil amendments (e.g., coal combustion byproducts and bio-solids from wastewater treatment facilities). The reforestation process is a natural combatant to soil erosion. If the reforestation plan includes harvesting the trees, there is a potential for sediment and erosion issues during the harvesting stage. Without proper management, the harvesting and re-planting process could introduce various wastes into the soils and shallow groundwater (e.g., fuel spills and oil and grease from harvesting and planting equipment).

4.3.3.8 Co-Sequestration of H_2S and CO_2

The impact criteria with respect to the co-sequestration of H_2S and CO_2 are discussed below.

- Impacts on geologic resources associated with the co-sequestration of CO_2 with H_2S from sour gas fields or IGCC plants generally would be similar to those described for geologic sequestration in oil and gas reserves or saline formations. Adding H_2S to the CO_2 injection stream has the potential to exacerbate the magnitude of the impacts described above for injecting CO_2 alone. For example, H_2S is a strong corrosive agent, so it is likely to cause an increase risk of well casing leaks. In the event of casing leakage into a shallow potable aquifer, the H_2S would create more acidic groundwater and thus have the potential to mobilize higher concentrations of trace metals in the aquifer. Nonetheless, as with the cases for pure CO_2 injection, proper planning and implementation of BMPs can help avoid or mitigate potential impacts to the geologic resources of an area due to the sequestration process.

- The combination of H_2S with injected CO_2 would increase the potential for contamination of useable groundwater, therefore, the protection of water supply aquifers in the vicinity of the injection zone would be a foremost priority. A competent low-permeability caprock and geologic features that restrict vertical flow, which are typical characteristics of natural subsurface petroleum reservoirs, would isolate the sequestered CO_2 and H_2S from any aquifer that could be used as a source of potable water. Also, the addition of CO_2 and H_2S to a saline water-bearing formation can decrease the water pH and alter the Eh of the water causing the mobilization of trace elements (e.g., arsenic, selenium, lead). However, the subsurface leakage of formation fluids can be controlled by utilizing BMPs for design, construction, operation, and monitoring. Injection pressures would be carefully monitored and controlled to avoid hydrofracturing of the formation or caprock that could allow formation fluids to migrate to shallower aquifers.

4.3.4 Mitigation of Potential Adverse Impacts

The measures discussed in the following section are recommended to mitigate potential adverse impacts of CO_2 sequestration technologies on the geologic resources of an area. Significant impacts can be avoided by using a rigorous site evaluation process to select CO_2 injection sites having favorable hydrogeologic characteristics for the long-term isolation of CO_2 and formation fluids. Additionally, BMPs employed during all phases of the project would help protect the resources of the project area. A well-designed contingency plan is essential to minimize any potential impacts to the geologic resources of an area. Various measures that should be employed to protect the geologic resources of a project area are discussed below.

4.3.4.1 Project Planning and Design

Effective site selection is a critical requirement for a successful carbon sequestration project. The planning and design phase of any project is pivotal to the protection of the surrounding geologic resources. Detailed site selection studies and subsurface investigations would be required for collecting site-specific hydrogeologic data to determine the hydraulic characteristics of the injection zone and overlying confining units (e.g., exploratory drilling, groundwater quality sampling, hydraulic testing, and geologic testing). In addition, groundwater flow and transport modeling is a well-established technical basis for predicting the future hydraulic responses of injection and the potential effects of fluid migration. Additionally, baseline levels should be established for a variety of environmental parameters that may be used to detect effects of the sequestration (e.g., water quality analyses, bradenhead tests, soil vapor analyses). As part of project planning, a monitoring program should be developed that includes monitoring surrounding wells and other potential points of migration into the biosphere. Both the monitoring frequency and the constituents to be analyzed should be specified. A spill prevention and contingency plan is also a fundamental component of the planning and design phase of a project. This plan should include the steps necessary to avoid potential impacts to the surrounding geologic environment.

> Detailed site selection studies and subsurface investigations would be required to determine the hydraulic characteristics of the injection zone and overlying confining units.

> *Bradenhead testing* - The bradenhead is the portion of the wellhead that is in communication with the annular volume between the surface casing and the next smaller casing string. Conceptually, if there is positive pressure at the bradenhead, this indicates that a casing leak or an inadequate cement job could exist on a well.

The monitoring plan should include:

- Measure water levels, pressures, temperatures, and water chemistry parameters in aquifer monitor wells surrounding the injection wells at specified intervals prior to, during, and following injection of CO_2.

- Monitor water chemistry at base of slightly-saline groundwater zone for early detection of potential upward leakage.
- Conduct mechanical integrity tests (e.g., bradenhead tests) at project injection wells and other surrounding petroleum extraction wells.
- Install additional monitor wells, as necessary, to provide a means of early detection of potential migration of the injected CO_2 both vertically and laterally, and to thus protect water supply aquifers.
- Inventory and monitor springs, seeps, wetlands, and surface water bodies (especially along the outcrop of a coal seam utilized in an ECBM-sequestration project).
- Utilize thermal infrared and near-infrared aerial photos over time to document the pre-injection, injection, and post-injection vegetation and surface water conditions in the site area.

The spill prevention and contingency plan should include:

- Shut down the project injection wells if undesirable leakage, seepage, or other problems are detected.
- If a problem is detected, increase monitoring scope to evaluate the nature and extent of impact.
- Implement a corrective action to control the rate of degradation and migration (e.g., pumping at lower pressure, extract and re-inject water) if the water chemistry parameters measured in the monitored groundwater or wells exceeds drinking water standards or other cleanup goals.

Hydrogeologic investigations, including aquifer testing and hydrostratigraphic logging, followed by numerical flow and transport modeling, would help in project planning and monitoring plan development and thus aid in preventing adverse impacts to water supply aquifers in the project area. Additionally, a survey of the surrounding water wells should be included in the planning phase of the project. Hydrogeologic characteristics and project design features that would mitigate potential negative effects of the sequestration process include:

- Competent, extremely tight caprock overlying the injection reservoir – for example, a thick and laterally-continuous shale unit.
- Marginal- to poor-quality overlying aquifers are not used as water supplies.
- Minimize injection pressure to not exceed the hydraulic pressure needed for fracture initiation (also known as the critical pressure or breakdown pressure).
- Remediate any old or poorly-completed wells prior to injection.
- Avoid any area containing a "sole source aquifer" as designated by the EPA.

> To avoid potentially significant adverse impacts, geologic sequestration injection areas should not be sited near sole-source aquifers (as designated by EPA).

In order to protect the soils in the project area, the design for the site should minimize land disturbance, including the clearing of native vegetation for development of access roads or the creation of new pipeline corridors. Reclaimed land is only an approximation of the natural system as the *in-situ* materials are replaced with fill materials. Consequently, the soil productivity in reclaimed land areas requires extensive time to recover. However, to aid in the recovery process, topsoil removed during the construction phase should used for rehabilitation. Extensive soil erosion controls should be added to the project design to decrease the potential for soil loss and sedimentation in nearby surface water bodies.

The sequestration project should be designed to avoid mineable resources (e.g., mineral deposits, petroleum reservoirs, coal seams, and surface sand, gravel, or aggregate deposits) and valuable soil resources (e.g., fertile, high quality farmland). The CO_2 injection pressure should be designed to not exceed the fracture initiation pressure in the target formation. This would help preserve the natural, geologic trap for the sequestered CO_2 as well as prevent hydrofracturing and potential associated geologic hazards. Injecting CO_2 into sufficiently porous and permeable rock would help avoid this excessive buildup of pressure, and the target formation should be tested for these hydrogeologic characteristics during the project design.

> For geologic sequestration, it is essential to select sites with favorable hydrogeologic conditions for isolating the CO_2 from groundwater resources, especially sole source aquifers. Areas with known geologic hazards (including earthquakes and landslides) should also be avoided.

Other geologic hazards, such as landslide-prone areas and areas of instability, can be avoided through the proper geotechnical testing and design. Situating the project on the site in areas of low topographic relief would help minimize disturbances and avoid such hazards. Geotechnical engineering measures (e.g., subsurface drainage, retaining walls, and soil reinforcement) can also help to avoid an impact to both the natural environment and the project facilities.

4.3.4.2 Construction

In general, the design and planning phase of the sequestration project should provide for the construction measures needed to protect the geologic resources in the project area. The use of BMPs during construction would help eliminate any unforeseen impacts due to the execution of the sequestration technology. Several actions that can be incorporated into the construction planning include the following.

- Minimize the footprint of the facilities and disturbed land thereby maintaining the native vegetation and decreasing the potential for erosion.
- Use effective soil erosion control measures.
- Use topsoil that is removed and stockpiled during construction for re-vegetation to stabilize restored areas during reclamation process.
- Proper injection well design is essential to minimize potential impacts to the local groundwater system. All wells must be properly completed utilizing materials to minimize corrosion (acidic-saline water created), and wells should be properly developed and tested.
- Mechanical integrity tests (e.g., bradenhead tests) should be performed on all new and existing wells.
- Any poorly completed wells should be remediated prior to the initiation of CO_2 injection.

4.3.4.3 Operation

As with the construction phase of the sequestration project, the measures taken to avoid impacts to the geologic resources of the site during operation should be accounted for in the planning and design of the project. BMPs should be followed during the operation of the sequestration technology to avoid any unforeseen adverse impacts to the surrounding environment. Monitoring and contingency plans should be included as part of the project planning phase, and must be implemented during the realization of the technology. Various measures can be incorporated in the operation of the sequestration project to protect the resources in the surrounding area, as described below.

- Minimize the increase in injection target formation pressures to minimize the potential for hydrofracturing, which could allow CO_2 migration out of the target formation at a point of weakness (e.g., fault, fracture, annulus of poorly-completed well).
- Implement groundwater monitoring plan.
- Implement contingency plan, if required.
- Replace any wells impacted by the sequestration technology.

Several MM&V technologies, such as geophysical techniques (including surface and borehole seismic, electromagnetic, gravity, and other methods) and injected tracers, can be utilized during the site selection and detailed site hydrogeologic characterization to establish baseline values. These baseline data could be compared to future detection monitoring data to evaluate potential leaks and impacts.

- Seismic tomography and monitoring
- Wireline geophysical logging
- Measurement of *in-situ* temperatures and pressures
- Electromagnetic imaging
- Injected tracers to track migration of CO_2

4.3.5 Regional Considerations

Potential impacts to the geologic resources of an area would vary between the states, and would be influenced by the number and size of geologic sequestration projects, and the specific geologic characteristics of the receiving formations. For each sequestration technology, there are key siting factors that should be considered, as discussed below. These factors may limit the locations that would be amenable to the implementation of the particular sequestration technology. A description of U.S. geologic resources is found in Section 3.3. For all geologic sequestration technologies, it is essential to avoid sites located in areas where sole source aquifers have been designated. Also, projects that would require significant withdrawals of groundwater for process operations may pose problems in areas where groundwater supplies are constrained and local restrictions apply. Areas of known geologic hazards (including earthquakes and landslides) should be avoided during project siting. Additionally, areas of non-renewable resources (e.g., mineral or petroleum deposits, surface deposits, or soil resources) should be carefully evaluated, avoided and protected prior to initiation of CO_2 sequestration activities at each facility.

- **Sequestration in coal seams** – Limitations for use of coal seam CO_2 sequestration relate mainly to the geologic setting of the coal deposit. For example, shallow coal seams or coal seams that outcrop near the injection locations are not suitable sites for sequestration due to increased risk of leakage to the biosphere. Additionally, competent caprocks must be present to avoid potential adverse impacts to the surrounding environment due to migration of the injected CO_2.

- **Sequestration in depleted oil and gas reservoirs** – Site condition requirements for sequestration of CO_2 in depleted oil and gas reservoirs are similar to those described above for coal seam sequestration. Site selection and characterization activities are necessary to determine whether favorable hydrogeologic conditions exist for the long-term storage of the injected CO_2.

- **Sequestration in saline water-bearing formations** – Isolation of the target injection zone from overlying water supply aquifers is essential. An adequate caprock must be present and the geologic trap should be competent to prevent vertical or lateral migration of the injected CO_2. Areas near large population centers where groundwater is a key resource are not ideal for this type of sequestration project.

- **Terrestrial Sequestration: Reforestation** – The climate and existing soils must be suitable for the implementation of a reforestation project.

4.3.6 Summary of Potential Impacts

Table 4-7 provides an overall qualitative assessment of potential impacts on geologic resources for respective sequestration technologies. In general, the impacts of potential projects on these resources would range from negligible to minor provided that site selection is performed properly and that BMPs and other mitigation protocols are implemented effectively during planning, design, construction, and operation. Under these circumstances, significant adverse impacts would not be anticipated for any proposed technologies. However, site-specific NEPA reviews would be required to ensure that locally significant resources would not be adversely affected by proposed projects.

Risk factors that could result in moderate to significant adverse impacts include:

- lack of caprock integrity;
- seismic activity;
- uplift and subsidence;
- unsealed boreholes;
- degradation of sealed boreholes (such as corrosion well materials over time or incomplete sealing);
- EOR-induced seismicity;
- fault activation;
- undetected faults, fracture networks, shear zone, etc.; and

- proximity of sole-source aquifers or other drinking water aquifers.

The unintended release of CO_2 from its destination formation into any overlying drinking water aquifer or the atmosphere could result in significant adverse impacts. Gradual releases of CO_2 to the surface or water supplies would generally not cause significant adverse impacts to humans or the environment. Conversely, rapid and large volume releases may cause significant adverse impacts to human health and the environment as discussed in Section 4.10. The impacts caused by a release of sequestered CO_2 to overlying water supplies could vary, depending on: the amount CO_2 released; any H_2S contained in the sequestered gas; the quality of the formation fluid; the lowering of pH and alteration of the redox potential (Eh) of groundwater; and the potential of the CO_2 to mobilize metals and other minerals in the aquifer.

Terrestrial sequestration projects involving the reclamation of abandoned mine lands may have net beneficial impacts on geologic resources at selected sites, including reduced landslide potential, soil stabilization and enhanced erosion control, and potential improvement in groundwater availability and quality afforded by the restoration of natural vegetation.

Coal seam sequestration with ECBM recovery and geologic sequestration with EOR would potentially have net beneficial impacts attributable to the recovery of these economically valuable mineral resources.

Table 4-7. Potential Impacts of Program Technologies on Geologic Resources

Impact Considerations	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Geologic hazards	·	·	O	O	O	O	+	·
Valuable mineral deposits	·	·	+	+	·	·	·	+
Soil erosion	·	·	·	·	·	·	+	·
Prime or unique farmland	·	O	·	·	·	·	·	·
Groundwater availability and uses[1]	·	·	O	O	O	O	+	O
Groundwater quality[1]	·	·	O	O	O	O	+	O

[1] The impacts under groundwater availability and uses and groundwater quality for geologic sequestration technologies could range from moderate to significant if a catastrophic release of CO_2 occurred where it contaminated an overlying drinking water aquifer.

Key: · Negligible Impact, O Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

4.4 SURFACE WATER RESOURCES

This section describes the potential impacts to surface water resources that could occur during the implementation of carbon sequestration technologies. The surface water resources that could be affected by sequestration technologies are described in Section 3.4. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.4.1 Impact Considerations

Surface water resources that may be affected by sequestration projects include rivers, streams, lakes, ponds, reservoirs, estuaries and oceans. Potential impacts on surface water resources have been assessed using the general criteria outlined below and the definitions found in Section 4.1.1. Short-term impacts for surface water resources are defined as impacts occurring for less than 1 year. Localized impacts for surface water resources are defined as those occurring within 1 mile of the relevant source.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- adversely affect capacity of available surface water resources.
- conflict with established water rights or regulations protecting water resources for future beneficial uses.
- contaminate public water supplies and other surface waters exceeding water quality criteria or standards established in accordance with the Clean Water Act, state regulations or permits.
- conflict with regional water quality management plans or goals.
- substantially alter storm water discharges and adversely affect drainage patterns, flooding, and/or erosion and sedimentation.
- conflict with applicable storm water management plans or ordinances.
- cause construction of facilities in or otherwise impede or redirect flows in the 100-year floodplain or other hazard areas.
- cause filling of wetlands or otherwise alter drainage patterns that would adversely affect jurisdictional wetlands.

The extent to which surface water resources that could be affected by carbon sequestration projects depend on the operational effectiveness of systems for wastewater management, spill prevention, seepage control and monitoring implemented at the project site, the proximity to surface water bodies, amount of land to be disturbed and any permitted discharges.

4.4.2 Regulatory Framework

Carbon sequestration projects would need to consider applicable federal, state, and local laws and regulations concerned with surface water resources. Major federal laws and regulations for surface water resources are listed in Table 4-8. Provisions of the Clean Water Act relevant to the Program are described in Table 4-9.

Table 4-8. Major Laws and Regulatory Requirements for Surface Water

Law/Regulation	Key Elements
Clean Water Act of 1977, as Amended (Federal Water Pollution Control Act of 1972, as Amended) (33 USC § 1251).	This Act is a compilation of decades of Federal water pollution control legislation. The Act amended the Federal Water Pollution Control Act (FWPCA) and requires Federal agency consistency with state nonpoint source pollution abatement plans. The CWA is the major Federal legislation concerning improvement of the Nation's water resources. The Act was amended in 1987 to strengthen enforcement mechanisms and to regulate stormwater runoff. The Act provides for the development of municipal and industrial wastewater treatment standards and a permitting system to control wastewater discharges to surface waters. The CWA contains specific provisions for the regulation of dredge soil disposal within navigable waters and for the placement of material into wetlands. Permits are required under sections 401, 402, and 404 for Proposed Actions that involve wastewater discharges and/or dredging/placement of fill in wetlands or navigable waters. These permits are required prior to the initiation of Proposed Actions.
Oil Pollution Act (OPA) of 1990 (Public Law 101-380, 33 USC § 2701).	This Act prohibits the harmful discharges of oil and hazardous substances into waters of the U.S. or discharges that may affect natural resources owned or managed by the U.S.. The Act amended section 311 of the CWA to augment Federal response authority, increase penalties for oil spills, expand the organizational structure of the Federal response framework, and provide an emphasis on preparedness and response activities.
Rivers and Harbors Act of 1899 (33 USC § 401).	This Act, commonly referred to as the Refuse Act, provides authority to the U.S. Army Corps of Engineers to issue or deny permits for the construction of dams, dikes, or other structures in or affecting navigable waters of the U.S..
Wild and Scenic Rivers Act 16 U.S.C. § 1271 et seq.)	The Wild and Scenic Rivers Act was enacted to preserve, in free-flowing condition, certain select rivers of the Nation which "possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values." The Act designates over 130 rivers, with adjacent land, as components of the System. Wild river areas are defined as rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America. Scenic river areas are defined as rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads. Recreational river areas are defined as rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.
Executive Order 11990, Protection of Wetlands (24 May 1977; 42 FR 26961)	Federal agencies must minimize the destruction, loss or degradation of wetlands.
Executive Order 11988, Floodplain Management (24 May 1977; 42 FR 26951)	Federal agencies must reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains.

Table 4-9. Clean Water Act Provisions

Section	Description
Subchapter III - Standards and Enforcement	
Section 301 - Effluent limitations	This section prohibits the discharge of a pollutant from a point source to waters of the U.S. without a permit. A point source is any discrete conveyance (e.g., pipe, ditch, spillway, etc.). Section 301 also describes the authority that the EPA Administrator has to add or remove substances from the list of priority pollutants. It outlines a set of procedures that must be followed whenever a substance is moved on or off the list. Anyone wishing to discharge pollutants through a ‘point source' must obtain a permit from EPA or an authorized state agency.

Section	Description
Section 307 - Toxic and pretreatment effluent standards	This section describes the factors that EPA must consider when setting effluent standards for toxic pollutants. It requires public consideration of those standards before they are finalized and orders all standards to be reviewed every three years. There are two types of standards for priority pollutants. One group applies to industries that discharge their effluent directly to receiving waters. The other group applies to industries that must pretreat their effluent before releasing them to public sewers. Furthermore, this section provides the authority for the Agency's overall pretreatment program, which regulates discharges from industrial users into Publicly Owned Treatment Works (POTWs).
Section 308 - Records and reports; inspections	This section gives EPA the authority to require all dischargers to maintain adequate monitoring and record-keeping reports, install equipment, sample, and provide other information at the facilities. EPA and its authorized representatives can also inspect facilities or records and monitoring stations.
Section 309 - Enforcement.	This section gives EPA the authority to seek administrative, civil, or criminal penalties and injunctive relief against violators. The Agency may issue an administrative order or initiate a civil judicial action to require a discharger to achieve compliance and seek a civil penalty; or seek criminal penalties for negligent violations, knowing violations, or false statements made in the documents required to be submitted under the Act.
Section 311 - Oil and hazardous substance liability	This section prohibits the discharge of oil or hazardous substances to navigable waters, or adjoining shorelines. This section also provides for the establishment of the National Contingency Plan for removing oil and hazardous substances. This section authorizes the federal and state governments to recover the cost of pollution control and of damages caused by violations, depositing them in the Plan's account. This section also gives EPA the authority to seek penalties for violations of Section 311. This section also establishes the Agency's authority to promulgate regulations for the Spill Prevention Control and Countermeasures (SPCC) program.
Subchapter IV - Permits and Licenses	
Section 402 - National Pollutant Discharge Elimination System (NPDES)	This section establishes the National Pollutant Discharge Elimination System permit program under which the Administrator (or an authorized state) may issue a permit to a point source for the discharge of any pollutant, or combination of pollutants. EPA published permit application requirements for Phase I stormwater sources on November 16, 1990. Under Phase I, EPA required NPDES permit coverage for stormwater discharges from: Medium and large municipal separate storm sewer systems located in incorporated places or counties with populations of 100,000 or more; Eleven categories of industrial activity which includes construction activity that disturbs five or more acres of land. Phase II became final on December 8, 1999, which requires permitting for small construction activities that result in land disturbance of equal to or greater than 1 and less than 5 acres and certain regulated small municipal separate storm sewer systems.
Section 404 - Permits for dredged or fill material	This section authorizes a special permit program to control dredge and fill operations. The Secretary of Army and the EPA Administrator are jointly responsible for setting the guidelines by which permits are to be judged. EPA controls what areas can be listed as suitable disposal sites and can prohibit certain materials from being discharged at an approved site on certain grounds. In addition, Section 10 of the Rivers and Harbors Act requires a permit from the Army's Corps of Engineers for obstructions in navigable waters.
Section 405 - Disposal or use of sewage sludge	This section authorizes the issuance of permits for the disposal of sewage sludge generated at a publicly owned treatment works (including the removal of in-place sewage sludge from one location and its deposit at another location).

Source: EPA, 2004a and 2004b.

4.4.3 Generalized Siting and Operational Impacts of Technologies

4.4.3.1 Post-combustion Capture

As described in Section 2.5, post-combustion capture projects would be retro-fitted to an existing power plant. Such projects are likely to be located in an industrial site adjacent to an existing power plant or other industrial facility. Utility hookups and access roads are expected to already exist. The construction of such a project would require amendment to the facility's Phase I NPDES.

A single commercial sized post-combustion capture project is predicted to require the delivery of thousands of gallons of aqueous solvent a day (30 percent monoethanolamine) and tons of soda ash each month (see Section 2.5). Delivery, storage and handling of these materials would require incorporating these processes into existing facility Storm Water Management and SPCC plans.

4.4.3.2 CO_2 Compression and Transport

As described for the model project in Section 2.5, two options were considered for transporting CO_2 to a sequestration site. In the first option, CO_2 from flue gas or another industrial source would be transported by compressed gas pipeline to a sequestration site. In the second, liquid CO_2 would be transported to the site via commercial refrigerated tank trucks.

Either option would require small land areas for surface facilities which would most likely be located on the property of a power plant or other industrial facility (CO_2 source). However, the use of a compressed gas pipeline would require transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements would be required. The construction of pipelines and/or support facilities would require either a Phase I or Phase II NPDES permit. Pipelines that cross water bodies may require a Section 404 permit from the Corps of Engineers.

The option of transporting CO_2 to a sequestration site via tank trucks is expected to have minimal impacts on surface water resources.

Compression of CO_2 will result in condensate water at a per project rate of approximately 25 to 346 gallons per hour for transport by pipeline (see CO_2 Transport Model Project). This condensate water may contain impurities and traces of other chemicals, such as benzene. If dissolved concentrations of trace chemicals or salinity of this water exceeds standards for discharge to surface water, the condensate water would be collected and then disposed of in compliance with applicable regulations. The typical practice for disposing of saline water containing significant dissolved petroleum constituents is to inject the wastewater into a nearby deep salt water disposal well, which is permitted under the Underground Injection Control Program.

4.4.3.3 Sequestration in Coal Seams

Site preparation activities would include road development and clearing of ground cover. The use of a compressed gas pipeline would require additional land and surface disturbance for transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements would be required. The construction of pipelines and/or support facilities would require either a Phase I or Phase II NPDES permit. Pipelines that cross water bodies may require a Section 404 permit from the Corps of Engineers, and/or a Section 10 permit from the Coast Guard.

Short-term surface water impacts during construction of the surface facilities would be minor, relating to the activities necessary to clear the site. These construction activities would comply with state or local soil conservation permit requirements and BMPs to reduce sedimentation of nearby water bodies. Introduction of large areas of impervious surfaces such as paved roads and parking lots may require stormwater retention or detention basins to be constructed.

> CBM sites can generate large quantities of water with the released CBM, which may contain elevated levels of dissolved solids and may have high salinity. Without proper treatment, discharge of poor quality water to surface water could cause degradation of the receiving water body.

Commercial sized CBM sites (with or without CO_2 injection) tend to generate large quantities of water with the CBM, which may have elevated dissolved solids and high salinity in some areas. Without proper treatment, discharge of poor quality water from CBM activities to surface water supplies could cause degradation of the receiving body of surface water. To avoid such impacts, CBM projects that produce water exceeding CWA standards or local surface water regulations typically reinject the produced water into a deep saline formation on-site. If the site does not have direct access to an injection well permitted under the UIC program, it can be trucked to a site that does have a permitted wastewater injection well. Depending on the quantity of water generated, it may be stored in lined ponds or in steel tanks until it can be transported to the deep saline well disposal site. On the other hand, if the produced water is relatively pure with low salinity, and meets CWA standards, CBM operators may apply for a permit (i.e., a NPDES or SPDES permit) to discharge this water (pre-treated if necessary) to a local water body, such as streams or rivers. Regardless of the option used for disposing of this water, any options for discharging process water to surface or groundwater would require an appropriate discharge permit and meet stringent standards in accordance with local, state and federal guidelines. These discharges would require routine monitoring and reporting.

For example, in January 2005 Powder River Gas LLC was issued a permit from the Montana Department of Environmental Quality to discharge water from CBM operations to specific outfalls on the Tongue River under permit MT0030660. Under this permit, effluent must meet specific criteria for the following parameters: pH, specific conductivity, sodium, calcium, magnesium, dissolved solids, sodium adsorption ration, total suspended solids, cadmium, selenium, arsenic, mercury and radium. In addition, for the first two years of the permit, Powder River Gas LLC must monitor 16 additional parameters, including biological oxygen demand, chemical oxygen demand, nitrite/nitrate, a large range of metals, oil and grease, and must also perform quarterly biologic toxicity testing (Montana DEQ, 2004).

Although the carbon sequestration program does not directly result in the water discharges from CBM production, the ability to enhance CBM production through CO_2 injection may increase the lifespan of existing CBM facilities and cause new CBM facilities to be constructed. Therefore, the carbon sequestration program may cause an increase of associated discharges to surface water bodies.

Long-term surface water impacts from operations would be negligible to moderate depending upon the location of surface facilities. Impacts associated with wastewater from compressing CO_2 and recovery of CBM could be mitigated with proper collection, treatment, monitoring and disposal methods.

4.4.3.4 Sequestration in Depleted Oil and Gas Reserves

As described in Section 2.5, there are many existing commercial-sized projects where CO_2 is injected into oil reservoirs as part of EOR from which the following information is based. Siting for these projects would depend on the identification of suitable, existing oil reservoirs within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance.

Site preparation activities would include road development and clearing of ground cover. The use of a compressed gas pipeline would require additional land and surface disturbance for transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements or rights-of-way would be required.

Short-term aesthetic impacts during construction of the surface facilities would be minor, relating to the activities necessary to clear the site. These construction activities would comply with state or local soil conservation permit requirements and BMPs to reduce sedimentation of nearby water bodies. Introduction of large areas of impervious surfaces such as paved roads and parking lots may require stormwater retention or detention basins to be constructed. Wells used for CO_2 injection should be cased and cemented to prevent leakage into freshwater sources.

Like the CBM process, EOR operations would generate wastewater when separating CO_2 and water from the recovered oil. Similarly, wastewater from EOR operations is typically reinjected into a UIC-permitted saltwater disposal well. If such a well is located off-site, the wastewater would be stored in lined ponds or steel tanks until it can be economically trucked to appropriate disposal site. Storage of wastewater in lined ponds would require an appropriate permit and compliance with any associated monitoring and reporting requirements. If the wastewater has acceptable quality for discharge to surface water, a NPDES permit would be required prior to such a discharge.

Like the CBM process, EOR operations typically reinject wastewater into UIC-permitted saltwater disposal wells.

Long-term surface water impacts from operations would be negligible to moderate depending upon the location of surface facilities. Impacts associated with wastewater from compressing CO_2 and recovery of oil could be mitigated with proper collection, treatment, monitoring and disposal methods.

4.4.3.5 Sequestration in Saline Formations

Siting for carbon sequestration projects in saline formations would depend on the identification of suitable formations within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance. Therefore, saline formations located near existing fossil fuel-fired power plants or other CO_2 sources would be optimal candidates for commercial application initially.

Site preparation activities would include road development and clearing of ground cover. Wells used for injection should be cased and cemented to prevent leakage into freshwater sources. However, the use of a compressed gas pipeline would require transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements would be required.

Short-term surface water impacts during construction of the surface facilities would be negligible, relating to the activities necessary to clear the site. These construction activities would comply with state or local soil conservation permit requirements and BMPs to reduce sedimentation of nearby water bodies. Introduction of large areas of impervious surfaces such as paved roads and parking lots may require stormwater retention or detention basins to be constructed. Long-term surface water impacts from operations would be negligible, as the process would not generate wastewater requiring surface discharge. As injection of CO_2 would occur in deep saline formations that would undergo thorough geologic characterization, breakthrough of CO_2 to the surface and to surface water bodies is very unlikely.

4.4.3.6 Sequestration in Basalt Formations

Siting for carbon sequestration projects in basalt formations would depend on the identification of suitable formations within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance. Therefore, basalt formations located near existing fossil fuel-fired power plants or other CO_2 sources would be optimal candidates for commercial application initially.

Land would be required for surface facilities. The use of a compressed gas pipeline may require additional land for transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements would be required. Site preparation activities would include road development and clearing of ground cover. The construction of pipelines and/or support facilities would require either a Phase I or Phase II NPDES permit. Pipelines that cross water bodies may require a Section 404 permit from the Corps of Engineers, and/or a Section 10 permit from the Coast Guard.

Short-term surface water impacts during construction of the surface facilities would be negligible, relating to the activities necessary to clear the site. These construction activities would comply with state or local soil conservation permit requirements and BMPs to reduce sedimentation of nearby water bodies. Introduction of large areas of impervious surfaces such as paved roads and parking lots may require stormwater retention or detention basins to be constructed.

As injection of CO_2 would occur in deep basalt formation, where the CO_2 is expected to undergo mineralization over time, breakthrough of CO_2 to the surface and to surface water bodies is very unlikely.

4.4.3.7 Terrestrial Sequestration - Reforestation

The enhancement of terrestrial carbon sequestration through reforestation projects involving landscapes that have been degraded from the extraction of fossil fuels would have a net beneficial impact on surface water resources. The planting of trees in these areas would not only provide the potential for removing CO_2 from the atmosphere, but reforestation would reduce soil erosion and water body sedimentation. Trees help reduce stormwater runoff by intercepting rainwater on its leaves, branches and trunk, where it evaporates, or slowly soaks into the ground, reducing peak flow after a storm. Trees also reduce the volume of runoff.

It has been suggested that the afforestation of grasslands, shrublands, and croplands could have some negative impacts on surface and groundwater. Trees have far greater water demands than smaller woody or herbaceous plants, thus, the streamflows of nearby streams and rivers could be reduced as a result of afforestation efforts. Also, trees have greater nutrient demands than other, smaller plant species and afforestation projects could lead to reduced nutrient levels and increased salinities of soil (Jackson et al., 2005). The focus of terrestrial sequestration efforts is to reforest barren, formerly mined lands, not to alter areas that are currently farmed or contain natural, undisturbed vegetation. Therefore, it is assumed that the benefits of reforestation projects outweigh the potential negative effects to surface and ground water and soil geochemistry. However, the potential for these negative impacts to occur should be considered during the planning of terrestrial sequestration projects.

The DOE's carbon sequestration program would focus forestation projects primarily on formerly mined lands. The non-point source pollutants of primary concern from coal mining are Acid Mine Drainage (AMD) and siltation from erosion of poorly revegetated mined lands. Acid drainage is water containing acidity, iron, manganese, aluminum, and other metals. It is caused by exposing coal and bedrock high in pyrite (iron-sulfide) to oxygen and moisture as a result of surface or underground mining operations. If produced in sufficient quantity, iron hydroxide and sulfuric acid, a result of chemical and biological reaction, may contaminate surface and ground water. For example, in 1997 Pennsylvania reported the single biggest water pollution problem was polluted water draining from abandoned coal mining operations, where over half of the streams that didn't meet water quality standards. More than 2,400 miles were degraded because of mine drainage (Rossman, 1997). One goal of mine reclamation is to minimize these pollutants.

> Acid Mine Drainage is water containing acidity, iron, manganese, aluminum, and other metals. It is caused by exposing coal and bedrock high in pyrite to oxygen and moisture as a result of mining operations.

Short-term soil erosion during site preparation activities could be avoided using soil conservation BMPs. Although long-term stabilization of the site is accomplished by planting trees, during initial stages some erosion may occur. To prevent short-term erosion, a tree-compatible ground cover mix that includes annual and perennial grasses and legumes can be planted (Burger and Zipper, 2002).

Reforestation projects on previously mined lands would have overall long-term positive impacts on associated nearby surface water quality by substantially reducing acid mine drainage and soil erosion that can contribute to sedimentation.

4.4.3.8 Co-Sequestration of H_2S and CO_2

Potential short-term (i.e. the construction stage) and long-term impacts related to the sequestering of both H_2S and CO_2 would be similar to the potential impacts for sequestering in coal seams, oil and gas fields, or saline groundwater formations. For the most part, surface facilities would be the same, with the exception that materials used for compressing and transporting the gas would have to resist the corrosive nature of H_2S. Short-term surface water impacts during construction of the surface facilities would be minor, relating to the activities necessary to clear the site. These construction activities would comply with state or local soil conservation permit requirements and BMPs to reduce sedimentation of nearby water bodies. Introduction of large areas of impervious surfaces such as paved roads and parking lots may require stormwater retention or detention basins to be constructed. Long-term surface water impacts from operations would be negligible to moderate depending upon the location of surface facilities. Disposing of process water by discharge to surface or groundwater would require an appropriate discharge permit and meet stringent standards in accordance with local, state and federal guidelines. These discharges would require routine monitoring and reporting. Long-term surface water impacts from operations would be negligible to moderate depending upon the location of surface facilities. Impacts associated with wastewater from compressing H_2S and CO_2 and recovery of oil could be mitigated with proper collection, treatment, monitoring and disposal methods.

4.4.4 Mitigation of Potential Adverse Impacts

The following BMPs are recommended to mitigate potential adverse impacts of carbon sequestration projects on surface water resources. BMPs are protective, economically feasible measures that can be developed and implemented, on a site-specific or project-specific basis, during the project planning and design, construction, and operation phases. These measures are aimed at reducing, preventing, or mitigating adverse environmental impacts to the surface water quality.

4.4.4.1 Project Planning and Design

- Select locations for equipment and pipelines away from floodplains, wetlands and other surface water bodies whenever possible. Delineate local wetlands as necessary.
- Design project components to minimize stormwater runoff. Where necessary, construct stormwater retention or detention basins.
- Investigate permit requirements under NPDES for construction and operations.
- Obtain soil conservation permits for construction activities and incorporate BMPs into construction specifications.
- Update facility stormwater management plans and Spill Prevention, Control and Countermeasures Plans as necessary.

4.4.4.2 Construction

Projects would require coverage under the NPDES Program for anticipated erosion and runoff resulting from site development activities. A General Construction Activity Storm Water Permit is an element of the NPDES program that would apply to projects. BMPs to reduce surface-water impacts associated with construction include:

- Placement of hay bales, silt fencing, straw wattles, and sediment traps to reduce erosion.
- Flagging and placing silt fencing around storm drains, wetlands and other sensitive areas.
- Storing oils, antifreeze and fuels in closed containers away from any surface drainages. Inspecting machinery daily for fluid leaks and spills.
- Minimizing areas of cleared and disturbed lands.
- Reclaiming disturbed soils as quickly as possible or applying protective covers.
- Existing drainage systems should not be altered, especially in sensitive areas such as erodible soils or steep slopes.
- On-site surface runoff control features should be designed to minimize the potential for increased localized soil erosion. Drainage ditches should be constructed only where necessary. Potential soil erosion should be controlled at culvert outlets with appropriate structures. Catch basins, drainage ditches, and culverts should be cleaned and maintained regularly.

4.4.4.3 Operation

- Maintaining good housekeeping procedures. Do not allow trash, debris, unused or broken equipment and materials, or hazardous wastes to accumulate or come into contact with storm water.
- Reporting and cleaning up spills of hazardous materials quickly.

4.4.5 Regional Considerations

Potential impacts on surface water resources from sequestration projects would be comparable among the various states. As described in Sections 2.3 and 2.4, the availability of CO_2 sources and potential sequestration sinks largely determines the applicability of various technologies in particular states and regions.

Construction aspects of all carbon sequestration technologies would require soil conservation permits and controls to minimize sedimentation of surface waters and construction. Depending on the size of the construction site, construction activities would also need a Phase I or Phase II General Construction Activity Storm Water Permit. Similarly, industrial sites under all technologies may be required to implement or amend a storm water management plan.

> Water discharges resulting from ECBM, EOR and co-sequestration activities could result in potentially moderate impacts to surface water quality.

The carbon sequestration program may result in new facilities to recover CBM. The CBM operations can generate substantial amounts of process water that may seek to discharge this water to groundwater or surface water. These projects would require permitting in accordance with state and federal NPDES provisions of the CWA.

4.4.6 Summary of Potential Impacts

Table 4-10 provides an overall qualitative assessment of potential impacts to surface water resources for each sequestration technology. For the most part, expected impacts would be expected to be negligible, with the exception of potentially moderate (short-term and widespread impacts resulting infrequently due to operator error) impacts to surface water quality from water produced by sequestration in coal seams, EOR, and the co-sequestration of H_2S and CO_2. Sequestration by reforestation of mined lands would have long-term beneficial impacts on surface water resources by reducing acid-mine drainage and soil erosion that can contribute to sedimentation of surface waters.

Table 4-10. Potential Impacts of Program Technologies on Surface Water Resources

Impact Considerations	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Surface water availability and uses	·	·	·	·	·	·	+	·
Surface water quality	·	·	○	○	·	·	+	○
Storm water drainage	·	·	·	·	·	·	+	·
Floodplains*	·	·	·	·	·	·	·	·
Wetlands	·	·	·	·	·	·	·	·

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

4.5 BIOLOGICAL RESOURCES

This section describes the potential impacts to biological resources that could occur during the implementation of carbon sequestration technologies. The biological resources that could be affected by sequestration technologies are described in Section 3.5. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.5.1 Impact Considerations

The types of ecological resources potentially affected by carbon sequestration projects depend on the specific location of the proposed project and its environmental setting. Ecological resources that may be affected include vegetation, fish, and wildlife, as well as their habitats. Affected biota may include species that have been designated as threatened, endangered, or species of special concern by FWS or state natural resource agencies. The ecological provinces were compared with areas of the Regional Partnerships. This provides a broad indication of the types of plant communities and wildlife species that could be affected by carbon sequestration projects. The criteria that have been used to assess potential adverse impacts on biological resources are described below. Impacts were assessed using the definitions found in Section 4.1.1. Short-term impacts for biological resources are defined as impacts occurring for the duration of the construction phase. Localized impacts for biological resources are defined as those occurring within the project footprint.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Cause substantial displacement of terrestrial communities or loss of habitat.
- Diminish the value of habitat for wildlife or plants to an unusable level.
- Cause a native wildlife population to drop below self-sustaining levels.
- Substantially interfere with the movement of any native resident or migratory wildlife species for more than one reproductive season.
- Conflict with applicable management plans for wildlife and habitat.
- Alter drainage patterns causing the displacement of fish species.
- Diminish the value of habitat for fish species to an unusable level.
- Cause a native fish population to drop below self-sustaining levels.
- Substantially interfere with the movement of any native resident or migratory fish species for more than one reproductive season.
- Conflict with applicable management plans for aquatic biota and habitat.
- Cause unmitigated temporary or long-term loss of a wetland habitat.
- Cause the introduction of non-native wetland plant species.

- Adversely affect or displace special status species.
- Cause encroachment or an adverse effect on a designated critical habitat.

Qualitative descriptions of the potential impacts are presented in the following sections. Most impacts can only be fully evaluated on a site-specific level and on the basis of a variety of factors, such as the status of native and invasive plant and animal populations, the types of habitats that would be disturbed, and the nature of the disturbance.

4.5.2 Regulatory Framework

Carbon sequestration projects would need to consider applicable federal, state, and local laws and regulations concerning biological resources. Major federal laws and regulations for biological resources are listed in Table 4-11.

Table 4-11. Major Laws and Regulatory Requirements for Biological Resources

Law/Regulation	Key Elements
Endangered Species Act of 1973 (16 USC § 1531)	This Act determines and protects both plant/animal species and their critical habitats that are threatened or endangered. The Act prohibits any Federal action that may jeopardize such species and provides for the designation of critical habitat of such species wherein no action is to be taken concerning degradation of the habitat. The Act requires a biological assessment of Federal agency actions when an endangered or threatened species may be present in the area affected by the actions.
Bald Eagle Protection Act of 1940, as Amended (16 USC § 668).	This Act, amended in 1972, prohibits the killing, harassment, possession, or selling of bald eagles. The Act also imposes penalties for the possession of bald eagles or eagle parts taken from birds after June 1940. The Act provides an exemption for the use of bald eagle parts in American Indian religious ceremonies, provided that the appropriate permit is granted to the tribe by the USFWS.
Executive Order 13186 - Responsibilities of Federal Agencies To Protect Migratory Birds (10 January 2001)	Each Federal agency taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations is directed to develop and implement, within 2 years, a Memorandum of Understanding (MOU) with USFWS that promotes the conservation of migratory bird populations.
Executive Order 13112 Invasive Species	On February 3, 1999, the President issued Executive Order 13112 to prevent the introduction of invasive species and provide for their control, and to minimize the economic, ecological, and human impacts. In accordance with Executive Order 13112 on invasive species, native plant species would be used in the landscaping and in the seed mixes where practicable.

4.5.3 Generalized Siting and Operational Impacts of Technologies

4.5.3.1 Post-combustion Capture

Construction and operation of the Post-Combustion CO_2 Capture model project would entail retrofitting an existing power plant or other CO_2 source, as described in Section 2.5. It is anticipated that the post-combustion capture facility would be constructed immediately adjacent to the existing power plant and share infrastructure, such as access roads and utility requirements, and resources, such as cooling water and cooling towers, if applicable. The site would most likely be located in an industrial setting on land that has been previously disturbed.

A detailed evaluation of potential impacts would depend upon the specific location for a representative project. In general, the following types of impacts may be expected. Because the facility would likely be constructed on or adjacent to an existing industrial facility, the potential impacts are expected to be negligible. Existing vegetation would be removed, destroying habitat for any wildlife that may inhabit the area, which may include reptiles, amphibians, birds, and small mammals depending on the exact location.

If there were similar habitat adjacent to the proposed site, the wildlife would be displaced. If, however, suitable habitat were not available adjacent to the proposed site, the less mobile wildlife most likely would not survive. While the potential presence of protected species in industrial areas would be unlikely, informal consultation with the USFWS and appropriate state and local agencies would take place and, if necessary, surveys for protected species would be implemented.

If the project area includes wetlands, consultation with the U.S Army Corp of Engineers would determine whether the wetlands are jurisdictional and, if so, what protective measures must be implemented. If the wetlands have been previously impacted or are of low quality, an appropriate mitigation may be the replacement of wetlands in another suitable location.

Most of the waste materials generated by this facility would be disposed of offsite in licensed landfill or treatment facilities. Cooling water from the facility may be combined with cooling water from the power plant and discharged to local receiving waters. Modification of discharge permits for the existing facilities would be necessary to include the discharge from the CO_2 capture facility.

4.5.3.2 CO_2 Compression and Transport

It is assumed that the equipment for compressing CO_2 for transport to a sequestration site would be co-located with the CO_2 capture equipment. The incremental impacts of construction and operation of CO_2 compression facility would be small compared to the potential impacts from construction and operation of the CO_2 capture facilities in terms of amount of land disturbed.

> New CO_2 pipelines should be sited to avoid wetlands and minimize stream crossings. Existing rights-of-way should be used whenever possible.

Standard construction techniques and BMPs would be used to minimize impacts to biological resources. Pipelines can be sited to avoid wetlands and minimize crossing of streams. Impacts on vegetation would be localized, restricted to the rights-of-way, and temporary. Existing rights-of-way would be used whenever possible. If the pipeline route were to traverse a forest, trees would be clear-cut along the rights-of-way, and new trees would not be allowed to grow in the ROW during operation of the pipeline. It is more likely that regulatory conditions would guide the location of compression equipment and pipelines away from wetlands and areas where protected species are known to reside. Subsequently, compression and transport projects are more likely to result in minor adverse (short-term and localized) impacts to terrestrial communities during the construction phase. It is assumed that piping would be buried underground and areas reseeded. Because of regulatory processes requiring pre-construction surveys for species of concern and the costs associated with wetland permitting and mitigation, impacts to aquatic communities, wetland communities and special status species are expected be negligible.

The alternative use of compressed gas trucks to transport CO_2 to sequestration sites via existing highways would have negligible impacts on biological resources.

4.5.3.3 Sequestration in Coal Seams

This technology entails the injection of CO_2 into coal seams and the subsequent recovery of methane from the coalbed. It is assumed that a feasible project would be implemented in an area previously disturbed by coal mining or CBM recovery projects. Therefore, much of the infrastructure would exist, such as access roads, ROW for pipelines, and utilities required, for the CO_2 sequestration project. Additional wells may be required, which would involve construction of new well pads and drilling of wells. Existing wells may be converted to CO_2 injection or monitoring wells.

During construction, adverse ecological impacts may occur from erosion and runoff; fugitive dust; noise; introduction and spread of invasive vegetation; modification, fragmentation, and reduction of habitat; mortality of biota; exposure to contaminants; and interference with behavioral activities. Site clearing and grading, along with construction of drill pads, ancillary facilities, pipelines, and access roads, could reduce, fragment, or dramatically alter existing habitat in the disturbed portions of the project area. The types of impacts from construction are expected to be similar to those that have occurred at comparable construction projects. The construction impacts of most concern with regard to ecological resources are those associated with the reduction, modification, and fragmentation of habitat.

In general, potential adverse impacts on both the flora and fauna within and surrounding the project area would most likely be minor and restricted to the immediate vicinity. This same conclusion was reached in the *Environmental Assessment for Enhanced Coalbed Methane Production and Sequestration of CO_2 in Unmineable Coal Seams* (DOE, 2002).

Potential impacts associated with construction and operation phases of a coal seam sequestration project and associated impact avoidance strategies are discussed below. Assuming proper planning, site surveys, BMPs, and restoration practices are instituted, impacts to terrestrial communities, wetland communities and special status species are expected to be negligible. Due to the common practice of discharging wastewater from ECBM extraction to surface waters, there is potential for minor adverse (localized and short-term) impacts to aquatic communities.

4.5.3.3.1 Construction Effects on Vegetation

A number of construction-associated activities may adversely impact vegetation at a site for sequestering CO_2 in coal seams. These activities include the clearing and grading of vegetated areas for construction of drill pads, ancillary facilities, access roads and pipelines. Impacts associated with these activities may be of long- or short-term duration and would largely be localized to the immediate project area. The introduction of invasive vegetation into disturbed areas of the project site, and possibly into surrounding areas, could result in long-term impacts to the native plant community at the site, access routes, and in surrounding areas. These potential impacts are summarized in Table 4-12.

Table 4-12. Potential Effects of Project Construction on Vegetation

Ecological Stressor	Associated Project Activity	Potential Effect	Extent and Duration of Effect
Direct injury or destruction of vegetation	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Destruction and injury of vegetation leading to reduced productivity and reproductive success	Permanent loss of vegetation within footprint of drill pads, ancillary facilities, and access roads. Short-term loss in areas adjacent to foot print.
Fugitive Dust	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Reduced productivity of plant caused by reduced photosynthesis and related effects	Short-term, limited to construction site and surrounding area.
Exposure to contaminants	Accidental spills of fuel or lubricating oil during equipment maintenance.	Exposure may affect plant survival, reproduction, development, or growth	Short-term, localized to spill area
Invasive vegetation	Site clearing and grading	Establishment of non-native and/or invasive vegetation; decrease in natural vegetation and habitat quality	Long-term in areas cleared of natural vegetation but not used for permanent facilities.

The nature of the construction impacts to vegetation would be comparable for all states, while the extent of the impacts would depend on the size of the project. Clearing, grading, and construction activities would result in direct injury to and/or loss of vegetation, thereby altering or eliminating the plant communities in the permanently disturbed portions of the project site. Impacts to vegetation in the temporary construction areas would be short-term. Native vegetation would be expected to regenerate following completion of construction activities. Additional impacts on vegetation communities could occur from soil compaction, loss of topsoil, and removal of or reductions in the seed bank. The clearing of trees adjacent to a proposed project site or within access road rights-of-way may also be required.

The temporary disturbance of vegetation in some project areas during facility construction would not be considered ecologically significant. Nevertheless, it could take several years for temporarily affected areas to recover (Erickson et al., 2003), and some types of habitat may never fully recover from disturbance.

Fugitive dust generated during clearing, grading, and construction activities may impact vegetation immediately surrounding the project area. A dust coating on leaves has been shown to increase leaf temperature, which in turn increases transpiration rate or water loss from the leaf. Leaf temperature is one of the major parameters controlling photosynthesis. Dust coating on leaves has also been shown to reduce photosynthesis through shading (Hirano et al., 1995).

Fugitive dust generation may be relatively high at carbon sequestration project sites located in the more arid ecological provinces. However, the generation of fugitive dust during the construction phase of a carbon sequestration project can be expected to be short-term and localized to the immediate area of the ground disturbance.

Construction equipment would need to be refueled, and some hazardous materials or wastes, such as waste paints and degreasing agents, may be generated during the construction phase. Accidental spills of fuel, lubricating oils or hazardous materials could result in damage to vegetation. Re-establishment of the vegetation may be delayed because of residual soil contamination. These impacts would be expected to be small and localized. With the removal of contaminated soil, residual effects would be minimized.

Land that has been cleared at a carbon sequestration project site may create an opportunity for invasive plant species to become established. The magnitude and extent of invasive plant establishment would be a function of the aggressiveness of the introduced plants, the number and frequency of seed introductions to a particular area, and the availability of suitable conditions (e.g., disturbed habitat) for colonization by the introduced seeds. Seeds can be easily introduced into construction areas and the surrounding vegetation communities via construction vehicles that have been in other areas where invasive species are present. Invasive vegetation could also be introduced into the soils used to backfill and grade portions of a construction site. Depending on the source of the fill, it may contain seeds, cuttings, or spores of invasive plant species and thus provide an opportunity for introduction of invasive species. The establishment of invasive vegetation may be limited by early detection and subsequent eradication of the plants.

4.5.3.3.2 Construction Effects on Wildlife

The wildlife that may be affected by construction of a carbon sequestration project would depend on the ecological province in which the project is planned and the nature and extent of the habitats in the project area and surrounding vicinity. Construction activities may adversely affect wildlife through habitat reduction, alteration, or fragmentation, as well as cause direct injury or mortality of wildlife, cause a decrease in water quality from erosion and runoff, create disturbing noise, and interfere with behavioral activities. Potential effects of construction on wildlife are summarized in Table 4-13.

Table 4-13. Potential Effects of Project Construction on Wildlife

Ecological Stressor	Associated Project Activity	Potential Effect	Extent and Duration of Effect
Habitat Disturbance	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Reduction or alteration of habitat in and around the construction area	Long-term habitat reduction within construction footprint. Long-term reduction of habitat quality on adjacent areas.
Direct Injury or Mortality	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Destruction and injury of wildlife	Short-term effect on wildlife population
Erosion and Runoff	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Reduction in habitat quality for amphibians using surface waters. Wildlife drinking water supply may be affected	Short-term, may extend beyond site boundaries
Noise	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Disturbance of foraging and reproductive behaviors; Habitat avoidance by birds and mammals	Short-term, limited to the site and immediately surrounding area.
Interference with behavioral activities	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Disturbance of migratory movements. Disturbance of foraging and/or reproductive behaviors	Short-term

The construction involved with a coal seam carbon sequestration project may impact wildlife through the reduction, alteration, or fragmentation of habitat. This represents the greatest construction-related impact to onsite wildlife. All existing habitats within the construction footprints of drill pads and ancillary facilities and along access road corridors would be destroyed. The construction of a coal seam carbon sequestration project would not only result in the direct reduction or alteration of wildlife habitat within the project footprint but could also affect the diversity and abundance of area wildlife through the fragmentation of existing habitats. The nature of the construction impacts to vegetation would be similar in all states, while the extent of the impacts would depend on the size of the project. The extent of habitat destruction would be the same as the impact on vegetation presented above.

The effects of habitat reduction, disturbance, or fragmentation on wildlife would be related to the type and abundance of the habitats affected and to the wildlife that occur in those habitats. For example, reduction, disturbance, or fragmentation of habitats that are not common or well represented in the area surrounding the site may have a greater impact on wildlife inhabitants than common habitats that are well represented in the surrounding area. Fewer impacts would be expected for projects located on previously disturbed lands. Forest interior species and some terrestrial birds, such as pheasants, turkeys, and grouse, may be especially affected by habitat fragmentation.

Clearing and grading activities may result in the direct injury or death of wildlife that are not mobile enough to avoid construction operations (e.g., reptiles, small mammals, and young), that utilize burrows (e.g., ground squirrels, burrowing owl), or that are defending nest sites (such as ground-nesting birds). More mobile species of wildlife, such as deer and adult birds, would avoid the initial clearing activity by moving into habitats in adjacent areas. This may result in increased competition for resources in adjacent habitats and, in the worst-case scenario, may preclude the incorporation of the displaced individual into the resident populations if the surrounding habitat has reached carrying capacity.

The overall affect of construction-related injury or death on local wildlife populations would depend on a number of factors. The number and types of species present at the site that could be affected would be a function of the habitat that could be disturbed. The abundance of the affected species on the site and in surrounding areas would have a direct influence on population level effects. Impacts to common and abundant species may be expected to have less population-level effects than would the loss of individuals from a species that is uncommon. The greater the size of the project site, the greater the potential for more individual wildlife to be injured or killed. Finally, the timing of construction activities could directly affect the number of individual wildlife injured. For example, construction during the reproductive period of ground-nesting birds, such as sage-grouse, would have a greater potential to kill or injure birds than would construction at a different time.

Construction activities may result in increased erosion and runoff from freshly cleared and graded sites. This erosion and runoff could reduce water quality in onsite and surrounding water bodies that are used by amphibians, thereby affecting their reproduction, growth, and survival. The potential for water quality impacts during construction would be short-term, for the duration of construction activities and post-construction soil stabilization (e.g., re-establishment of natural or man-made ground cover). Any impacts to amphibian populations would be localized to the surface waters receiving site runoff. Although the potential for runoff would be temporary, pending completion of construction activities and stabilization of disturbed areas with vegetative cover, erosion could result in significant impacts to local amphibian populations if an entire recruitment class is eliminated (e.g., complete recruitment failure for a given year because of siltation of eggs or mortality of aquatic larvae).

Principal sources of noise during construction activities would include truck traffic, operation of heavy machinery, and foundation blasting (if necessary). The most adverse impacts associated with construction noise could occur if critical life-cycle activities were disrupted (e.g., mating and nesting) (NWCC, 2002). If birds were disturbed sufficiently during the nesting season to cause displacement, nest or brood abandonment might occur, and the eggs and young of displaced birds would be more susceptible to cold or predators. Increased noise levels due to construction activities would be temporary. Noise intensity decreases exponentially with distance, so the effects of increased noise levels would be limited to the site and the immediate surrounding area.

Construction activities at a coal seam carbon sequestration project site may affect local wildlife by disturbing normal behavioral activities such as foraging, mating, and nesting. Wildlife may avoid foraging, mating, or nesting or vacate active nest sites in areas affected by construction. In addition, active construction may also affect movements of some birds and mammals; for example, they may avoid a localized migratory route because of ongoing construction. It would be expected that mobile wildlife would avoid the construction area for the duration of construction, thus the impacts would be short-term and restricted to the immediate construction area.

4.5.3.3.3 Construction Effects on Wetland and Aquatic Biota

A coal seam carbon sequestration project could be sited in an area with surface water features such as streams or rivers, lakes, ponds, and wetlands. The layout of the project would be flexible enough that surface water features could be avoided in siting drill pads and ancillary facilities, however, the situation might occur that access roads or pipelines may have to cross a stream, river, or wetland. The types of aquatic biota and wetlands that could be affected would be a function of the ecological province in which the facility is located and the site-specific environmental conditions present at the facility location. Construction activities may adversely affect wetlands and aquatic biota through habitat disturbance, direct mortality or injury of biota, erosion and runoff, and interference with migratory movements (Table 4-14). Except for the construction of stream crossings for access routes or the unavoidable location of pipelines in a wetland, construction within wetlands or other aquatic habitats would be largely prohibited. Thus, most potential impacts to wetlands and aquatic biota would be indirect.

The overall impact of construction activities on wetlands and aquatic resources would depend on the type and amount of aquatic habitat that would be disturbed, the nature of the disturbance (e.g., grading and filling, or erosion in construction support areas), and the aquatic biota that occupy the project site and surrounding areas. The construction of stream crossings would directly impact aquatic habitat and biota within the crossing footprint. This impact would be long-term, but of relatively small extent and magnitude.

Table 4-14. Potential Effects of Project Construction on Aquatic and Wetland Habitat

Ecological Stressor	Associated Project Activity	Potential Effect	Extent and Duration of Effect
Habitat Disturbance	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Reduction or alteration of habitat in and around, affecting all aquatic biota	Long-term habitat reduction within construction footprint. Long-term reduction of habitat quality on adjacent areas.
Direct Injury or Mortality	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Destruction and injury of aquatic biota	Short-term effect on aquatic populations
Erosion and Runoff	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Decreased water quality, including increased turbidity and siltation, decreased light penetration, and decreased dissolved oxygen levels; siltation of eggs, larvae, and/or adults of aquatic invertebrates and vertebrates; decreased primary productivity; decreased wetland function.	Short-term, localized, may extend beyond site boundaries
Interference with behavioral activities	Site clearing and grading, Construction of support facilities and access roads; Construction of drill pads	Disturbance of migratory movements. Disturbance of foraging and/or reproductive behaviors	Short-term

Compliance with the CWA regarding activities in wetlands would limit the likelihood of construction occurring in or impacting wetland habitats. Otherwise, clearing, grading, and construction activities may result in direct disturbance or reduction of aquatic and wetland habitats that may be present within construction footprint, including access roads and pipelines. Impacts would be expected only if the overall site layout was not sufficiently flexible to avoid crossing a stream or wetland. In this case, site clearing and grading could result in the reduction of aquatic and wetland habitats. Wetlands and other aquatic habitats may also be affected if erosion from construction areas results in runoff and siltation thus decreasing water quality and silting-over biota.

Water quality and aquatic habitat may be affected if construction activities cause an increase in runoff or erosion of soils. Turbidity and sedimentation from erosion are part of the natural cycle of physical processes in water bodies, and most aquatic organisms tolerate short-term changes in these parameters. Generally, adverse impacts only occur if sediment loads are unusually high, last for extended periods of time, or occur at unusual times of the year. Increased sediment can decrease the feeding efficiency of aquatic biota; reduce plant, invertebrate, and fish abundance; and decrease fish spawning success by adversely affecting the survival of eggs and fry. Erosion and runoff could also affect wetland hydrology, function, and water quality.

While any impacts to aquatic biota would be localized to the surface waters receiving site runoff, significant impacts to local populations could result if the magnitude and duration of the runoff were sufficiently high. However, the amount of erosion and runoff into aquatic habitats at, and in the vicinity of, the site is expected to be very small. Impacts from erosion and runoff are expected to be localized and temporary. The potential for water quality impacts during construction would be short term (the duration of construction activities), and post-construction soil stabilization activities (e.g., re-establishment of natural or man-made ground cover) would greatly reduce or eliminate further erosion and runoff from the site. As previously discussed, projects would be subject to the CWA, and if a project was expected to disturb 5 or more acres (2 or more hectares) of wetland, a Storm Water Pollution Prevention Plan (SWPPP) and NPDES compliance permit would be needed.

4.5.3.3.4 Construction Effects on Threatened and Endangered Species

The potential for construction activities to affect threatened, endangered, and sensitive species would be dependant on a number of factors, including the ecological province in which the project would be located and, more importantly, the specific location of the site. Prior to any construction activities on the selected site, including clearing and grubbing, informal consultation with the USFWS or corresponding state agency would take place. If necessary, field surveys specifically designed to detect the presence or absence of protected plant and wildlife species would be implemented. Since many plants cannot be accurately identified unless flowering, the surveys may have to span several seasons.

Direct impacts on threatened, endangered, and sensitive wildlife species could include reduction or fragmentation of habitat, reduction or displacement of habitat features such as cover and forage, exposure to contaminants (e.g., diesel fuel) from a spill, and destruction of individual biota (e.g., from clearing and grubbing activities or from vehicle collisions). In addition, critical habitat, as designated by the FWS, is protected. Because of the regulatory requirements of the ESA and various state regulations, and of other resource-specific regulations and guidelines, appropriate survey, avoidance, and mitigation measures would be identified and implemented prior to any construction activities to avoid impacting any sensitive species or the habitats on which they rely.

4.5.3.3.5 Operation Effects on Vegetation

It is assumed that the project would be implemented in an area with existing developed coal resources or CBM production operation. Also, an economically feasible project would be sited near a source of CO_2 (e.g. an existing fossil fuel power plant or gas plant).

The permanent loss of vegetation would be considered a minor impact to the region. Whenever possible, existing wells would be modified to meet the needs of the project, thus reducing the number of new well pads required. Sensitive lands and vegetation would be avoided. There also consists the potential of damage to vegetation due to accidental spillage of fuel, lubricating oil, or other hazardous materials. The adverse effects of accidental spills would be contained to the immediate area. All contaminated soils would be removed and replaced with clean soils.

4.5.3.3.6 Operation Effects on Wildlife

The effects of operation of the project on wildlife within the site and surrounding area would likely be minor, primarily because of the size of the permanently disturbed areas compared to the size of the site. The probability of causing harmful fragmentation of existing habitat or impeding the movement of wildlife would be very low.

Maintenance of the various well sites, access roads, and ancillary facilities may entail mowing to control vegetation immediately surrounding area. This would most likely preclude much of the native vegetation and may allow non-native, invasive vegetation to become established. Appropriate measures may have to be taken to minimize the harmful effects invasive species may have.

The CO_2 would be injected into the coal seam under pressure by pumps. The CO_2 compressor and pumps would generate noise. On-site electric generators, if required, would also generate noise. This noise would be disruptive to wildlife in the immediate vicinity of the site. The noise would be relatively constant; therefore, much of the wildlife would habituate to the noise. There may be animals, such as some birds and small mammals that may continually avoid the vicinity of the noise. This effect would be considered minor because of the limited size of the area that would contain facilities that generate the noise compared to the size of the whole project site. In addition, noise levels would be reduced exponentially with distance from the source, further limiting the size of the affected area.

4.5.3.3.7 Operation Effects on Wetland and Aquatic Biota

If the project were developed in the vicinity of surface water resources or wetlands, there would be a potential for adverse impacts on these resources, primarily due to the potential for decreased water quality caused by increased erosion and runoff from the site and the introduction of contaminants to the water body or wetland. Potential operational impacts on wetlands and aquatic resources would be expected to be of lesser magnitude and significance than impacts that could be incurred during construction of the project. Wetlands and aquatic resources could be affected by site maintenance activities that involve mowing or cutting of wetland and riparian vegetation and decreased water quality due to surface runoff from the site.

4.5.3.4 Sequestration in Depleted Oil and Gas Reserves

A project for sequestering CO_2 in depleted oil and gas reserves would be implemented at existing oil and/or gas fields. There are several commercial installations using CO_2 for EOR in operation. The potential impacts on biological resources would be very similar to those described in Section 4.5.2.3, Sequestration in Coal Seams.

4.5.3.5 Sequestration in Saline Formations

A project for sequestering CO_2 in a saline formation would most likely be implemented at an existing oil and/or gas field. Saline formations are often associated with an oil field and much of the infrastructure for the sequestration of CO_2 would already be in place. The potential impacts to biological resources would be very similar to those for carbon sequestration in coal seams.

The DOE prepared an Environmental Assessment for *Pilot Experiment for Geological Sequestration of Carbon Dioxide in Saline Aquifer Brine Formations* (DOE, 2003), a project proposed for an existing oil field in eastern Texas. This document concluded that potential impacts from surface activities from this pilot experiment would be minor and comparable to on-going activities at the site. It is expected that a larger, commercial-scale project would have greater environmental impacts than a field validation project, especially for saline formation sequestration projects that would not be located on an existing industrial site.

Assuming proper planning, site surveys, BMPs, and restoration practices are instituted, impacts to terrestrial communities, aquatic communities, wetland communities and special status species are expected to be negligible.

4.5.3.6 Sequestration in Basalt Formations

Unlike EOR or coal seam sequestration projects, projects for sequestering CO_2 in basalt formations would likely be located in areas that were not subject to previous resource extraction. Therefore, the likelihood of potentially siting projects in areas with higher ecological value is somewhat higher. The potential impacts on biological resources would be very similar to those described in Section 4.5.2.3.

Because the Columbia River Basalt Group (CRBG) in the Pacific Northwest is more highly characterized for potential sequestration activities than others in the U.S., it is likely that first commercial sequestration projects would be attempted in the Pacific Northwest. The presence of another large basalt formation, the Snake River Plain, also supports the assumption that projects, and subsequently ecological impacts, would probably be greater in the Pacific Northwest than in other regions.

Assuming proper planning, site surveys, BMPs, and restoration practices are instituted, impacts to terrestrial communities, aquatic communities, wetland communities and special status species are expected to be negligible.

4.5.3.7 Terrestrial Sequestration – Reforestation

For the purposes of this document, the sequestration of CO_2 in terrestrial systems is limited to the reclamation of land that has been previously mined. In many cases grasses are planted on newly recontoured land as an effective means of erosion control. Reforestation would entail the planting of trees, preferably trees native to the area, in the mined area (Section 2.5).

> Reforestation would increase or re-establish edge environment, which is the transition areas between forest and grasslands. Many predator species and small mammals use this edge habitat for hunting.

Potential site-specific impacts cannot be accurately assessed until a specific location for a reforestation project has been chosen. However, because of the nature of such a project, i.e., the planting of trees in a clear-cut area, the overall impacts to biotic resources would be expected to be beneficial. In many cases, clear-cutting an area for mining entails removal of the climax or near-climax ecosystem, the pine or hardwood forest. Reclamation of the mined area begins with the planting of grasses, primarily for rapid control of erosion. In nature, grasses and shrubs are the pioneer plants, the first to become established in a disturbed area. Reforestation, especially with native species of trees, decreases the time it takes for the area to reach climax or near-climax ecosystem.

Planting trees in a reclaimed mined area would increase the biodiversity of the area, resulting in a beneficial impact to terrestrial communities. As the trees grow and mature, they would out-compete the grasses for resources, primarily by shading the grasses from sun. Forest ecosystems support a greater diversity of both plants and animals than grasslands. However, certain species that may have invaded the grasslands, such as prairie species, would be eliminated from the area as trees and undergrowth replace the grasses.

Reforestation would increase or re-establish edge environment, which is the transition area between the forest and grasslands. Many predator species, such as raptors, and small mammals, such as fox, use this edge habitat for hunting. The forest provides cover and trees for roosting and the fields are habitat for small mammal prey species, such as mice, voles, and rabbits.

Reforestation also would likely have a beneficial impact on the aquatic habitat of streams. Trees shade the water, which reduces water temperature. In addition, the forest vegetation furthers the control of runoff, thus reducing the sediment loading of the stream and ponds. Trees and vegetation that grow along the banks of rivers, streams, and ponds may also provide increased cover for fish and other aquatic species. Protection of headwater streams may be particularly beneficial. Headwater streams are important ecologically, because they contain both diverse invertebrate assemblages and some unique aquatic species. Headwater streams also provide organic energy that is critical to fish and other aquatic species throughout an entire river.

Terrestrial reforestation projects would have a negligible impact on wetlands, as projects would generally be located in upland areas. Impacts to special status species are also expected to be negligible, as these previously disturbed mining areas are less likely to currently support these species in general.

4.5.3.8 Co-Sequestration of H_2S and CO_2

Potential short-term, (i.e. the construction stage), and long-term impacts related to the sequestering of both H_2S and CO_2 would be similar to the potential impacts for sequestering in coal seams, oil and gas fields, or saline formations. For the most part, surface facilities would be the same, with the exception that materials used for compressing and transporting the gas would have to resist the corrosive nature of H_2S. Potential impacts to terrestrial and aquatic habitats and biota would be expected to be negligible. Potential impacts to protected species would be negligible if the appropriate mitigation measures are implemented.

4.5.3.9 Biological Effects of Seismic Imaging

Seismic imaging may be an essential pre-requisite to the siting of new geologic sequestration projects. Although seismic imaging is a relatively mature technology, DOE's Program will either directly support further research in this area or indirectly support new seismic surveys through funding of related sequestration field validation projects where further characterization of subsurface geology is needed. As carbon sequestration technology becomes commercialized, it is also reasonable to assume that seismic imaging would be used by private industry to characterize potential geologic sinks. Therefore, it is important that any future proponents of projects involving seismic surveys understand and conduct a review (including NEPA study as required) of any potential ecological impacts that may occur and obtain any necessary state or local permits prior to initiating these surveys. This discussion of impacts of seismic surveys focuses on land surveys, as the Program will focus primarily on on-shore activities. The impacts of seismic surveys on marine mammals is well documented and any seismic surveys conducted in areas that could affect marine life would also require environmental studies and permits as applicable.

> Reforestation would increase or re-establish edge environment, which is the transition areas between forest and grasslands. Many predator species and small mammals use this edge habitat for hunting.

Seismic imaging or exploration involves sending man-made seismic waves into the Earth. These waves reflect from the Earth's geologic layering and features, which cause echoes or reflections that travel back up to the Earth's surface. Electromagnetic transducers, or geophones, pick up the echoes and convert them into electrical signals. These signals are then processed into images of the Earth's shallow structures, and interpreted by geologists or geophysicists to determine what types of rocks may be located below the testing area, and in the case of oil exploration, determine if those rocks or formation contain hydrocarbon deposits (Zimmermann, 2005).

Seismic exploration uses either huge vibroseis trucks weighing 56,000 pounds, with heavy steel vibrators on them, or explosives, to produce sounds at or near the surface. This is done along potentially thousands of "shot" points along lines that are surveyed across the study area. There are many potential adverse environmental effects from seismic exploration. This 3-D seismic testing is more effective in determining geologic structures than 2-D surveying, but can have more impact. The 3-D seismic crews are larger, and there are potentially more vehicles traversing the area because the grid is tighter, requiring vehicle travel to lay out grids of recording equipment roughly 1,000 to 1,400 feet apart. By contrast, conventional seismic lines are spaced six to ten miles apart (VanTuyn, 2000).

Seismic imaging projects can potentially cover up to 100,000 square miles. Seismic imaging may be conducted in the planning stages of a carbon sequestration project to accurately locate suitable formations and could be used after project initiation to monitor the sequestered CO_2. Both the site characterization and monitoring phases would require imaging operations that extend beyond the CO_2 storage site. The extent of the seismic imaging area is generally larger than the storage site in order to create an image of CO_2 accumulation. The area predicted to be disturbed under each model project in Section 2.5 does not take into account disturbance as a result of seismic imaging. Therefore, if a project will use seismic imaging, it is important to note that the areal extent of disturbance would be greater than the target reservoir and that the area could be subject to repeated seismic imaging.

In an Environmental Assessment for the WesternGeco Horse Point 3-D Seismic Exploration Project, it was estimated that 0.3 percent of the project area would be involved with surface disturbance (or 65 acres disturbed over the 19,840 acre study area). However, this project utilized shot hole techniques where no large vibroseis trucks were involved, no dozing or heavy equipment was used, and portable drill equipment was transported by truck, buggy or helicopter depending on the terrain to minimize off-road travel (BLM, 2002). Because this project used a less vehicle-intensive method to conduct the testing, this percentage of land disturbed would represent the low-end range of land potentially disturbed by seismic imaging.

Although the testing is relatively short in duration, potentially long-term impacts could result from the creation of dirt roads through ecologically sensitive areas. Heavy vehicles (vibroseis trucks, drill rigs, ATV's for placing the geophones) involved in the seismic testing are usually driven cross-country, resulting in depressions in soil and crushed vegetation that offer some indication of where vehicles used for the seismic project have driven. The main concern relating to road or two-track creation is that these newly formed paths could be used later by recreational off-road vehicles. If these roads are used frequently by off-road vehicles, the ecological impacts could become much more severe and apparent to wildlife, soil and vegetation (Zimmermann, 2005). Creating roads through natural areas could potentially lead to habitat fragmentation.

This surface-disturbing vehicle travel has the potential to also spread noxious weeds. Seeds transported by vehicles from outside the study area, some amount of surface disturbance and disruption of existing vegetation can create opportunities for new infestations of non-native invasive species.

Seismic surveys may also cause impacts to birds, including: nest abandonment (resulting from noise and human disturbance), direct mortality, reproductive failure, displacement, and destruction of nests (particularly for ground nesting birds). Shrub nesting birds may be affected due to the destruction of vegetation along seismic lines (BLM, 2002). Noise and human presence may cause other wildlife to move away from the study area as well.

In 1999, fieldwork conducted at Sabine National Wildlife Refuge studied the impacts of 3-D seismic operations on marsh soils and plants. Preliminary analyses indicated that immediately following the survey, the maximum vegetation height decreased within the survey zone and increased on control sites. Futher, in one of the two impoundments studied, *Spartina patens* (salt-meadow cordgrass) cover decreased in the impact zone but was unaffected on the control site. The results showed that 3-D seismic exploration flattens vegetation and can decrease cover of dominant plant species (Howard, 1999).

Overall, seismic surveys can result in some temporary and some potentially lasting adverse effects on wildlife, plants and habitat. Therefore, seismic survey plans should undergo environmental review before testing is authorized and conducted.

4.5.4 Mitigation of Potential Adverse Impacts

Potential impacts on biological resources from the construction and operation of a coal seam carbon sequestration project have been identified and evaluated to the extent possible without knowledge of a specific site. These potential impacts would be comparable for other land-disturbing projects as described in the preceding sections. There are a number of BMPs and mitigation measures that may be implemented for carbon sequestration projects to reduce or minimize potential ecological impacts. If appropriate, the monitoring of sensitive biological resources during the construction and operation of a carbon sequestration project can be implemented to support the identification and avoidance of potential adverse impacts before they become problematic. Monitoring data can be used to track the condition of ecological resources, to identify the onset of impacts, and to direct appropriate site management responses to address those impacts.

The following sections identify BMPs and mitigation measures that may be appropriate for minimizing potential impacts associated with carbon sequestration projects.

4.5.4.1 Project Planning and Design

BMPs and mitigation measures should be considered during the planning and design phase of the carbon sequestration project to minimize or avoid adverse impacts of the construction and operation of individual facility structures. The following measures should be incorporated into siting of individual structure and facilities of a carbon sequestration project:

- Identify important, sensitive, or unique habitat and biota in the project vicinity and, to the extent feasible, site and design the project to minimize or mitigate potential impacts to these resources. The design and siting of the facility should follow appropriate guidance and requirements of federal and state resource agencies, such as USFWS and USACE, as available and applicable.
- Contact appropriate agencies early in the siting and planning process to identify potentially sensitive ecological resources, such as protected species, critical habitat, or wetlands that may be present in the area of the carbon sequestration project.
- Conduct site walkovers or surveys for federally and state-protected species and other species of concern within the project area as directed by USFWS and the appropriate state agencies.
- Identify important, sensitive, or unique habitats in the vicinity of the project.
- Locate well pads, access roads, pipelines, and ancillary facilities in previously disturbed areas or areas least likely to impact important, sensitive, unique or designated critical habitats (such as wetlands and sagebrush habitat).
- Utilize existing rights-of-way for roads, pipelines, and utilities to the maximum extent feasible.
- Site individual project facilities and new rights-of-way for access roads, pipelines and utilities to avoid high quality habitats and minimize habitat fragmentation.
- Avoid crossing wetlands and minimize stream crossings with new rights-of-way for access roads, pipelines and utilities. Stream crossings should be designed to provide in-stream conditions that allow for and maintain uninterrupted movement and safe passage of fish.
- Develop a habitat restoration management plan that identifies vegetation, soil stabilization, and erosion reduction measures and requires that restoration activities be implemented as soon as possible following facility construction activities.

4.5.4.2 Mitigation Measures for Seismic Surveys

- Identify important, sensitive, or unique habitat and biota in the project vicinity and, to the extent feasible, site and design the survey to minimize or mitigate potential impacts to these resources.

- Use shot hole techniques to eliminate or reduce the need for vibroseis trucks.
- Travel along existing vehicle routes whenever possible to avoid disturbing natural areas.
- Avoid driving on soils that are saturated to avoid creating ruts.
- Reclaim disturbed areas by scarification and reseeding. Obscure two-tracks using rakes or brooms to discourage off-road recreational vehicle use.
- Conduct testing outside of the breeding season for migratory birds and other protected wildlife.
- Avoid seismic testing and vehicle use in and around wetland areas.
- Use helicopters, buggys (vehicles fitted with wide tires) or people on foot to transport receiver line and geophones to remote and sensitive locations to minimize use of trucks.

4.5.4.3 Construction

The impacts from construction required for a carbon sequestration project would be minimized by the use of an existing resource recovery site; i.e., the required facilities for injecting CO_2 and additional wells required for injection and monitoring would be constructed at an existing EOR site or CBM production site. This practice would minimize the incremental impacts from construction of a carbon sequestration project on ecological resources. In addition, a variety of mitigation measures may be implemented to minimize the severity of potential incremental impacts:

- Minimize the size of all disturbed areas.
- Minimize the extent of habitat disturbance by restricting vehicles to access roads and prohibiting foot and vehicle traffic through undisturbed areas.
- Initiate habitat restoration activities in lay-down areas and other temporary construction staging areas immediately after construction activities are completed.
- Schedule construction activities to avoid important periods of wildlife courtship, breeding, nesting, lambing, or calving. Consult with USFWS and other appropriate natural resource agencies to determine the most appropriate schedule.
- Instruct all construction employees to avoid harassment and disturbance of wildlife, especially during reproductive (e.g., courtship, nesting) seasons.
- Establish buffer zones around raptor nests, bat roosts, and biota and habitat of concern.
- Install and maintain noise-reduction devices (e.g., mufflers) on vehicles and construction equipment.
- Implement erosion controls that comply with county, state, and federal standards.
- Reclaim disturbed soil using weed-free native grasses, forbs, and shrubs. Implement reclamation activities as early as possible on disturbed areas.

- Implement dust abatement techniques (e.g., water spraying) on gravel and dirt roads and other unvegetated surfaces to minimize airborne dust. Construction materials and stockpiled soil should be covered if they are a source of fugitive dust.

- Establish and maintain a minimum number of designated fueling areas that include the use of secondary containment, such as drip pans to contain small spills and temporary berms to limit the spread of larger spills.

- Install drip pans under pumps and valve mechanisms used for transfer of fuels or hazardous chemicals.

- Prepare and implement a Spill Management Plan and initiate spill response immediately after a spill.

- Implement a program to minimize the introduction of noxious and invasive weeds

- Limit pesticide use to pesticides that are nonpersistent and immobile.

4.5.4.4 Operation

The potential impacts to biological resources during the operation of a carbon sequestration project would be expected to be fewer and of lesser intensity than during construction. The following mitigation measures would reduce or minimize potential adverse effects on biological resources during operations.

- Turn off all unnecessary lighting at night to minimize disruption of nocturnal behavior of local wildlife.

- Instruct employees, contractors, and site visitors to avoid harassment and disturbance of wildlife, especially during reproductive (e.g., courtship, nesting) seasons.

- As part of the Spill Management Plan, establish and maintain a minimum number of designated fueling areas that include secondary containment, such as the use of drip pans to contain small spills and temporary berms to limit the spread of larger spills.

- Install drip pans under pumps and valve mechanisms used for the transfer of fuels or hazardous chemicals.

- Prepare and implement a Spill Management Plan and initiate spill response immediately after a spill.

- Implement a program to minimize the introduction of noxious and invasive weeds

- Limit pesticide use to pesticides that are nonpersistent and immobile.

- Monitor access road, utility, and pipeline ROWs regularly for invasive species establishment. Weed control measures should be initiated immediately upon evidence of invasive species introduction.

4.5.4.5 Mitigation for Threatened, Endangered, and Sensitive Species

If federally listed species are present in the project vicinity, informal consultation under Section 7 of the ESA would be required before the start of construction and operation of the carbon sequestration project. If a protected species is found to inhabit the project area or adjacent area, and there is a potential for adverse impacts to the species, a Biological Assessment may be required in addition to the assessment of impacts in the site-specific NEPA document for the project. Subsequently, formal consultation with the FWS may be required that would result in a Biological Opinion issued by that agency. The Biological Opinion would specify reasonable and prudent measures and conservation recommendations to minimize impacts on the federally listed species at the site.

A variety of site-specific and species-specific measures may be required to mitigate potential impacts on special status species if present in the project area. Such measures may include:

- Conduct field surveys to verify the presence of the special status species in the project area and especially within individual project footprints. Such field surveys may also indicate the absence of a protected species.
- Avoid siting project facilities or lay-down areas in locations documented to contain or provide important habitat for protected species.
- Consult with federal and state agencies for further mitigation measures to avoid or minimize impacts to protected species on a site-specific basis.

4.5.5 Regional Considerations

Specific impacts to biological resources cannot be fully assessed without knowledge of the location of a proposed project. The type of impacts, the flora and fauna impacted, and to a certain extent the intensity of the potential impacts depend on the state where the project would be implemented and the proposed site within the state. In gross terms, a general description of the flora and fauna that may potentially be impacted can be known from the Ecological Domain and, more specifically, from the Ecological Province in which the project would be located.

A good example of the regional considerations that must be taken into account in siting and assessing the specific potential impacts is the reforestation model project. A reforestation project would not be as successful if sited in the Dry or Polar Domains as it would if sited in the Temperate Domain, primarily because forests in the Dry or Polar Domains are not as vigorous, and therefore would not be as efficient a carbon sink as a forest in the Temperate Domain. In the Temperate Domain, the Appalachian Coalfield Region encompasses the coal-bearing areas of Pennsylvania, Ohio, Maryland, North Carolina, Georgia, West Virginia, Virginia, eastern Kentucky, Tennessee, and Alabama. The Bituminous Coal Basin lies within the Appalachian Plateau physiographic province, extends in a northeast to southwest direction along the Appalachian Mountains, and encompasses the most historically important coal mining areas of the Appalachian Coalfield Region (USACE, 2003).

The *Programmatic Environmental Impact Statement on Mountain Top Mining / Valley Fill* (USACE, 2003) evaluated the impacts of surface coal mining in the Appalachian Coalfield Region, more specifically in the area where Kentucky, West Virginia, and Virginia meet. This area is in two ecological provinces, the Eastern Broadleaf Forest (Oceanic) Province and the Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow Province. These provinces are characterized by temperate deciduous forest dominated by tall broadleaf trees or a mixed oak-pine forest. This would be a good area for reforestation, which would have predominantly beneficial impacts and a minimum of adverse impacts. The land would be replanted with native trees to attempt to restore the area to its pre-disturbance condition. Although there may be long-lasting effects of the mining operations, such as the contours of the mountainous area and the valley fills remaining permanently altered, the area would receive a beneficial impact from the restoration activities.

> Based on the overall locations of geologic formations that could support carbon sequestration, only a limited number of ecological provinces have a high probability of being impacted.

If a reforestation project would be implemented in another state within the Temperate Domain, it may be located in a different Ecological Province. Although the species of native trees may be different, the impacts would likewise be primarily beneficial; i.e., increased bio diversity, increased erosion control, etc.

Other potential projects may result in the loss of habitat as described in the sections above. The types of habitat impacted would depend on the specific locations of the projects. Specific habitat types that may be impacted would be identified and described during the development of project-specific NEPA evaluation. Table 4-15 lists these ecological provinces that have suitable conditions for CO_2 sequestration and provides summary information about the biotic resources that may be impacted by potential projects.

Table 4-15. Ecological Provinces with High Probability of Being Impacted by Potential Carbon Sequestration Projects

Domain and Ecological Province*	Predominant Vegetation	Common Fauna	Birds	Representative Protected Species
Temperate Domain				
Eastern Broadleaf Forest (Oceanic)	Temperate deciduous forest dominated by tall broadleaf trees or pine-oak forests (Pine Barrens)	Whitetail deer Black bear Bobcat Squirrels and chipmunks	Turkey Ruffed grouse Bobwhite Mourning dove	Copperbelly water snake American Burying Beetle Virginia Big-eared Bat Gray Bat
Eastern Broadleaf Forest (Continental)	Broadleaf deciduous forests; draught resistant oak-hickory forests	Whitetail deer Squirrels and chipmunks	Blue jays	Copperbelly water snake American Burying Beetle Virginia Big-eared Bat Gray Bat
Prairie Parkland (Temperate)	Forest – Steppe; intermingled prairie, groves and strips of deciduous trees	Both prairie and forest fauna;	Belted kingfisher, spotted sandpiper, green-backed heron, horned lark, eastern meadowlark	Indiana Bat Hind's Emerald Dragonfly
Southeastern Mixed Forest	Medium to tall forests of broadleaf deciduous and needleleaf evergreen trees; Loblolly pine and shortleaf pine	Whitetail deer Cottontail rabbits Fox squirrels	Eastern wild turkey Bobwhite quail Mourning dove	Virginia Big-eared Bat Red-cockaded Woodpecker
Outer Coastal Plains Mixed Forest	Temperate rainforest, evergreens, oaks, and members of the laurel and magnolia families.	Whitetail deer Raccoons opossums Flying squirrels Rabbits	Bobwhite quail Wild turkey Numerous migratory non-game birds species and migratory waterfowl	American Burying Beetle
Dry Domain				
Southwest Plateau and Plains Dry Steppe and Shrub	Arid grasslands – blue gramma and buffalo grasses. Mesquite, oak and Ashe juniper	Mexican ground squirrel Gray fox Whitetail deer Ringtail	Wild turkey Mourning doves Scaled quail Several species of hawks and owls	Golden-cheeked Warbler Black-capped vireo

Domain and Ecological Province*	Predominant Vegetation	Common Fauna	Birds	Representative Protected Species
Chihuahuan Semi-Desert	Thorny shrubs, associated with short grass, e.g. gramma grass. Honey mesquite, cacti Sonoran Desert – Yuccas	Shorttail weasel Black bear Striped skunk Marmot	White-throated sparrow Northern junco Yellow-bellied Sapsucker	
Great Plains-Palouse Dry Steppe	Scattered trees and shrubs – sagebrush and rabbitbrush, buffalo grass, locoweed	Pronghorn antelope Mule deer Whitetail deer	Sage grouse Greater prairie chicken Sharp-tailed grouse Horned lark Western meadowlark Mountain plover	Blackfooted Ferret Lesser Prairie Chicken Piping Plover
Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow	Alpine tundra Engelmann spruce, subalpine fir Ponderosa pine and Douglas fir Sagebrush	Elk Deer Bighorn sheep Mountain lion Black bear Grizzly bear Moose	Mountain bluebird Red-breasted nuthatch Gray jay Steller's jay	
Intermountain Semi-Desert and Desert	Sagebrush bitterbrush, and shadescale. Woodland zone with pinyon pine and juniper	Mule deer, mountain lion, bobcat Pronghorn antelope Whitetail prairie dog	Burrowing owl Sage sparrow American kestrel Golden eagle	Attwater's greater prairie chicken
Colorado Plateau Semi-Desert	Arid grasslands – sagebrush, cactus, yucca Ponderosa pine Douglas fir	Mule deer Mountain lion Coyote Bobcat Elk	Bushtit Pinyon jay Red-tail hawk Golden eagle Red-shafted flicker	

More detailed information about these, and all the Ecological Provinces is presented in Section 3.5

4.5.6 Summary of Potential Impacts

Table 4-16 provides an overall qualitative assessment of potential impacts to biological resources for each sequestration technology. For the most part, expected impacts to both terrestrial and aquatic habitats and biota would be expected to be negligible to minor (as discussed in 4.5.2), with the exception of potentially beneficial impacts on biological resources from terrestrial reforestation. Implementation of appropriate BMPs and mitigation measures would help minimize potential impacts. Potential impacts to special status species would be negligible, provided that the siting of surface facilities avoids these species or designated critical habitats.

Table 4-16. Potential Impacts of Program Technologies on Biological Resources

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Terrestrial communities	·	○	·	·	·	·	+	·
Aquatic communities	·	·	○	○	·	·	+	·
Wetland communities	·	·	·	·	·	·	·	·
Special status species	·	·	·	·	·	·	·	·

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

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4.6 CULTURAL RESOURCES

This section describes the potential impacts to cultural resources (paleontological, archeological and historic resources) that could occur during the implementation of carbon sequestration technologies. The cultural resources that could be affected by sequestration technologies are described in Section 3.6. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.6.1 Impact Considerations

The types of cultural resources that could be affected by a carbon sequestration projects depend on the specific location of the proposed project and its environmental context. Cultural resources that could be affected include paleontological, archaeological and historical resources as well as their contexts. Criteria for assessing the potential for adverse impacts on cultural resources from a potential project are provided below. Impact levels are assessed using the definitions found in Section 4.1.1. Short-term impacts for cultural resources are defined as impacts occurring during the construction timeframe. However, it is important to note that any adverse impacts occurring within the construction timeframe, such as the destruction of previously undiscovered archaeological artifacts, could result in a permanent adverse impact on those resources. Localized impacts for cultural resources are defined as those occurring within the project footprint.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Cause the potential for loss, isolation or substantial alteration of an archaeological resource eligible for listing on the *National Register of Historic Places*.
- Cause the potential for loss, isolation or substantial alteration of a historic site or structure eligible for listing on the *National Register of Historic Places*.
- Introduce visual, audible or atmospheric elements that would adversely affect a historic resource eligible for listing on the *National Register of Historic Places*.
- Cause the potential for loss, isolation or substantial alteration of a American Indian resources, including graves, remain and funerary objects.

4.6.2 Regulatory Framework

In this section, federal laws, executive orders and relevant DOE directives, regulations and/or standards are summarized.

4.6.2.1 Federal Laws and Executive Orders

Several federal laws and related policies have been enacted to protect and manage the Nation's cultural resources. These include:

- National Historic Preservation Act (NHPA) of 1966, as amended (e.g., Sections 101, 106, and 110)
- Antiquities Act of 1906

- Archeological Resources Protection Act (ARPA) of 1979
- Archeological and Historic Preservation Act (AHPA) of 1974
- Native American Graves Protection and Repatriation Act (NAGPRA) of 1990
- American Indian Religious Freedom Act of 1978 (AIRFA)
- Curation of Federally-Owned and Administered Archaeological Collections (36 CFR Part 79)
- Protection and Enhancement of the Cultural Environment (Executive Order No. 11593)
- Indian Sacred Sites (Executive Order No. 13007)
- Consultation and Coordination with Indian Tribal Governments (Executive Order No. 13175)
- Preserve America (Executive Order No. 13287)
- 36 CFR 800, Protection of Historic and Cultural Properties
- 43 CFR Part 10, NAGPRA Regulations
- DOE O 450.1, Environmental Protection Program
- DOE P 141.1, Department of Energy Management of Cultural Resources
- DOE P 454.1, Use of Institutional Controls
- DOE O 430.1B, Real Property Asset Management

In addition, factors that also would be considered include potential land disturbance, contextual intrusion, and access restrictions particularly to American Indian sacred space and traditional use areas. Beyond this, more detailed analysis (including file and field investigations, predictive modeling, direct consultation with tribal representatives, and NRHP eligibility determination) will be done when site-specific or project-specific NEPA documents are developed.

4.6.2.1.1 National Historic Preservation Act (NHPA) of 1966 as amended.

The NHPA is the overarching law concerning the management of cultural resources in the U.S. The law requires that each state appoint a State Historic Preservation Officer (SHPO) to oversee the management of cultural resources that state, and it creates the Advisory Council on Historic Preservation (ACHP), which provides national oversight and dispute resolution. The SHPO is also designated as the repository for all cultural resource information in each state. Section 106 of the NHPA, defines the process for the identification of a cultural resource and the process for determining if a project will adversely affect the resource. The NHPA establishes the processes for consultation among interested parties, the agency conducting the undertaking, and the SHPO, and for government-to-government consultation between U.S. government agencies and American Indian Tribal governments. Section 106 of the NHPA also addresses the appropriate process for mitigating adverse effects. The NHPA applies to federal undertakings and undertakings that are federally permitted or funded. A summary of DOE responsibilities under Section 106 is provided in Table 4-17.

Table 4-17. Summary of the NHPA Section 106 Provisions

(1) Under this section of the NHPA, the DOE is responsible to identify, evaluate, and take into account the effects of all undertakings on historic properties in accordance with the procedures set forth in 36 CFR 800. The ACHP is responsible for providing comments on undertakings that affect historic properties. The SHPO in each state or territory is a significant participant in the Section 106 compliance process by providing comments on efforts to identify, evaluate and treat any effects on historic properties. If an undertaking on DOE lands may affect properties having historic value to a federally recognized Indian tribe, such tribe shall be afforded the opportunity to participate as interested persons during the consultation process defined in 36 CFR 800. Traditional cultural leaders and other American Indians, Native Alaskans, and Native Hawaiians are considered to be interested persons with respect to undertakings that may affect historic properties of significance to such persons.

(2) Failure to take the effects of an undertaking on historic properties into account can result in formal notification from the ACHP to DOE of foreclosure. A notice of foreclosure can be used by litigants against DOE in a manner that can halt or delay critical mission activities.

(3) DOE shall ensure that the efforts to identify, evaluate, and treat historic properties follow the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* and are conducted under the supervision of personnel who meet the applicable professional qualifications standards set forth in 36 CFR 61. Disagreements between DOE and the SHPO regarding the eligibility of a property for listing on the NRHP shall be resolved through the procedures at 36 CFR 63.2(d).

(4) Programmatic Agreements (PAs) and Memoranda of Agreement (MOAs) executed pursuant to NHPA Section 106 and 36 CFR 800 are compliance agreements that set forth how DOE will satisfy the responsibilities of Section 106 of the NHPA in the context of a DOE undertaking that will affect an historic property.

Section 110 of the NHPA imposes specific responsibilities on all federal agencies (such as DOE) regarding historic preservation. Section 110 (a)(1) requires that the affirmative preservation responsibilities in Section 110 must be undertaken in a manner consistent with an organization's mission. Such responsibilities include but are not limited to the following:

(1) Establishing an historic preservation program to include the identification, evaluation, and nomination of historic properties to the NRHP in consultation with the ACHP, SHPO, local governments, Indian tribes, Native Alaskans, Native Hawaiian organizations, and the interested public as appropriate.

(2) Prior to acquiring, constructing, or leasing buildings, using available historic properties to the maximum extent feasible.

(3) Documenting historic properties that will be altered or destroyed as a result of the federal action. Such actions must be reviewed in accordance with NHPA Section 106.

(4) In transferring historic properties, ensuring that the significant historic values of the property are appropriately preserved.

(5) Documenting decisions to proceed with agency undertakings that adversely affect historic properties when the they has been unable to reach agreement through execution of an MOA or PA with the ACHP and SHPO.

Section 101(d)(2) of the NHPA provides for the assumption by federally recognized Indian tribes of all or any part of the functions of a SHPO with respect to tribal lands (e.g., all lands within the exterior boundaries of any Indian reservation and all dependent Indian communities). Section 101(d)(6) requires federal activities, in carrying out their Section 106 responsibilities, to consult with federally recognized Indian tribes, Native Alaskans, and Native Hawaiian organizations that attach religious or cultural significance to an historic property. Agencies must consult with federally recognized Indian tribes and Native Hawaiian organizations in the Section 106 process to identify, evaluate, and treat historic properties that have religious or cultural importance to those groups.

4.6.2.1.2 Antiquities Act of 1906, Archeological Resources Protection Act (ARPA) of 1979, Archeological and Historic Preservation Act (AHPA) of 1974

The Antiquities Act of 1906 and ARPA prohibit the excavation, collection, removal, and disturbance of archaeological resources (as defined by ARPA) and objects of antiquity (as referenced in the Antiquities Act) on federally owned property without a permit. Violation of ARPA may result in the assessment of civil or criminal penalties and forfeiture of vehicles and equipment that were used in connection with the violation.

The AHPA specifically provides for the survey and recovery of scientifically significant data that may be irreparably lost as a result of any alteration of the terrain from any federal construction projects, or federally licensed project, activity, or program. Known paleontological resources must also be addressed in any NEPA documentation prepared for actions that might affect or cause irreparable loss or destruction of such resources.

When the DOE finds or is notified in writing by an appropriate authority that its activities might cause irreparable loss or destruction of scientifically significant paleontological resources, the DOE must notify the Secretary of the Interior in writing and provide information concerning the activity in accordance with the AHPA. Such notification may be incorporated as part of the NEPA public review and comment process for the subject activity.

Archaeological resources, objects of antiquity, and significant scientific data from federal installations belong to the installation, except where NAGPRA requires repatriation to a lineal descendant, Indian tribe, or Native Hawaiian organization (See below for a summary of NAGPRA.). Archaeological resources, objects of antiquity, and significant scientific data from nonfederal land belong to the state, territory, or landowner. Such resources from lands used by the DOE but for which fee title is held by another agency are the property of the agency designated as the land manager in the land use instrument (e.g., Public Land Order, Special Use Permit, etc.).

4.6.2.1.3 Native American Graves Protection and Repatriation Act (NAGPRA) of 1990.

The intent of NAGPRA is to identify proper ownership and to ensure the rightful disposition of cultural items that are in federal possession or control. NAGPRA mandates that DOE summarize, inventory, and repatriate cultural items in its possession or control to lineal descendants or to culturally affiliated federally recognized Indian tribes, Native Alaskans, or Native Hawaiian organizations. NAGPRA also requires that certain procedures be followed when there is an intentional excavation of or an inadvertent discovery of cultural items. DOE must ensure compliance with NAGPRA (23 USC 3002) and its implementing regulation (43 CFR Part 10).

DOE may enter into Comprehensive Agreements (CAs) with federally recognized Indian tribes, Native Alaskans, and Native Hawaiian organizations for the purposes of compliance with NAGPRA and 43 CFR Part 10. CAs should establish responsibilities and address all installation land management activities that could result in the intentional excavation or inadvertent discovery of cultural items; establish standard consultation procedures; and provide for the determination of custody, treatment, and disposition of cultural items.

Without a CA, DOE must take reasonable steps to determine whether a planned activity might result in the intentional excavation or inadvertent discovery of cultural items from DOE-owned or controlled lands. When it is determined that cultural items might be encountered, before issuing approval to proceed with the activity, DOE must carry out the consultation procedures and planning requirements at 43 CFR 10.3 and 10.5. Following consultation per 43 CFR 10.5 as part of the intentional excavation or inadvertent discovery of cultural items, a written Plan of Action must be prepared in accordance with 43 CFR 10.5(e).

Such procedures and actions should be coordinated with the requirements of the NHPA and ARPA when such excavations or discoveries might involve historic properties and/or archaeological resources.

If an *inadvertent discovery* of cultural items occurs in connection with an ongoing activity on DOE lands and there is no CA in effect that sets forth agreed-upon procedures for such instances, DOE must comply with 43 CFR 10.4(a-d). Such compliance measures include but are not limited to notifications; cessation of the activity for 30 days in the area of the discovery; protection of the discovery; consultation with Indian tribes, Native Alaskans, or Native Hawaiian organizations affiliated with the discovery in accordance with 43 CFR 10.5; and preparation of a written Plan of Action.

DOE must ensure that all authorizations to carry out activities on federally owned or controlled lands, including leases and permits, require the holder of the authorization to notify DOE immediately upon the inadvertent discovery of cultural items and to protect such discoveries until applicable compliance procedures are satisfied. DOE also must ensure that intentional excavation and response to any inadvertent discovery of NAGPRA cultural items are carried out in compliance with all applicable statutory and regulatory requirements of NAGPRA, ARPA, and NHPA. Each statute mandates compliance with independent requirements. Compliance with one statutory requirement, therefore, may not satisfy other applicable requirements.

All activities carried out to comply with NAGPRA and 43 CFR 10 must occur only with federally recognized Indian tribes, Native Alaskans, and Native Hawaiian organizations, and lineal descendants as defined and provided for by NAGPRA.

4.6.2.1.4 American Indian Religious Freedom Act (AIRFA) of 1978 and Executive Order No. 13007 Indian Sacred Sites.

Under AIRFA and EO 13007, DOE must develop and implement procedures to protect and preserve the American Indian, Eskimo, Aleut, and Native Hawaiian right of freedom to believe, express, and exercise these peoples' traditional religions, including, but not limited to, access to sacred sites, use and possession of sacred objects, and freedom to worship through ceremonials and traditional rites. DOE must consult with Indian tribes and Native Hawaiians to identify sacred sites that are necessary to the exercise of traditional religions and must provide access to DOE installations for Indian tribe, Native Alaskan, and Native Hawaiian practice of traditional religions, rights, and ceremonies. DOE may impose reasonable terms, conditions, and restrictions on access to such sites when it is deemed it necessary for the protection of personal health and safety, or to avoid interference with the Agency mission, or for other reasons of national security.

DOE must maintain the confidentiality of sacred site locations. The DOE is required to avoid adversely affecting the physical integrity of sacred sites and must establish procedures to ensure reasonable notice is provided to federally recognized Indian tribes, Native Alaskans, and Native Hawaiian organizations when proposed actions or land management policies and practices may restrict future access to or ceremonial use of or adversely affect the physical integrity of sacred sites. If a sacred site might be affected by DOE land management policies or practices, then the DOE must also ensure that the compliance requirements of the NHPA are met if the sacred site meets the NHPA definition of an historic property.

4.6.2.1.5 Curation of Federally Owned and Administered Archeological Collections (36 CFR 79)

DOE must ensure that all "collections," as defined in 36 CFR 79.4(a), are processed, maintained, and curated in accordance with the requirements of 36 CFR Part 79. However, NAGPRA cultural items and human remains in DOE's possession and control must be disposed of in a manner consistent with the requirements of NAGPRA and 43 CFR Part 10. DOE archaeological collections may be processed, maintained, and curated on and by DOE or another federal agency, state agency, or other outside institution or nongovernmental organization, in cooperative repositories maintained by or on behalf of multiple agencies, or in other facilities, under contract, cooperative agreement, or other formal funding and administrative arrangement provided the standards of 36 CFR Part 79 are met.

4.6.2.1.6 Protection and Enhancement of the Cultural Environment (Executive Order. No. 11593)

This Executive Order requires federal agencies to initiate measures to preserve, restore and maintain federally owned sites, structures and objects of historical, architectural or archaeological significance, and in consultation with the ACHP to institute procedures to assure that federal plans and programs contribute to the preservation and enhancement of non-federally owned sites, structures and objects of historical, architectural or archaeological significance. Federal agencies must inventory their cultural resources and to record, to professional standards, any cultural resource that may be altered or destroyed.

4.6.2.1.7 Consultation and Coordination with Indian Tribal Governments (Executive Order No. 13175)

This Executive Order requires federal agencies to establish regular and meaningful consultation and collaboration with tribal officials in the development of federal policies that have tribal implications, and to strengthen government-to-government relations with Indian tribes.

4.6.2.1.8 Preserve America (Executive Order No. 13287)

This Executive Order seeks to enhance federal stewardship of historic properties, promote the benefits of historic preservation, and improve federal agency planning and accountability. Federal agencies such as DOE must maximize their efforts to integrate the policies procedures and practices of the NHPA and this order into their program activities in order to advance historic preservation objectives while efficiently and effectively pursuing their mission.

4.6.2.2 DOE Directives, Policy and Guidance

In addition to the above, there are a number of DOE directives, regulations and/or standards that are relevant to protecting and managing the Agency's cultural resources. These include:

- DOE O 450.1, Environmental Protection Program
- DOE P 141.1, DOE Management of Cultural Resources
- DOE G 450.1-3, Environmental Guidelines for Development of Cultural Resource Management Plans
- DOE P 454.1, Use of Institutional Controls
- DOE O 430.1B, Real Property Asset Management

4.6.2.2.1 DOE O 450.1, Environmental Protection Program

This Order requires implementation of sound stewardship practices to protect natural and cultural resources impacted by DOE operations, and allow the Agency to meet or exceed compliance with applicable environmental, public health, and resource protection requirements in a cost-effective way. This objective is accomplished through the implementation of Environmental Management Systems

(EMSs) as part of Integrated Safety Management Systems (ISMSs) that are established by DOE facilities to comply with DOE P 450.5, *Safety Management System Policy.* DOE Order 450.1 specifically notes that cultural resources should be considered in EMSs.

4.6.2.2.2 DOE P 141.1, Department of Energy Management of Cultural Resources

The purpose of this policy is ensure that cultural resource management is integrated into DOE's missions and activities, and to raise the level of awareness and accountability among DOE contractors concerning the importance of DOE's cultural resource-related legal and trust responsibilities. Specifically cited are DOE's responsibilities under all of the above referenced requirements (viz., NHPA,AHPA, ARPA, NAGPRA, and Executive Orders 11593, 13175 and 13007) as well as the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation, Standards and Guidelines for Federal Agency Historic Preservation Programs*, and *Standards for Rehabilitation* and *Guidelines for Rehabilitating Historic Buildings.* The policy states that the DOE will uphold these laws by preserving, protecting and perpetuating cultural resources for future generations in a spirit of stewardship, and will implement management accountability for compliance with all applicable laws, treaties, orders and guidance. Finally, responsible DOE managers are required to develop, implement and periodically review a Cultural Resources Management Plan at all DOE facilities, and that Lead Program Secretarial Officers (LPSOs) and Cognizant Secretarial Officers (CSOs) will carry out these efforts, including integration of cultural resource concerns into program and project planning, for sites and facilities for which they have landlord responsibilities.

4.6.2.2.3 DOE G 450.1-3, Environmental Guidelines for Development of Cultural Resource Management Plans

The purpose of this document is to provide guidelines to DOE field managers who are responsible for the development of an individual Cultural Resource Management Plan (CRMP) for each DOE facility and program. The guidelines are developed as a planning vehicle for ensuring that each DOE facility and program complies with laws, regulations, Executive Orders and DOE directives governing the management of cultural resources, and that the cultural resource planning process is integrated into compliance actions driven by other environmental laws such as NEPA. The guide provides a format for the preparation of CRMPs as well as recommendations, alternatives and approaches for meeting CRMP requirements.

4.6.2.2.4 DOE P 454.1, Use of Institutional Controls

This policy specifies how DOE will use institutional controls to manage its resources, facilities and properties. The policy specifically notes that DOE uses a wide range of such controls to manage and protect cultural resources under its jurisdiction. Institutional controls may include administrative or legal controls, physical barriers or markers, and methods to preserve information and data.

4.6.2.2.5 DOE O 430.1B, Real Property Asset Management

This order describes DOE's system for establishing a "corporate, holistic and performance-based" approach to real property life-cycle asset management. It requires that cultural asset management and historic preservation be considered in land use and disposition plans.

4.6.3 Generalized Siting and Operational Impacts of Technologies

4.6.3.1 Post-combustion Capture

Post-combustion capture projects would be retrofitted to existing, or added to proposed, fossil fuel combustion facilities or comparable industrial processes. Generally, the addition of a CO_2 capture process to an existing facility would have negligible impacts to cultural resources or their context, unless they were encountered (and left in place) during the initial development of the existing facility or a site file and/or field investigation was not adequately done when the existing facility was initially developed. An exception might be if the new process required a significant expansion of the facility property or would otherwise introduce features that would adversely affect cultural resources or their context.

A post-combustion capture project would likely be sited at an existing fossil-fueled power plant or other compatible industrial facility. Such facilities generally provide adequate property for expansion within the site boundary. However, if a CO_2 capture project created a need to acquire additional land for the facility, an assessment of site-specific impacts on cultural resources would be required. In the event that a capture process would be associated with a proposed new industrial facility, the site-specific impacts on cultural resources for the project would be encompassed within the environmental review for the new facility.

4.6.3.2 CO_2 Compression and Transport

CO_2 compression facilities would require a small footprint of land, most likely located in proximity to a CO_2 capture process on the property of an existing power plant or comparable industrial facility. Generally, the addition of CO_2 compression facilities to an existing industrial site would not likely result in significant adverse impacts to cultural resources and would have a negligible, if any, impact on their context. Exceptions would occur if additional site acquisition or significant expansion of the facility property were required, and/or if it would otherwise introduce features that would adversely affect cultural resources and their context.

Although smaller scale field validation projects may allow for transportation of CO_2 to a sequestration site via compressed gas container trucks or rail cars, it is assumed that a cost-effective commercial application would require conveyance via compressed gas pipelines. Therefore, the principal aspect of a CO_2 compression and transport project that would affect cultural resources if there were a potential need for easements and rights-of-way for CO_2 pipelines and booster stations. Where practicable, impacts on cultural resources can be minimized by co-utilizing easements already in use for other utility pipelines and power transmission lines. Otherwise, new easements must be established, in which case a survey would have to be performed of the utility corridor to determine potential site-specific impacts on cultural resources.

Although it is assumed that proper planning and study would be conducted on areas affected by construction of compression and transport facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.3.3 Sequestration in Coal Seams

Siting for coal seam sequestration projects would depend on the identification of suitable coal seams within sufficient proximity of potential CO_2 sources. Therefore, coal seams closest to existing fossil fuel-fired power plants or other CO_2 sources would be the optimal candidates for commercial application initially. Hence, before selecting a suitable location for a coal seam sequestration project, an assessment of site-specific impacts on cultural resources would be required.

Clearing, grading, runoff and erosion, along with construction activities associated with drill pads, ancillary facilities, access roads and pipelines could result in direct alteration or destruction of cultural resources. The significance of the potential impact to any cultural resources cannot be known without proper investigation and analysis at each specific site. In addition, clearing adjacent to a proposed project site or within access road ROW may also be required and this would further raise the prospect of impacts to cultural resources.

Fugitive dust generated during clearing, grading, and construction activities could impact cultural resources or their context in the vicinity of the project area. Fugitive dust generation may be relatively high at sites located in the more arid ecological provinces. In these instances, most impacts are expected to be short term, although the potentially abrasive nature of fugitive dust may impact susceptible cultural resources (e.g., fragile structures, rock art, etc.).

Construction equipment would need to be refueled and some hazardous materials or wastes, such as waste paints and degreasing agents, may be generated. Accidental spill of fuel, lubricating oils or hazardous materials could result in damage to cultural resources at the project site. While these impacts would be expected to be small and localized, they also could significantly alter and/or damage some cultural resources. With the removal of contaminated soil, residual effects would be minimized.

Coal seam carbon sequestration model projects could be sited in an area with surface water features such as streams or rivers, lakes, ponds, and wetlands. Because of the importance of water to human and other animal life, it is possible there may be increased occurrences of cultural resources near these water features, especially if they are generally in the same location now as during historic, archaeological and paleontological periods. The layout of the project would be flexible enough that surface water features could be avoided in siting drill pads and ancillary facilities, however, the situation could occur that access roads or pipelines may have to cross a stream, river or a wetland.

The types of cultural resources that could be affected would be a function of the site-specific environmental conditions present at the facility location. Clearing, grading, erosion and runoff, and construction activities may result in direct disturbance or reduction of cultural resources that may be present within construction footprint, including access roads and pipeline. Compliance with the applicable requirements would limit the likelihood of construction occurring in or impacting cultural resources.

Although it is assumed that proper planning and study would be conducted on areas affected by construction of coal seam sequestration facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.3.4 Sequestration in Depleted Oil and Gas Reserves

Sequestration in depleted oil and gas reserves is similar to sequestration under the coal seam concept. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation.

During construction, adverse cultural resource effects could occur from activities such as the modification of drainage patterns, erosion and runoff, fugitive dust, removal of vegetation cover, exposure of cultural resources to contaminants, and modification of the subsurface strata. Site clearing and grading, along with construction of drill pads, ancillary facilities, pipelines, and access roads could disturb, dramatically alter or destroy existing cultural resources in the disturbed portions of the project area.

Fugitive dust generated during clearing, grading, and construction activities could impact cultural resources or their context in the vicinity of the project area. Fugitive dust generation may be relatively high at sites located in the more arid ecological provinces. In these instances, most impacts are expected to short-term, although the potentially abrasive nature of fugitive dust may impact susceptible cultural resources (e.g., fragile structures, rock art, etc.).

Construction equipment would need to be refueled and some hazardous materials or wastes, such as waste paints and degreasing agents, may be generated. Accidental spill of fuel, lubricating oils or hazardous materials could result in damage to cultural resources at the project site. While these impacts would be expected to be small and localized, they also could significantly alter and/or damage some cultural resources. With the removal of contaminated soil, residual effects would be minimized.

Although it is assumed that proper planning and study would be conducted on areas affected by construction of EOR sequestration facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.3.5 Sequestration in Saline Formations

Sequestration in a saline geologic formation is similar to sequestration under the coal seam concept. Both types of projects consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation. The construction phase would consist of drilling wells into a saline geologic formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, methane, and water.

During construction, adverse cultural resource effects could occur from activities such as the modification of drainage patterns, erosion and runoff, fugitive dust, removal of vegetation cover, exposure of cultural resources to contaminants and modification of the subsurface strata. Site clearing and grading, along with construction of drill pads, ancillary facilities, pipelines, and access roads could disturb, dramatically alter or destroy existing cultural resources in the disturbed portions of the project area.

Fugitive dust generated during clearing, grading, and construction activities could impact cultural resources or their context in the vicinity of the project area. Fugitive dust generation may be relatively high at sites located in the more arid ecological provinces. In these instances, most impacts are expected to short-term, although the potentially abrasive nature of fugitive dust may impact susceptible cultural resources (e.g., fragile structures, rock art, etc.).

Construction equipment would need to be refueled and some hazardous materials or wastes, such as waste paints and degreasing agents, may be generated. Accidental spill of fuel, lubricating oils or hazardous materials could result in damage to cultural resources at the project site. While these impacts would be expected to be small and localized, they also could significantly alter and/or damage some cultural resources. With the removal of contaminated soil, residual effects would be minimized.

Although it is assumed that proper planning and study would be conducted on areas affected by construction of saline formation sequestration facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.3.6 Sequestration in Basalt Formations

Sequestration in a basalt formation is similar to sequestration under the coal seam concept. Both types of projects consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation. The construction phase would consist of drilling wells into a basalt formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, methane, and water.

During construction, adverse cultural resource effects could occur from activities such as the modification of drainage patterns, erosion and runoff, fugitive dust, removal of vegetation cover, exposure of cultural resources to contaminants and modification of the subsurface strata. Site clearing and grading, along with construction of drill pads, ancillary facilities, pipelines, and access roads could disturb, dramatically alter or destroy existing cultural resources in the disturbed portions of the project area.

Fugitive dust generated during clearing, grading, and construction activities could impact cultural resources or their context in the vicinity of the project area. Fugitive dust generation may be relatively high at sites located in the more arid ecological provinces. In these instances, most impacts are expected to short-term, although the potentially abrasive nature of fugitive dust may impact susceptible cultural resources (e.g., fragile structures, rock art, etc.).

Construction equipment would need to be refueled and some hazardous materials or wastes, such as waste paints and degreasing agents, may be generated. Accidental spill of fuel, lubricating oils or hazardous materials could result in damage to cultural resources at the project site. While these impacts would be expected to be small and localized, they also could significantly alter and/or damage some cultural resources. With the removal of contaminated soil, residual effects would be minimized.

Although it is assumed that proper planning and study would be conducted on areas affected by construction of basalt formation sequestration facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.3.7 Terrestrial Sequestration - Reforestation

Terrestrial sequestration projects generally would entail efforts aimed at reforesting and amending landscapes degraded by previous mining operations through the establishment of shrubs and trees that will convert CO_2 into biomass. The cycle of typical site activities would include preparation (clearing, disking, soil amendment, applying herbicides), planting and seeding (hand or mechanical), and maintenance (thinning, harvesting, fertilization, monitoring, and security).
Because of the present degraded character of these landscapes, it is anticipated that any cultural resources that were present would not be impacted further. Therefore, terrestrial sequestration is expected to have a negligible impact on cultural resources. Regardless of this assumption, all applicable laws, regulations, policies, standards and directives must be followed. In addition, potential impacts associated with American Indian sacred space and traditional use areas, contextual intrusion, and land disturbance should be considered.

> Because DOE reforestation projects would be focused on already degraded areas, it is likely that any cultural resources that may have been present would not be impacted further by future activities.

4.6.3.8 Co-Sequestration of H_2S and CO_2

Potential short-term (i.e., the construction stage) and long-term impacts related to the sequestering of both H_2S and CO_2 would be similar to the potential impacts for sequestering in coal seams, oil and gas fields, or saline formations. For the most part, surface facilities would be the same, with the exception that materials used for compressing and transporting the gas would have to resist the corrosive nature of H_2S. Although it is assumed that proper planning and study would be conducted on areas affected by construction of co-sequestration facilities, there is some potential for accidental and minor adverse impacts to archeological and buried American Indian artifacts during the construction phase.

4.6.4 Mitigation of Potential Adverse Impacts

Cultural resources could be encountered on lands utilized in association with carbon sequestration projects. These would be generally identified and assessed on a project-specific basis. Because fossils only appear in sedimentary rock formations, this is an efficient initial screen as to the potential for the presence of fossils in a project area. Many states maintain a database or repository for information on past paleontological, archaeological and historic resources either through the SHPO or through a designated repository, such as a university. If there would be a strong potential for cultural resources to be present in a project area, a survey would be required. The following measures are recommended to mitigate the adverse impacts of Carbon Sequestration technologies on cultural resources:

4.6.4.1 Project Planning and Design

- If the project would be located at an existing industrial facility, determine whether adequate, suitable land area is available to accommodate new facilities without affecting cultural resources. If the project will require the acquisition of new sites for facilities, areas should be avoided that may result in the disturbance or destruction of cultural resources or their context. The presence of archaeological sites and historic properties in the area of potential effect should be determined on the basis of an investigation of recorded sites and properties in the area and/or an archaeological survey. The SHPO is the primary repository for this Cultural Resource information.

- Archaeological sites and historic properties present in the area of potential effect should be reviewed to determine whether they meet the criteria of eligibility for listing on the National Register of Historic Places (NRHP). Cultural resources listed on or eligible for listing on the NRHP are considered "significant" resources.

- Consultation with American Indian governments should be done early in the planning process to identify issues and areas of concern. Aside from the fact that this consultation is required under the NHPA, consultation is necessary to establish whether the project is likely to disturb traditional cultural properties, affect access rights to particular locations, disrupt traditional cultural practices, and/or visually impact areas important to the tribe(s).

- If cultural resources are present at the site, or if areas with a high potential to contain cultural material have been identified, a CRMP should be developed. This plan should address mitigation activities to be implemented for cultural resources found at the site. Mitigation options include avoidance of the area, archaeological survey and excavation (as warranted), and monitoring. If an area exhibits a high potential, but no artifacts are observed during an archaeological survey, monitoring by a qualified archaeologist could be required during all excavation and earthmoving in the high-potential area. A report should be prepared documenting these activities. The CRMP also should (1) establish a monitoring program, (2) identify measures to prevent potential looting/vandalism or erosion impacts, and (3) address the education of workers and the public to make them aware of the consequences of unauthorized collection of artifacts and destruction of property on public land.

- If a project is proposed to be located on lands controlled by Federal or state agencies, confer with the appropriate representatives of the respective landowner to determine potential limitations, restrictions and procedures that would be applicable to the project.

- Determine whether rights-of-way will be required for pipeline corridors, access roads, or other facilities. Identify and assess the occurrence of cultural resources that may be present to accommodate additional pipelines or access roads in the proposed transmission corridor.

4.6.4.2 Construction

- Depending on the specific location, the construction necessary for development would have the greatest potential to impact cultural resources because of the increased ground disturbance during this phase. The footprint of land area disturbance required for a proposed project should be minimized. Consultation pursuant to Section 106 of the NHPA would minimize potential effects on cultural resources.

- Vehicular traffic and ground clearing (such as the removal of vegetation cover) could affect cultural resources directly or indirectly through compacting soils, potentially crushing artifacts, disturbing historic features (e.g., trails), displacing cultural material from its original context, and soil erosion. These activities might also impact areas of interest to American Indians, such as sacred areas or areas used for harvesting traditional resources, such as medicinal plants. The creation of access roads could also modify drainage patterns and possibly result in impacts caused by erosion. Erosion has the potential to alter fossil beds and archaeological artifacts, including the possible separation of a collection of fossils and artifacts. Site investigations and implementation of a CRMP would mitigate these potential impacts.

- American Indian concerns should be identified through direct consultation with tribal representatives and field visits with tribal religious specialists during site-specific tiered NEPA documents. Contacts would be identified by reference to the ethnographic literature, by state and national pantribal organizations, and by agency and academic anthropologists.

4.6.4.3 Operation

Fewer impacts on cultural resources are likely from the operation of a carbon sequestration project than from its construction. Impacts associated with operation are possible, however, because of the improved access to the area and the presence of workers and the public. Throughout the period of facility operations, diligence would have to be exercised with respect to archaeological sites, traditional cultural and historic properties, and paleontological resources. Facility operations will be conducted in compliance with applicable cultural resource laws, regulations, policies and procedures, including DOE directives.

4.6.5 Summary of Potential Impacts

Table 4-18 provides an overall qualitative assessment of potential impacts to cultural resources for each sequestration technology. In general, impacts on historical resources are expected to be negligible, because these resources can be avoided most effectively during project siting. Potential impacts on archaeological and American Indian resources would be related to the potential existence of resources on or beneath proposed sites and the extent of land area to be disturbed for site preparation and construction of drill pads, ancillary facilities, pipelines, and access roads. These impacts are anticipated to be negligible to minor, because most projects would be located in areas that have already been disturbed for coal, oil, and gas extraction. Furthermore, impacts can be mitigated appropriately through the performance of site-specific file investigations, consultations, field surveys, and data recovery where necessary. Terrestrial reforestation projects are expected to occur on lands damaged during prior mining operations, where they would be expected to have negligible impacts on cultural resources. Post-combustion capture projects are expected to have negligible impacts on cultural resources, because they would be located on the properties of existing fossil-fueled

> Potential impacts to archeological resources from geologic sequestration projects are anticipated to be negligible to minor, because most projects would be located in areas already disturbed for coal, oil and gas extraction.

plants or would be included in the site-specific investigations for new facilities.

Table 4-18. Potential Impacts of Program Technologies on Cultural Resources

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Archaeological resources	·	○	○	○	○	○	·	○
Historic resources	·	·	·	·	·	·	·	·
American Indian resources	·	○	○	○	○	○	·	○

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

4.7 AESTHETIC AND SCENIC RESOURCES

This section describes the potential impacts to aesthetic and scenic resources that could occur during the implementation of carbon sequestration technologies. The aesthetic and scenic resources that could be affected by sequestration technologies are described in Section 3.7. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.7.1 Impact Considerations

Aesthetic and scenic resources that may be affected by a sequestration project include landforms, bodies of water, vegetation, and structures. Some of these resources have been listed in the National Register of Historic Places by the National Park Service and designated as National Historic Sites, National Parks, National Preserves, National Rivers, National Seashores, National Wild and Scenic Rivers, or other similar designation. Potential impacts on aesthetic and scenic resources have been assessed using the general criteria outlined below and the definitions provided in Section 4.1.1. Short-term impacts for aesthetic and scenic resources are defined as impacts occurring during the construction timeframe. Localized impacts for aesthetic and scenic resources are defined as those that could occur within the visual range of the project footprint.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would: cause the potential for loss, isolation or substantial alteration of a American Indian resources, including graves, remain and funerary objects.

The types of aesthetic and scenic resources that could be affected by carbon sequestration projects depend on the assessment of the area's scenic values, the size of the area, and the specific location of the proposed project. The Bureau of Land Management (BLM) has developed a Visual Resource Management (VRM) system to identify and evaluate the scenic value of public lands. The system also provides a way to analyze potential visual impacts of proposed projects and activities, and it may be useful for evaluating impacts on aesthetic resources during site selection for potential carbon sequestration projects. The BLM is responsible for managing 262 million acres of land--about one-eighth of the land in the U.S.--and about 300 million additional acres of subsurface mineral resources. Subsequently, many carbon sequestration projects could potentially be influenced by BLM guidelines and regulations.

In the VRM system, the BLM applies visual design techniques to ensure that surface-disturbing activities are in harmony with their surroundings (BLM, 2005). The VRM system first inventories the visual quality of scenic resources through the rating of key factors (landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications) and then assigns the area to a management class with established objectives (BLM, 2005a). "The process involves rating the visual appeal of a tract of land, measuring public concern for scenic quality, and determining whether the tract of land is visible from travel routes or observation points" (BLM, 2005). The BLM then can determine whether the potential project would meet the established management objectives for the area or if design changes/modifications need to be made. It can also identify measures to mitigate potential visual impacts (BLM, 2005b). VRM classes and objectives are listed in Table 4-19.

Table 4-19. Bureau of Land Management Visual Resource Management Classes

Class	Management Objective
Class I	To preserve the existing character of the landscape. The level of change to the characteristic landscape should be low and must not attract attention.
Class II	To retain the existing character of the landscape. The level of change to the characteristic landscape should be low.
Class III	To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate.
Class IV	To provide for management activities which require major modifications of the existing character of the landscape. The level of change to the characteristic landscape can be high.

Source: BLM, 2005.

4.7.2 Regulatory Framework

Carbon sequestration projects would need to consider applicable federal, state, and local laws and regulations concerned with aesthetic and scenic resources. Major federal laws and regulations are listed in Table 4-20.

Table 4-20. Major Laws and Regulatory Requirements for Aesthetic and Scenic Resources

Law/Regulation	Key Elements
Wild and Scenic Rivers Act of 1968, as amended (16 USC § 1271).	The Act establishes a National Wild and Scenic Rivers System and prescribes the methods and standards through which additional rivers may be identified and added to the system. Rivers are classified as wild, scenic, or recreational, and hunting and fishing are permitted in components of the system under applicable Federal and State laws. The Act authorized the Secretary of the Interior and the Secretary of Agriculture to study areas and submit proposals to the President and Congress for addition to the system. It describes procedures and limitations for control of lands in Federally administered components of the system and for dealing with disposition of lands and minerals under Federal ownership.
Noise Control Act of 1972 (42 USC § 4901)	This Act authorizes the establishment of Federal noise emissions standards for products distributed in commerce and coordinates Federal research efforts in noise control.

4.7.3 Generalized Siting and Operational Impacts of Technologies

4.7.3.1 Post-combustion Capture

It is assumed that post-combustion capture projects would be retrofitted to an existing industrial facility where CO_2 is formed as a product of fossil fuel combustion. Such projects are likely to be located in an industrial site adjacent to an existing power plant or other industrial facility. Utility hookups and access roads are expected to already exist. While the addition of this technology may cause some increase in personnel (traffic flow) and waste generation, the visual impacts of such projects are expected to be negligible (little or no change) because of the likely industrialized location of post-combustion capture projects.

4.7.3.2 CO_2 Compression and Transport

As described for the model project in Section 2.5, two options were considered for transporting CO_2 to a sequestration site. In the first option, CO_2 from flue gas or another industrial source would be transported by compressed gas pipeline to a sequestration site. In the second, liquid CO_2 would be transported to the site via commercial refrigerated tank trucks.

The use of a compressed gas pipeline would require transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new rights-of-way would need to be cleared. This clearing would result in potential moderate adverse impacts (long-term and localized) on aesthetic and scenic resources. Such impacts may range from negligible to moderate depending upon the existing characteristics of the proposed corridor.

The option of transporting CO_2 to a sequestration site via tank trucks is expected to have negligible impact on aesthetic and scenic resources. The principal impacts would result from the need for CO_2 storage tanks at the compression site and the increase in truck traffic between the capture site and the sequestration site. Because the compression facilities and storage tanks would most likely be located on the property of a power plant or other industrial facility (CO_2 source), aesthetic and scenic impacts would be negligible. The impact on scenic resources from additional truck traffic from the capture facility to the sequestration site could be minimized by selecting appropriate truck routes that avoid sensitive resources.

4.7.3.3 Sequestration in Coal Seams

Siting for coal seam sequestration projects would depend on the identification of suitable coal seams within sufficient proximity of potential CO_2 sources to enable cost-effective conveyance. As described in Section 2.5, sequestration projects would most likely be located in close proximity to an existing power plant or other industrial facility (CO_2 source). Therefore, unmineable coal seams located near existing fossil fuel-fired power plants or other CO_2 sources would be optimal candidates for commercial application initially. Exploration for new coals seams suitable for ECBM and CO_2 sequestration is anticipated. Hence, future projects may be located in areas that have previously been undisturbed, which may in turn cause degradation to currently pristine areas.

Site preparation activities would include access road development and clearing of ground cover. Aboveground structures would likely consist of well equipment, a small mobile trailer, and storage tanks to store waste water recovered during CBM recovery. Additionally, the use of a compressed gas pipeline would require transmission corridors. If existing rights-of-way were not available or accessible between the capture facility and the sequestration site, new easements would be required. The need for new rights-of-way to be cleared of extensive vegetation and remain accessible for maintenance vehicles would result in potential moderate adverse impacts on aesthetic and scenic resources as described in Section 4.7.2.2.

Short-term aesthetic impacts during construction of the surface facilities would be minor (short-term and localized), relating to the activities necessary to clear the site, and include the exhaust emissions, fugitive dust, and noise from construction equipment. Long-term aesthetic impacts from operations would be negligible (not perceptible) to minor (localized) assuming that surface facilities would not be located in important scenic and natural areas.

4.7.3.4 Sequestration in Depleted Oil and Gas Reserves

There are many existing commercial-sized projects of geologic sequestration in oil reservoirs as part of EOR from which the following information is based. Siting for these projects would depend on the identification of suitable, existing oil reservoirs within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance. Impacts during construction and operation would be similar to those for coal seam sequestration projects (Section 4.7.3.3).

4.7.3.5 Sequestration in Saline Formations

Siting for carbon sequestration projects in saline formations would depend on the identification of suitable formations within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance. Therefore, saline formations located near existing fossil fuel-fired power plants or other CO_2 sources would be optimal candidates for commercial application initially. Impacts during construction and operation would be similar to those for coal seam sequestration projects (Section 4.7.3.3).

4.7.3.6 Sequestration in Basalt Formations

Siting for carbon sequestration projects in basalt formations would depend on the identification of suitable formations within sufficient proximity of existing power plants or other industrial facilities (CO_2 sources) to enable cost-effective conveyance. Therefore, basalt formations located near existing fossil fuel-fired power plants or other CO_2 sources would be optimal candidates for commercial application initially. Impacts during construction and operation would be similar to those for coal seam sequestration projects (Section 4.7.3.3).

4.7.3.7 Terrestrial Sequestration - Reforestation

The enhancement of terrestrial carbon sequestration through reforestation projects involving landscapes that have been degraded from the extraction of fossil fuels would have a net beneficial impact (long-term restoration) on aesthetic and scenic resources. The planting of trees in these areas would not only provide the potential for removing CO_2 from the atmosphere, but reforestation would improve the visual quality of the areas by restoring the landscape, reducing soil erosion and sedimentation in surface waters, and increasing potential wildlife habitat.

4.7.3.8 Co-Sequestration of H_2S and CO_2

Co-sequestration of H_2S and CO_2 would be similar to sequestration of CO_2 in coal seams, oil and gas reserves and saline formations. The facilities and infrastructure would be the same, however, different materials for pumps, compressors, and pipelines would be used to guard against the corrosive nature of the sour gas. As with the aforementioned model projects, short-term aesthetic impacts during construction of the surface facilities would be minor (short-term and localized), relating to the activities necessary to clear the site and including the exhaust emissions, fugitive dust, and noise from construction equipment. Long-term aesthetic impacts from operations would be negligible to minor assuming that surface facilities would not be located in important scenic and natural areas.

4.7.4 Mitigation of Potential Adverse Impacts

The following BMPs are recommended to mitigate potential adverse impacts of sequestration technologies on aesthetic and scenic resources. The BMPs are protective, economically feasible measures that can be developed and implemented, on a site-specific or project-specific basis, during the project planning and design, construction, and operation phases. These measures are aimed at reducing, preventing, or mitigating adverse environmental impacts to the aesthetic and scenic quality of the lands.

> The need for cleared and maintained pipeline corridors for CO_2 transmission may result in the most extensive impacts on scenic resources. These impacts could be avoided by using existing corridors where feasible.

4.7.4.1 Project Planning and Design

- Use established easements and existing rights-of-way wherever feasible to avoid the need for clearing and maintaining new corridors for CO_2 transmission.

- Maintain the integrity of topographic units by locating projects away from prominent topographic features and designing projects to blend with topographic forms in shape and placement (BLM, 2005b).

- Minimize the number of visible structures (BLM, 2005b). Great effort should be taken in locating structures and sites away from highly scenic areas, prominent features, or other highly visible areas (e.g., ridgetops) in order to mitigate visual impacts.

- Minimize the contrast between structures and natural surroundings by using earthtone paints and stains, using cor-ten steel (self-weathering), treating wood for self-weathering, using natural stone surfaces, burying part or all of the structure, and selecting paint finishes with low levels for reflectivity (i.e., flat or semi-gloss) (BLM, 2005b).

- Redesign structures that do not blend or fit with the viewscape by using rustic designs and native building materials, using natural-appearing forms to complement landscape character (use special designs only as a last resort), and relocating the structure, if possible (BLM, 2005b).

- Plan road systems to avoid unnecessary surface disturbance and construction costs. Use existing roads whenever possible.

- Plan and design the smallest footprint possible. Reduce the size of disturbed area to the minimum that is needed for the site.

- Involve and inform the public about the visual site design elements of the proposed project. Possible approaches include conducting public information meetings and disseminating information concerning project features (BLM, 2004).

- Avoid placing commercial symbols (such as logos), trademarks, messages, advertising messages, and billboards at the site or on ancillary structures or equipment (BLM, 2004).

- Avoid designs that require security lighting. If such lighting is necessary, use motion detectors to activate lights (BLM, 2004).

- Provide workers with project orientation to increase their understanding of the sensitivity of the environment and lands on which the project is located (NPS, 2004). Ensure that all workers are trained in how to handle hazardous materials spills that may occur on site and the ecological and aesthetic damage that they may cause.

4.7.4.2 Construction

- Reduce the size of cut and fill slope by avoiding steep slopes, changing the road width and grade, changing the road alignment to follow existing grades, and prohibiting the dumping of excess material on downhill slopes (BLM, 2005b). Roads located along ridgetops may be less visible than those located on the ridge face due to increased cut, fill, and sidecast material.

- Reduce earthwork contrasts by rounding and/or warping slopes; retaining rocks and trees; toning down freshly broken rock faces with asphalt emulsion spray or with gray point; adding topsoil, mulch, or hydromulch; shaping cuts and fills to appear as natural forms; cutting rock areas so forms are irregular; designing projects to take advantage of natural screens such as vegetation and land forms; and seeding of cuts and fills (BLM, 2005b).

- Retain existing vegetation by using retaining walls on fill slopes, reducing surface disturbance, and protecting roots from damage during excavations (BLM, 2005b).

- Enhance revegetation by mulching cleared areas; controlling planting times; furrowing slopes; planting holes on cut/fill slopes; choosing native plant species; stockpiling and reusing topsoil; and fertilizing, mulching, and watering vegetation (BLM, 2005b).

- Minimize the impact on existing vegetation by partial cutting instead of clear cutting, using irregular clearing shapes, feathering/thinning edges, disposing of all slash, controlling construction access, utilizing existing roads, limiting work within the construction area, selecting the appropriate type of equipment to be used, minimizing the clearing size (i.e., strip only when necessary), and grass seeding of cleared areas (BLM, 2005b).

- Maintain the integrity of vegetative units by utilizing the edge effect for structure placement along natural vegetative breaks (BLM, 2005b).

- Minimize the impact of utility crossings by making crossings at right angles, setting back structures at a maximum distance from the crossing, leaving vegetation along the roadside, minimizing viewing time, and utilizing natural screening (BLM, 2005b).

- Recognize the value and limitations of color by painting structures somewhat darker than the adjacent landscape to compensate for the effect of shade and shadow and selecting color to blend with the land and not the sky. Realize that color (hue) is most effective within 1,000 feet. Beyond that point color becomes more difficult to distinguish and tone or value determines visibility and resulting visual contrast. Also, color has limited effectiveness (in the background distance zone) in reducing visual impacts on structures that are silhouetted against the sky (BLM, 2005b).

- Bury pipelines, utility lines, or other cables, whenever possible.

- Avoid creating potential sources of dust by covering construction truck beds, avoiding stockpiling of materials that may blow dust, covering materials, and using other dust suppression methods.

4.7.4.3 Operation

- Maintain good housekeeping procedures. Do not allow trash, debris, unused or broken equipment and materials, or hazardous wastes to unnecessarily accumulate. Keep the amounts of materials stored on-site to a minimum. Maintain the painting and upkeep of the structures.

4.7.5 Regional Considerations

Potential impacts on aesthetic and scenic resources from carbon sequestration projects would be comparable among the various states. As described in Sections 2.3 and 2.4, the availability of CO_2 sources and potential sequestration sinks largely determines the applicability of various technologies in particular states and regions. Section 4.8.4 in land use provides additional discussion of potential locations of various coal seams, depleted oil and gas reserves, saline formations, and other geologic formations for sequestration, as well as cropland, agricultural lands, and forests that could be used for terrestrial sequestration. The potential for visual impacts in each particular region depends on the location of a national park, scenic byway, or other scenic resource in proximity to potential sequestration locations. Significant impacts on scenic resources can be avoided by effective site selection and design.

4.7.6 Summary of Potential Impacts

Table 4-21 provides an overall qualitative assessment of potential impacts to aesthetic and scenic resources for each sequestration technology. For the most part, potential impacts would be negligible to minor during construction stage. Potential long-term impacts from operations would be negligible to moderate, depending upon the location of surface facilities. The need for cleared and maintained pipeline corridors for CO_2 transmission may result in the moderate impacts (long-term and localized) on scenic resources. However, significant adverse impacts can be avoided by using existing corridors where feasible and by carefully routing pipeline corridors not to interfere with scenic vistas and resource areas. Selecting appropriate truck routes that avoid sensitive resources could minimize the impact on scenic resources from additional truck traffic between the capture facility and the sequestration site.

The impacts to aesthetic and scenic resources posed by coal seam, EOR, saline, and basalt sequestration as well as co-sequestration of H_2S and CO_2 would yield similar minor adverse impacts (short-term and localized) because they are all associated with site-clearing activities or site-placement. Post-combustion capture would yield negligible impacts (little or no change) because these projects would likely be located in industrialized areas. CO_2 compression and transport would yield moderate adverse (long-term and localized) impacts because these projects may require new rights-of-way that would have to be cleared of vegetation for site access. Terrestrial reforestation projects would yield net beneficial impacts (long-term restoration) because they will include re-vegetating landscapes that have been substantially degraded by fossil-fuel extraction.

Table 4-21. Potential Impacts of Program Technologies on Aesthetic and Scenic Resources

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Scenic Resources	·	⦿	○	○	○	○	+	○

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

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4.8 LAND USE

This section describes the potential impacts to land use that could occur during the implementation of carbon sequestration technologies. The land resources that could be affected by sequestration technologies are described in Section 3.8. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.8.1 Impact Considerations

Potential impacts on land use have been assessed using the general criteria outlined below and the impact definitions found in Section 4.1.1. Short-term impacts for land use are defined as impacts occurring during the construction timeframe. Localized impacts for land use are defined as those occurring within the project footprint.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Introduce structures and uses that are incompatible with land uses on adjacent and nearby properties (including noise and visual impacts).
- Introduce structures or operations that require substantial restrictions on current land uses on or adjacent to a proposed site.
- Conflict with a jurisdictional zoning ordinance.
- Conflict with a jurisdictional noise ordinance or other ordinance restricting land use.
- Conflict with a local or regional land use plan or policy.

4.8.2 Regulatory Framework

In general, land use in the U.S. is regulated on a local and regional basis. Impacts on land use from the implementation of carbon sequestration technologies would be related to the compatibility of proposed facilities with existing land uses, zoning, and land use plans in locations where they would be sited, as well as construction-related impacts on surrounding communities and land uses. Impacts may also result from potential restrictions on land uses that would be required for the implementation of proposed projects, such as restrictions on land uses to achieve terrestrial sequestration project goals, the need to provide buffer zones for geologic sequestration projects, or the need for CO_2 transmission corridor easements. Carbon sequestration projects would need to consider applicable federal, state, and local laws and regulations concerned with land use. The Farmland Protection Policy Act of 1981 (7 USC§ 4201) is intended to minimize the impact Federal programs have on the unnecessary and irreversible conversion of farmland to nonagricultural uses. It assures that—to the extent possible—Federal programs are administered to be compatible with state, local units of government, and private programs and policies to protect farmland.

4.8.3 Generalized Siting and Operational Impacts of Technologies

4.8.3.1 Post-Combustion Capture

Post-combustion capture projects would be retrofitted to existing, or added to proposed, fossil fuel combustion facilities. Generally, adding a CO_2 capture process to an existing or proposed industrial site would not alter the character or use of the property. Thus, it would not conflict with existing land uses or zoning ordinances and would have a negligible impact on surrounding communities. An exception would occur if the new process required a significant expansion of the facility property or would otherwise introduce features (increased air emissions, noise, hazardous materials, etc.) that would adversely affect adjacent land uses and nearby communities.

Post-combustion capture projects would generally fall within the site boundary of the power plant or other source facility. However, if a CO_2 capture project created a need to acquire additional land for the facility, an assessment of site-specific impacts on land use would be required based on criteria provided in Section 4.8.1. In the event that a post-combustion capture process would be associated with a proposed new industrial facility, the environmental review for the new facility would address all site-specific impacts on land use.

Most processes available for post-combustion CO_2 capture, such as the use of sorbents or separation membranes, would not introduce features that would adversely affect adjacent land uses when compared to the features of an existing or proposed combustion power plant. Therefore, the contributions of a CO_2 capture process to air emissions, hazardous materials, noise, and other features already associated with a power plant or comparable industrial process would have negligible additional impacts on adjacent land uses and nearby communities. However, the requirements for delivery of sorbents or other materials and the removal of wastes may increase the numbers of trucks entering and leaving the property on a daily basis, which would be addressed from the perspective of traffic impacts in site-specific NEPA documents.

4.8.3.2 CO_2 Compression and Transport

As described in Section 2.5, CO_2 compression facilities would require a small footprint of land located in proximity to a CO_2 capture process, most likely on the property of an existing power plant or comparable industrial facility. Generally, the addition of CO_2 compression facilities to an existing or proposed industrial site would not conflict with existing land uses or zoning ordinances and would have a negligible impact on surrounding communities. An exception would occur if the new process required new site acquisition or significant expansion of the facility property, or if it would otherwise introduce features (increased air emissions, noise, hazardous materials, etc.) that would adversely affect adjacent land uses and nearby communities.

Transport of CO_2 could be from compression facilities to sequestration sites via compressed gas pipeline or via commercial refrigerated tank trucks as described in Section 2.5. It has been assumed that a cost-effective commercial-scale project would likely provide conveyance by pipeline over a distance of approximately 20 miles or less. Therefore, the principal aspect of a CO_2 compression and transport project that would affect land use is the potential need for easements and rights-of-way for underground CO_2 pipelines and access roads. Where practicable, impacts on land use can be minimized by utilizing easements already established for other utility pipelines and power transmission lines. Otherwise, new easements would be required, which would necessitate an assessment of site-specific impacts on land use based on criteria in Section 4.8.1. In the event that tank trucks would transport CO_2, the principal impacts on surrounding land uses would be related to the numbers of trucks entering and leaving the respective compression and sequestration sites on a daily basis.

> Establishment of easements for pipeline corridors would not necessarily impose significant land use restrictions on the easement. Easements would remain suitable for open-space recreation and would not necessarily interfere with grazing and other agricultural uses.

Because CO_2 is an inert, non-toxic gas, the establishment of easements for pipeline corridors would not necessarily impose significant restrictions on many land uses affected by the easements. However, the easements would generally require that the corridors remain cleared of large trees and be accessible for inspection and maintenance of the pipelines, that permanent structures may not be built within the easements, and that subsurface excavation may not occur. The easements would remain suitable for open-space recreation and would not necessarily interfere with grazing and other agricultural uses.

4.8.3.3 Sequestration in Coal Seams

Siting for coal seam sequestration projects would depend on the identification of suitable coal seams within sufficient proximity of potential CO_2 sources to enable cost-effective conveyance. Hence, unmineable coal seams closest to existing fossil fuel-fired power plants or other CO_2 sources would be the optimal candidates for the application of a pilot or commercial scale project initially. Also, because site selection would be subject to local land use regulations and controls, as well as state and federal regulations affecting injection wells, current variations in the restrictions of local zoning ordinances and land use policies, as well as variations in state regulations, would likely influence the feasibility of siting a project in a particular location. Furthermore, the suitability of a prospective sequestration project would be affected by the proximity of coal seams to populated areas. Finally, a host of economic considerations would affect site selection, including the feasibility of future coal extraction from the seam by the holder of the mineral rights, the nature of the terrain, the accessibility of a proposed site, and the availability of suitable rights-of-way for conveyance corridors. Hence, before selecting a suitable location for a coal seam sequestration project, an assessment of site-specific impacts on land use would be required using the criteria provided in Section 4.8.1.

The most promising initial candidate sites for coal seam sequestration would include unmineable coal seams in areas that have already been disturbed by activities during previous coal mining operations.

Assuming that candidate coal seams underlie properties in all of the major land uses described in Section 3.8, it is feasible that potential sites for projects may be located in any category of land use. However, the siting of coal seam sequestration projects generally would avoid urban jurisdictions. Therefore, sites chosen for coal seam injection and associated MM&V facilities most likely would not be subject to local zoning ordinances, or they would likely be zoned for mineral extraction, agriculture, or other rural uses. Similarly, if feasible sites for coal seam sequestration were subject to comprehensive land use planning, they most likely would be designated for open space, recreation, agriculture, or comparable uses.

Based on the relatively small site footprints required for surface facilities associated with a coal seam sequestration project, the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities essentially would affect underground resources, aboveground uses in the majority of lands needed for coal seam sequestration projects generally would not be altered. Hence, forested areas, croplands, grasslands, and virtually all other lands overlying the affected coal seam could remain in their existing uses.

4.8.3.3.1 Split Estate Lands

While it is expected that new enhanced coalbed methane projects (that sequester CO_2) will occur primarily at existing coalbed methane extraction operations, it is possible that the ability to enhance its extraction would result in the expansion of existing projects or the placement of new coalbed methane operations on previously undisturbed lands. A significant amount of coalbed methane is located in the western U.S. (Figure 3-20) where in many places the mineral rights are owned not by the overlying land owner, but by the federal government.

Over the course of U.S. history, a series of Homestead Acts passed by Congress provided for the transfer of unoccupied land to each homesteader for a nominal fee. A patent certificate could be obtained from the homesteader after continuously residing on and cultivating the land for five years (WYSEI, 2005). Many patent agreements in the West included a subsurface reservation clause that includes the retention of the mineral rights to the federal government. This separation in ownership creates a situation where the minerals are owned by one entity and the surface is owned by a second entity, referred to as a "split estate" (WYSEI, 2005). Montana and Wyoming have over 11 million acres of split-estate lands (federal mineral rights under private surface lands) apiece. New Mexico, Colorado, North Dakota, Idaho, Arizona, Oregon, South Dakota and Utah individually have over a million acres of split-estate land.

Increasingly, landowners of split-estate lands are resisting the extraction of oil and gas from their lands. During the second half of the 1990's, CBM production increased dramatically nationwide to represent a significant new source of natural gas. In recent years, exploration and development of CBM has been under intense scrutiny, as heightened concerns over environmental issues relating to production practices increased (DOE, 2002).

In the 2003 BLM Powder River Basin Coalbed Methane Final EIS, BLM predicted that an estimated 40,000 additional CBM wells would be drilled over the next 10 years on federally-owned minerals, which could disturb as many as 212,000 acres. In response to the expansion of drilling proposed by BLM, Wyoming grassroots organizations, consisting of individuals and affiliate groups, applied for Environmental Conflict Resolution to investigate split estate issues involved with CBM development of the Powder River Basin.

Because the mineral rights owner (Federal government) has a dominant legal right to access and develop the minerals, those who own the surface rights often feel that their property rights have been violated during the CBM development process (U.S. Institute for Environmental Conflict Resolution, 2003). Some key concerns raised by landowners in the case of the Powder River Basin include:

- Perceived threat to the ranching way of life – that drilling wells with roads and power lines may lead to eventual subdivision of the land.
- Concern regarding the method of discharge of produced water.
- Oversight and enforcement of the Surface Use and Damage Agreement (SUDA) is extremely time consuming, where time is not compensated and results in lost work hours.
- Financial hardships associated with the legal costs of fighting CBM development or negotiating a protective SUDA.
- Perception that CBM development is greatly lowering the value of their properties by degrading the scenic beauty and open landscape.
- Feeling that current state and federal government bonding requirements are grossly inadequate.

Although this reflects some of the landowner views on resource extraction in one basin, similar land use and property concerns could be attributed to the federal sale of mineral rights underneath other areas of private land in other regions of the U.S.

In April 2003, BLM instituted an Instruction Memorandum that clarified the policy, procedures and conditions for approving oil and gas operations on split estate lands. Under this memorandum, BLM will not consider an Application for Permit to Drill administratively or technically complete until the federal lessee or its operator certifies that an agreement with the surface owner exists, or until the lessee or its operator complies with Onshore Oil and Gas Order No. 1. This order requires the Federal mineral lessee or its operator to enter into good-faith negotiations with the private surface owner to reach an agreement for the protection of surface resources and reclamation of the disturbed areas, or payment in lieu thereof, to compensate the surface owner for loss of crops and damages to tangible improvements. Crops include those for feeding domestic animals, such as grasses, hay, and corn, but not plants unrelated to stockraising.

Tangible improvements include those relating to domestic, agricultural and stockraising uses (BLM, 2004).

Although this BLM policy will aid in diminishing concerns of owners of split estate lands, it is expected that conflicts over the use of split estate lands will continue. Subsequently, both the government and industry need to be sensitive to landowner concerns and use a collaborative process to develop SUDAs that reduce environmental impacts and minimize disruption to current land uses.

4.8.3.4 Sequestration in Depleted Oil and Gas Reserves

The most promising candidate locations initially for pilot scale and commercial scale sequestration would include depleted oil and gas reserves that are situated within close proximity of fossil fuel-fired power plants or other large CO_2 sources. It is also likely that candidate sites would be situated on lands that have been substantially disturbed during years of oil and gas production.

Most of the assumptions pertaining to land uses associated with coal seam sequestration would be similar for depleted oil and gas reserves. Candidate sites may underlie properties in any of the major land uses described in Section 3.8; however, the siting of sequestration projects generally would avoid urban jurisdictions. Therefore, sites chosen for sequestration and associated MM&V facilities probably would not be subject to local zoning ordinances, or they would be zoned for uses compatible with oil and gas extraction. If addressed by comprehensive land use plans, suitable sites most likely would be designated for open space, recreation, agriculture, or comparable uses.

Based on the relatively small site footprints required for surface facilities associated with a sequestration project in a depleted oil or gas reserve, the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities would essentially affect underground resources, aboveground uses for the majority of lands needed for sequestration projects would not generally be affected. Hence, grasslands, croplands, forested areas, and virtually all other lands could remain in their current uses.

4.8.3.5 Sequestration in Saline Formations

The siting of projects to sequester CO_2 in saline formations would depend on the identification of suitable formations sufficiently near potential CO_2 sources to enable cost-effective conveyance. Site clearing for the development of surface structures, wells, equipment locations, and access roads would necessitate the disturbance of land.

Although the surface facilities needed for sequestration in saline formations would be similar to those for sequestration in unmineable coal seams and depleted oil and gas reserves, saline formations would not necessarily be associated with lands that have been disturbed during prior resource extraction. Hence, before selecting a suitable location for a saline sequestration project, an assessment of site-specific impacts on land use would be required using the criteria provided in Section 4.8.1. On a nationwide and regional basis, variations in local zoning, as well as in state programs pertaining to injection wells, would likely influence site selection.

Most of the assumptions pertaining to land uses associated with coal seam sequestration would be similar for saline formations. Candidate sites may underlie properties in any of the major land uses described in Section 3.8; however, the siting of sequestration projects generally would avoid urban jurisdictions. Therefore, sites chosen for sequestration and associated MM&V facilities would probably not be subject to local zoning ordinances, or would be zoned for agriculture and other rural uses. If addressed by comprehensive land use plans, suitable sites most likely would be designated for open space, recreation, agriculture, or comparable uses.

Based on the relatively small site footprints required for surface facilities associated with a sequestration project in a saline formation, the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities would essentially affect underground resources, aboveground uses for the majority of lands needed for sequestration projects would not generally be affected. Hence, grasslands, croplands, forested areas, and virtually all other lands could remain in their current uses.

4.8.3.6 Sequestration in Basalt Formations

The siting of projects to sequester CO_2 in basalt formations would depend on the identification of suitable formations sufficiently near potential CO_2 sources to enable cost-effective conveyance. Site clearing for the development of surface structures, wells, equipment locations, and access roads would necessitate the land disturbance.

Although the surface facilities needed for sequestration in basalt formations would be similar to those for sequestration in unmineable coal seams and depleted oil and gas reserves, basalt formations would not necessarily be associated with lands that have been disturbed during prior resource extraction. Hence, before selecting a suitable location for a basalt sequestration project, an assessment of site-specific impacts on land use would be required using the criteria in Section 4.8.1. On a nationwide and regional basis, variations in local zoning, as well as in state programs pertaining to injection wells, would likely influence site selection.

Most of the assumptions pertaining to land uses associated with coal seam sequestration would be similar for basalt formations. Candidate sites may underlie properties in any of the major land uses described in Section 4.8; however, the siting of sequestration projects generally would avoid urban jurisdictions. Therefore, sites chosen for sequestration and associated MM&V facilities would probably not be subject to local zoning ordinances, or would be zoned for agriculture and other rural uses. If addressed by comprehensive land use plans, suitable sites most likely would be designated for open space, recreation, agriculture, or comparable uses.

Based on the relatively small site footprints required for surface facilities associated with a sequestration project in a basalt formation, the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities would essentially affect underground resources, aboveground uses for the majority of lands needed for sequestration projects would not generally be affected. Hence, grasslands, croplands, forested areas, and virtually all other lands could remain in their current uses.

4.8.3.7 Terrestrial Sequestration - Reforestation

As described in Section 2.5, many terrestrial sequestration projects would involve efforts to reclaim and restore degraded landscapes through reforestation and afforestation that would convert CO_2 into biomass. Such projects would not normally cause adverse changes in land use, because it is assumed that candidate sites are already located on lands that have been degraded by prior mining operations for fossil fuel or mineral extraction and that such sites are most likely planned and zoned for reclamation as open space or recreational lands. Instead, the reclamation of degraded lands would have a net beneficial impact on open space utilization. However, if a potential project would alter land use in a manner that would adversely affect surrounding communities and land uses, an assessment of site-specific impacts on land use would be required.

4.8.3.8 Co-Sequestration of H_2S and CO_2

Co-sequestration of H_2S and CO_2 would be similar to sequestration of CO_2 in coal seams, oil and gas reserves, and saline formations. The facilities and infrastructure would be similar, however, different materials for pumps, compressors, and pipelines would be used to guard against the corrosive nature of the sour gas. As with the aforementioned model projects, based on the relatively small site footprints required for surface facilities the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities would essentially affect underground resources, aboveground uses for the majority of lands needed for sequestration projects would not generally be affected. Hence, grasslands, croplands, forested areas, and virtually all other lands could remain in their current uses.

4.8.4 Mitigation of Potential Adverse Impacts

The following measures are recommended to mitigate potential adverse impacts of sequestration technologies on land use:

4.8.4.1 Project Planning and Design

- Plan for efficient use of land and consolidation of infrastructure requirements as practical. Site design elements should be integrated with surrounding land uses. Establish appropriate buffer areas to minimize impacts on surrounding land uses.

- If the project (e.g., pre-combustion decarbonization, post-combustion capture) will be located at an existing industrial facility, determine whether adequate, suitable land area is available to accommodate new facilities without affecting established buffer areas or encroaching on adjacent land uses.

- If the project will require the acquisition of new sites for facilities, avoid areas that may result in land use conflicts. Consult local zoning maps and ordinances during the site selection process to determine whether the project would comply with restrictions on land use in respective zones.

- Confer with local and regional planning agencies and zoning authorities early during the site selection process to identify regional land use plans and policies that may create challenges for the proposed project, local ordinances that may restrict particular uses, and other sensitive land uses and potential planning goals and issues specific to the region that should be considered during project planning.

- If a project were to be located on lands controlled by federal or state agencies, confer with the appropriate representatives of the respective landowner to determine potential limitations and restrictions that may be applicable to the project.

- If a project were to be located on tribal lands, follow established DOE policies for consultation with the appropriate tribal representatives to determine potential limitations and restrictions that may be applicable to the project.

- Where appropriate, based on the identification of proposed project sites and on local, regional, Federal, or tribal land use plans and policies, undertake amendment of applicable land use plans in coordination with respective planning authorities to ensure compatibility with the proposed project.

- Determine whether rights-of-way will be required for pipeline corridors, access roads, or other facilities. Identify established easements that may be available to accommodate additional pipelines or access roads in the proposed transmission corridor and minimize the need for new easements. If new rights-of-way will be required, ensure that all of the preceding recommendations are followed during planning for corridor alignments.

4.8.4.2 Construction

- Adhere to site plans and minimize the footprint of land area disturbance required for a proposed project, including permanent structures, roads, temporary structures, staging areas, and other features.

- Maintain buffer zones to minimize construction impacts on adjacent communities and land uses.

- Limit trucking operations for deliveries and removals to non-peak periods, while avoiding noise-sensitive times of day, to minimize traffic and noise impacts on adjacent communities and land uses.

- Restrict construction activity to the least noise-sensitive times of day in accordance with local ordinances to minimize noise impacts on adjacent communities and land uses.

- Locate stationary construction equipment as far as practicable from property boundaries and adjacent communities.

- Require the implementation of noise suppression equipment and BMPs to reduce noise to acceptable levels at property boundaries of adjacent communities. For example, require sound-muffling devices on construction equipment that are no less effective than as provided on original equipment and ensure that devices are properly maintained.

- Implement BMPs for control of construction-related air emissions, erosion and sedimentation control, and habitat protection as described for other respective resources to minimize adverse impacts on adjacent land uses and communities.

- Reclaim and restore disturbed areas expeditiously in accordance with established landscaping plans for the project site upon completion of construction phases.

4.8.4.3 Operation

- Conduct facility operations within established local ordinances, as well as Federal and state regulations, to minimize impacts on surrounding communities and land uses.

- Limit trucking operations for deliveries and removals to non-peak periods to minimize traffic impacts on adjacent communities and land uses.

- Limit noise-emitting operations to the least noise-sensitive times of day in accordance with local ordinances to minimize noise impacts on adjacent communities and land uses.

- Require the implementation of noise suppression equipment and BMPs to reduce noise to acceptable levels at property boundaries of adjacent communities. For example, require sound-muffling devices on operational equipment that are no less effective than as provided on original equipment and ensure that devices are properly maintained.

4.8.5 Regional Considerations

The potential for impacts on land use from respective capture and sequestration projects would be comparable among the various states. The technologies and features associated with potential projects, as well as particular restrictions in jurisdictional ordinances, regional land use policies, and state regulations would more likely affect land use impacts. As described in Sections 2.3 and 2.4, the availability of CO_2 sources and potential sequestration sinks largely determines the applicability of various technologies in particular states and regions. The principal land uses that may be found in the prospective project locations are described in the following paragraphs.

In the Midwest states, candidate locations for sequestration in coal seams and depleted oil and gas reserves generally overlap in a band that coincides with the Appalachian Mountain range stretching from eastern Kentucky north to western Pennsylvania. These lands are predominantly forested. Additional geologic sequestration opportunities include coal seams and depleted oil and gas reserves in areas of central Michigan that are mainly cropland and forest. Saline formations also underlie cropland and forest in portions of Ohio and Michigan. Also, in addition to the extensive forested areas of West Virginia, Pennsylvania, Ohio, and Kentucky that already provide natural sequestration, opportunities for reclamation of mined lands in these states provide potential project sites for terrestrial sequestration through reforestation and afforestation.

Potential opportunities for geologic sequestration are found throughout most of Illinois, as well as southwestern Indiana and western Kentucky. In these areas, layers of coal seams, depleted oil and gas reserves, and saline formations underlie lands that are characterized by cropland and pasture.

The best candidate areas for geologic sequestration in the southeast include depleted oil and gas reserves and saline formations underlying areas in eastern Texas, Louisiana, Mississippi, and Alabama that are characterized by grassland and forest. Coal seams underlie forested lands in parts of northern Alabama, eastern Tennessee, and southwestern Virginia. In addition to the extensive forested areas in the region that already provide natural sequestration, opportunities for reclamation of degraded lands in these states provide potential project sites for terrestrial sequestration through reforestation and afforestation.

Depleted oil and gas fields are located extensively in Texas, Oklahoma, Kansas, Colorado, and New Mexico, and to a lesser extent in other states in the southwest. Saline formations are located in many of the same areas. Most of these resources underlie pasture and cropland in these states. Coal seams also underlie pasture and cropland in eastern Nebraska, Kansas, Oklahoma, and parts of Texas. Other coal seams underlie grassland and forest in parts of Wyoming, Utah, Colorado, and New Mexico. Degraded landscapes from prior mineral extraction throughout the region provide abundant opportunities for terrestrial sequestration projects.

In the west, the most promising sites for geologic sequestration in California are saline formations, and oil and gas reservoirs which are found throughout the Central Valley. In Arizona, suitable saline formations may be found in the northeast. Saline formations are also present in the coastal valleys of Oregon and Washington. Alaska has vast oil and gas reservoirs, saline formations and coal deposits that may be suitable for carbon sequestration projects.

Coal seams, depleted oil and gas reserves, and saline formations underlie grassland and cropland in parts of Montana. Lands degraded during prior mineral extraction in the region offer prospects for terrestrial sequestration projects.

Opportunities for geologic sequestration in the plains include coal seams that underlie cropland and pasture in Iowa and Missouri, as well as oil and gas reserves that underlie grassland and cropland in North Dakota, Wyoming, and Montana. Disturbed landscapes from prior mining operations throughout the region provide abundant opportunities for terrestrial sequestration projects.

4.8.6 Summary of Potential Impacts

Because sequestration projects essentially affect underground resources, aboveground uses for the majority of lands required for projects would not generally be affected.

Table 4-22 provides an overall qualitative assessment of potential impacts to land use for each sequestration technology. Based on the relatively small site footprints required for surface facilities, the impacts on land uses in rural areas would be negligible to minor in most cases. Because the project activities would essentially affect underground resources, aboveground uses for the majority of lands needed for sequestration projects would not generally be affected. Reforestation would be expected to have a beneficial impact on land use by reclaiming previously mined lands.

The impacts to existing land uses posed by coal seam, EOR, saline, and basalt sequestration as well as co-sequestration of H_2S and CO_2 would yield similar minor adverse impacts (short-term and within existing zoning laws) because they will each require relatively small site footprints located in rural areas. CO_2 compression and transport would also yield minor adverse impacts if the new process required new site acquisition or significant expansion of existing facilities, however in general terms, the impacts of this technology would be negligible (little or no change) because they would be added onto existing industrial facilities. Post-combustion capture would yield negligible impacts because these projects would involve retrofitting existing or adding onto proposed industrial facilities. Terrestrial reforestation projects would yield net beneficial impacts (long-term restoration) because they will include re-vegetating landscapes that have been substantially degraded by fossil-fuel or mineral extraction.

Each of the aforementioned technologies, except for terrestrial reforestation, would impose similar, negligible impacts (little or no change) on zoning and land use planning because they would be situated in either rural areas that would be zoned for rural uses or not be subject to local zoning ordinances at all or in existing industrialized areas. Terrestrial reforestation would have a net beneficial impact (long-term restoration) on land use planning because it is assumed that candidate sites would most likely be planned and zoned for reclamation as open space or recreational lands.

Table 4-22. Potential Impacts of Program Technologies on Land Use

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Existing land use	·	○	○	○	○	○	+	○
Zoning and other ordinances	·	·	·	·	·	·	·	·
Land use planning	·	·	·	·	·	·	+	·

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact, ● Significant Adverse Impact, + Beneficial Impact

4.9 MATERIALS AND WASTE MANAGEMENT

This section describes the potential environmental impacts from use of hazardous materials and disposal of waste from the implementation of carbon sequestration technologies. Baseline information regarding materials and waste management as they relate to carbon sequestration technologies are described in Section 3.9. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.9.1 Impact Considerations

Potential impacts have been assessed using the general criteria outlined below and the impact definitions in Section 4.1.1. Short-term impacts for materials and waste management are defined as impacts occurring during the construction timeframe. Localized impacts from materials and waste management are defined as occurring within the county(s) in which the project resides (as most waste is usually directed towards local and county landfills).

The following definitions are used in this section:

- **Solid Waste** means garbage, and other discarded solid materials resulting from industrial, commercial and agricultural operations, and from community activities.
- **Municipal Solid Waste** means solid waste resulting from or incidental to residential, community, trade or business activities, including garbage, rubbish, ashes, and all other solid waste.
- **Hazardous Waste** means any waste or combination of wastes which pose a substantial present or potential hazard to human health, the environment, and plants or animals because such wastes are nondegradable or persistent in nature, can be biologically magnified, can be lethal, or may otherwise cause or tend to cause detrimental cumulative effects.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Creates volumes of wastes (directly or indirectly) that exceed the capacity of solid waste collection services and landfills.
- Creates wastes for which there are no commercially available disposal or treatment technologies.
- Creates unsafe conditions for employees or surrounding neighborhoods.
- Creates hazardous wastes in quantities that would require a Treatment, Storage, and Disposal (TSD) permit.
- Creates reasonably foreseeable conditions that would significantly increase the risk of a release of hazardous waste or hazardous material.

In general, the implementation of carbon sequestration technologies would be related to the materials used in the construction and operation phases of proposed facilities and the wastes that would be generated. Impacts would be different and would depend on the technologies that would be used for sequestration projects, size of the facilities and the location.

The initial step in determining the potential impacts of the use of materials and the waste management practices is to determine the materials and wastes that would be used at the proposed facility. At this early stage in the planning of projects, the precise list of materials used and wastes that would be generated is not complete. However, the types of materials and wastes for some of the projects can be assumed. The following sections list the materials and waste streams that would be expected for the type of facility being analyzed. This is based on similar facilities that are already in operation or processes that are similar.

The early stage of planning also provides little or no information about the locations where the technology projects would be sited. Therefore there is no information to form the basis for the potential of hazardous waste to pose a risk to surrounding communities.

A broad assumption is included that each proposed facility would operate within the limits of environmental permits that would be obtained and applicable DOE directives, such as those listed in Table 4-23, as well as other applicable state, federal, and local regulations. Another assumption is that a Material Safety Data Sheet (MSDS) would be obtained from the manufacturer for each hazardous material used in the project construction or operation. It is expected that sequestration projects would not create wastes for which no ultimate treatment or disposal is available. Each of the technology projects would include a sanitary sewage system during the operational phase of the project. The construction phase of the projects may be served by portable toilets.

4.9.2 Regulatory Framework

4.9.2.1 Federal Laws and Policies

Several federal laws and related policies have been enacted to govern the management of materials and waste resources. The most significant regulations include:

- ***Resource Conservation and Recovery Act (RCRA).*** This Act gives the EPA the authority to regulate the generation, transportation, treatment, storage, and disposal of hazardous wastes ("cradle-to-grave" management). The most significant of the ten subtitles of RCRA is subtitle C, which establishes the national hazardous waste management program. The 1986 amendments to RCRA provide the EPA with regulatory authority over underground storage tanks (USTs) containing hazardous substances and petroleum. RCRA focuses only on active and future facilities. Of particular note is Section 3004(u) (i.e., corrective action) by which the EPA or a state may require the cleanup or a schedule for investigation and cleanup of all inactive Solid Waste Management Units on an installation before issuing a RCRA part B permit for current HW operations at the installation. Note that cleanup standards may be different under RCRA than under the Comprehensive Environmental Response, Cleanup and Liability Act (CERCLA).

- ***Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) (42 USC §11001 et seq.)*** This statute requires that inventories of specific chemicals used or stored onsite be reported on a periodic basis. The projects would manufacture, process, or otherwise use a number of substances subject to EPCRA reporting requirements.

- ***National Pollutant Discharge Elimination System (NPDES) (33 USC 1342 et. seq.)*** This federal regulation authorized under the CWA requires sources to obtain permits to discharge effluents (pollutants) and stormwaters to surface waters. Regulations implementing the NPDES program are found in 40 CFR 122. Under this program, permit modifications are required if discharge effluents are altered. The CWA authorizes EPA to delegate permitting, administrative, and enforcement duties to state governments, while EPA retains oversight responsibilities.

- ***Spill Prevention Control and Countermeasure (SPCC) Plan***. An SPCC Plan is required if onsite storage of petroleum products in any single tank greater than 660 gallons capacity and/or aggregate quantities greater than 1,320 gallons (this plan is a prerequisite for coverage under the EPA General Stormwater Permit for Construction Activities).

- ***Federal Energy Regulatory Commission (FERC), Section 7 Pipeline Permit.*** The application for this permit for construction and operation of a CO_2 pipeline will require preparation of FERC Environmental Resource Reports 1 through 13, which together are the equivalent of a comprehensive Environmental Impact Statement ("EIS").

- ***Toxic Substances Control Act (TSCA) of 1976 (15 USC § 2601).*** This Act provides for the Federal regulation of chemical substances that present a hazard to health or the environment. Such regulation requires the testing of new substances and subsequent control of their commercial distribution. The Act also contains specific requirements relative to polychlorinated biphenyls, asbestos, and radon.

- ***DOE O 231.1. Environment, Safety and Health Reporting.*** To ensure timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that the DOE and National Nuclear Security Administration are kept fully informed on a timely basis about events that could adversely affect the health and safety of the public or the workers, the environment, the intended purpose of DOE facilities, or the credibility of the Department.

Several DOE directives relate to materials and waste management aspects of carbon sequestration projects as listed in Table 4-23.

Although the facilities would be owned by the project proponent, compliance with DOE directives may be required as part of the cost sharing agreement with DOE even though the facilities would not be owned by DOE or staffed by DOE or contractor employees.

Table 4-23. DOE Directives Addressing Materials and Waste Management

Directive Number	Title	Purpose
DOE O 231.1A	Environment, Health and Safety Reporting	To ensure timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that the Department of Energy (DOE) is kept fully informed on a timely basis about events that could adversely affect the health and safety of the public or the workers, the environment, the intended purpose of DOE facilities, or the credibility of the Department.
DOE P 411.1	Safety Functions, Responsibilities and Authorities Policy	The DOE has the responsibility to ensure that operations at its facilities are conducted safely. The purpose of this policy and the associated manual is to define the DOE safety management functions, responsibilities and authorities to ensure that work is performed safely and efficiently. This policy statement succinctly defines the Department's expectation regarding DOE employees' responsibilities for safety management.
DOE O 440.1A	Worker Protection Management for DOE Federal and Contractor Employees	To establish the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE Federal and contractor workers with a safe and healthful workplace.

Directive Number	Title	Purpose
DOE O 450.1	Environmental Protection Program	To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by DOE operations and by which DOE cost effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, and DOE requirements.
DOE O 460.2	Departmental Materials Transportation Packaging and Management	To establish Department of Energy (DOE) policies and requirements to supplement applicable laws, rules, regulations, and other DOE Orders for materials transportation and packaging operations.
DOE 5480.4	Environmental Protection, Health, Safety and Health Protection Standards	To specify and provide requirements for the application of the mandatory environmental protection, safety, and health (ES&H) standards applicable to all DOE and DOE contractor operations, to provide a listing of reference ES&H standards; and to identify the sources of the mandatory and reference ES&H standards.

Source: DOE, 2005.

4.9.3 Generalized Construction and Operational Impacts of Technologies

4.9.3.1 Post-combustion Capture

4.9.3.1.1 Construction

Post-combustion capture projects would be retrofitted to existing, or added to proposed, fossil fuel combustion facilities or comparable industrial processes. Materials used during construction would include items common to industrial construction: concrete, wood, steel, plastics, composites, and paint. Hazardous materials such as solvents used in construction would be managed according to the applicable requirements of the RCRA, state requirements and DOE directives. Solvents that cannot be recycled would be sent to a permitted Treatment Storage and Disposal (TSD) facility for treatment and/or disposal. Industrial-related solid wastes would be generated including scrap wood and steel, and other leftover construction materials. This waste would be disposed in a local landfill that is permitted to accept such waste. It is too early in the planning process to know the specific information about landfill capacities.

4.9.3.1.2 Operations

Materials and wastes that are assumed to be used or generated, aside from solid waste, are listed in Table 4-24. A post-combustion capture project would include equipment and process streams to separate CO_2 from other gases in the exhaust stream from a co-located plant.

Solid wastes would be generated and would be transported by truck to a nearby permitted landfill. Most processes available for post-combustion CO_2 capture, such as the use of sorbents or separation membranes, would not introduce features that have unknown or substantially more hazardous materials when compared to the features of an existing or proposed combustion power plant. Wastes that would be produced such as spent carbon from amine filter beds and disposable filter cartridges can be disposed of safely without unusual risk to workers or members of the public.

Table 4-24. Materials and Waste Streams

Project	Material/Waste Stream	Management or Materials or Wastes[1]
Post-combustion Capture	Amine Reclaimer Sludge	Approximately 530 tons per month would be transported by truck to a permitted municipal landfill.
	Spent Carbon from amine filter beds	Approximately 16 tons per month would be transported by truck to a permitted municipal landfill
	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.
CO_2 Compression and Transport	Anhydrous ammonia	Ammonia is used in commercial compressors and is stored in a large tank.
	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.
Sequestration in Coal Seams	Drilling Cuttings and Drilling Mud	Cuttings and drilling mud would be disposed in place or at a local permitted landfill depending on the state and local requirements.
	Tracers	A variety of tracers may be injected into wells with the CO_2 to measure the movement of CO_2 in geologic formations. See Table 4-76 for a list of tracers that may be used.
	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.
Sequestration in Depleted Oil and Gas Reserves	Drilling Cuttings and Drilling Mud	Cuttings and drilling mud would be disposed in place or at a local permitted landfill depending on the state and local requirements.
	Tracers	A variety of tracers may be injected into wells with the CO_2 to measure the movement of CO_2 into geologic formations. See Table 4-76 for a list of tracers that may be used.
	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.
Sequestration in Saline Formations	Drilling Cuttings and Drilling Mud	Cuttings and drilling mud would be disposed in place or at a local permitted landfill depending on the state and local requirements.
	Tracers	A variety of tracers may be injected into wells with the CO_2 to measure the movement of CO_2 into geologic formations. See Table 4-76 for a list of tracers that may be used.
	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.
Terrestrial	Fuel for equipment and standby power generation	Diesel fuel, gasoline, propane, or natural gas may be used. Fuels would be stored in the tanks or other containers that would meet requirements for the particular fuel.

[1] CO_2 will be processed in all of the proposed projects. Proper management and safeguards would be observed to ensure that CO_2 is confined to vessels and pipelines and that any leaks are quickly detected and sealed.

4.9.3.2 CO_2 Compression and Transport

4.9.3.2.1 Construction

Construction activities associated with CO_2 compression and transport projects include retrofitting existing, or addition to proposed, fossil fuel combustion facilities or comparable industrial processes. Materials used during construction would include items common to industrial construction: concrete, wood, steel, plastics, composites, and paint. Hazardous materials such as solvents used in construction would be managed according to the applicable requirements of the RCRA, state requirements and DOE directives. Solvents that cannot be recycled would be sent to a permitted TSD facility for treatment and/or disposal. Industrial wastes would be generated including scrap wood and steel, and other leftover construction materials. Industrial waste would be disposed in a local landfill that is permitted to accept such waste. It is too early in the planning process to know the specific information about landfill capacities.

4.9.3.2.2 Operations

CO_2 compression facilities would require large compressors and pipelines. The CO_2 can be transported from compression facilities to sequestration sites via compressed gas pipeline or via commercial refrigerated tank trucks. It has been assumed that a cost-effective commercial-scale project would likely provide conveyance by pipeline.

Solid wastes would be generated and would be transported by truck to a nearby permitted landfill. Amine filter sludge and carbon from the reclaimer bed would be generated as noted in Table 4-24. Hundreds of gallons per day of water would be generated by the gas compression process. The water would be relatively free of contaminants and could be evaporated onsite or discharged to the onsite sanitary sewer depending on the capacity of the sewer system. The amount of lubricating oil used would depend on the size of the plant. Used lubricating oil would be collected and transported off-site for recycling or other use.

4.9.3.3 Sequestration in Coal Seams

4.9.3.3.1 Construction

Coal seam sequestration projects would be conducted at suitable coal seams near a potential CO_2 source such as a power plant. Materials used during construction would include items common to industrial construction: concrete, wood, steel, plastics and composites. Hazardous materials such as solvents used in construction would be managed according to the applicable requirements of RCRA, state requirements and DOE directives. Solvents that cannot be recycled would be sent to a permitted TSD facility for treatment and/or disposal. Industrial-related solid wastes would be generated including scrap wood and steel, and other leftover construction materials. The wastes would be disposed in a local landfill that is permitted to accept such waste.

The largest volume of waste generated during construction would be from drilling activities in the form of drilling mud and cuttings from the drilling. These drilling wastes would be exempt from RCRA and are considered non-hazardous. Drilling mud containing less than 15,000 mg/l TDS can be disposed of on-site with the landowner's permission. The amount of waste generated is not expected to overwhelm the landfills in the area of a project; however, location specific surveys of local landfill capacities would be needed to determine the level of impact.

4.9.3.3.2 Operations

Solid wastes would be generated and would be transported by truck to a nearby permitted landfill. Other impacts would result from spills of waste during maintenance activities, including waste oil from generators, paint waste from construction activities and other solid wastes from construction activities. Impacts would also occur from the use of pesticides and herbicides during access and construction activities. The construction phase would consist of drilling wells into coal seams for injection of CO_2. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as CH_4. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed and the drilling rig and associated equipment have been demobilized and replaced with a service rig. During the test, increasing pressures of CO_2 injection or borehole fluid would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig and a potentially unsafe condition for workers.

Tracers are sometimes injected into the CO_2 stream so that measurements can be made about the transport of the CO_2 within the formation. Amounts of the tracers that are collected in monitoring wells are compared for their distribution in area and time. The compounds used as tracers are typically nontoxic and will degrade within the formation over time.

> Tracers injected into the CO_2 stream for measurement purposes are typically non-toxic and will degrade within the formation over time.

4.9.3.4 Sequestration in Depleted Oil and Gas Reserves

4.9.3.4.1 Construction

Sequestration in depleted oil and gas reserves is similar to the sequestration in coal seam concept. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation.

The construction phase would consist of drilling wells into depleted oil deposits or reworking existing wells if they are deemed suitable to support the injection of CO_2. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry.

Similar to other sequestration projects that would use well drilling, the largest volume of waste generated during construction would be in the form of drilling mud and cuttings from the drilling. These drilling wastes would be exempt from RCRA and are considered non-hazardous. Drilling mud containing less than 15,000 mg/l TDS can be disposed of on-site with the landowner's permission. The amount of waste generated are not expected to overwhelm the landfills in the area.

4.9.3.4.2 Operations

As with other drilling operations, there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as CH_4. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed and the drilling rig and associated equipment have been demobilized and replaced with a service rig. During the test, increasing pressures of CO_2 injection or borehole fluid would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig and a potentially unsafe condition for workers.

Solid wastes would be generated and would be transported by truck to a nearby permitted landfill. Other impacts would result from spills of waste during maintenance activities, including waste oil from generators, paint waste from construction activities and other solid wastes from construction activities. Impacts would also occur from the use of pesticides and herbicides during access and construction activities. The construction phase would consist of drilling wells into coal seams for injection of CO_2. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

4.9.3.5 Sequestration in Saline Formations

Sequestration in a saline water-bearing formation is similar to the sequestration in coal seam concept. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation.

4.9.3.5.1 Construction

The construction phase would consist of drilling wells into a saline geologic formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

4.9.3.5.2 Operations

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as methane. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed and the drilling rig and associated equipment have been demobilized and replaced with a service rig. During the tests, increasing pressures of CO_2 injection or borehole fluid would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig and a potentially unsafe condition for workers.

As with the CO_2 transportation project, one safety concern would be to maintain a dry stream of CO_2 so that carbonic acid would not form that could lead to pipe corrosion and potential catastrophic failure of the injection system.

4.9.3.6 Sequestration in Basalt Formations

Sequestration in a basalt formation is similar to sequestration in coal seams. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation.

4.9.3.6.1 Construction

The construction phase would consist of drilling wells into a basalt geologic formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

4.9.3.6.2 Operations

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as methane. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed and the drilling rig and associated equipment have been demobilized and replaced with a service rig. During the tests, increasing pressures of CO_2 injection or borehole fluid would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig and a potentially unsafe condition for workers.

As with the CO_2 transportation project, one safety concern would be to maintain a dry stream of CO_2 so that carbonic acid would not form which could lead to pipe corrosion and potential catastrophic failure of the injection system.

4.9.3.7 Terrestrial Sequestration – Reforestation

4.9.3.7.1 Construction

As described in Section 2.5, terrestrial sequestration projects generally would entail efforts to reclaim and restore degraded landscapes through the establishment of trees and grasses that will convert CO_2 into biomass. The projects would entail work activities similar to those of the agricultural and forestry industries.

Herbicides and pesticides may be used during clearing and site preparation to eliminate invasive plant species and insects that would reduce the chances of success for the tree and shrub planting. Chemical treatments should be selected according to the site conditions and the needs of the project. Herbicides and pesticides would not be used unless there would be a clear benefit to the project at that specific site. For example, some pine forests are highly susceptible to tree damage from pine beetle infestation. Insecticide spraying to control pine beetles is not usually undertaken because of the vast size of the forest areas that are vulnerable to pine beetles and the prohibitive costs for treating the forest. However, the areas for CO_2 sequestration would be smaller in size and control of pests would be advisable to protect the reforestation investment. Workers would be trained in the proper use of the chemicals, safe storage, and the proper disposal of unused chemicals.

> Herbicides and pesticides would not be used for terrestrial sequestration projects unless there is a clear benefit at that site, such as eliminating invasive plant species and insects that would cause substantial damage to project plantings.

Fertilizers may be used initially to help the plants become established. The types of fertilizer used would be largely site-dependent.

Equipment used to prepare and plant the areas to be reforested would use fuel for internal combustion engines such as diesel. The diesel fuel would be stored in above-ground tanks with secondary leak/spill containment. A SPCC Plan would be prepared to address the spills or leaks of fuels or other liquids.

During the site preparation phase, dead vegetative material (slash) may be collected and composted for future use as a soil supplement on areas that are lacking in organic material such as mine spoil or overburden areas. Slash would not be burned because that would be counterproductive to the CO_2 sequestration efforts by releasing more carbon into the atmosphere.

Other wastes would include used lubricating oil and sanitary wastes. These wastes would be collected and sent to permitted facilities for treatment or disposal.

4.9.3.7.2 Operations

The operational phase of the reforestation project would consist of monitoring the growth of the forest stands, replacing dead seedlings, evaluating the need for additional applications of herbicides and/or pesticides, and measuring the performance (growth rate, percent land cover, mean trunk diameter, etc) of the forest stands.

In general, the operational phase would create a lower impact related to the generation of wastes because there would be less activity overall, less use of heavy equipment, and lower usage of pesticides, herbicides and fertilizers.

4.9.3.8 Co-Sequestration of H_2S and CO_2

Materials and waste management impacts associated with the co-sequestration of CO_2 with H_2S from sour gas fields or IGCC plants generally would be similar to those described for geologic sequestration of CO_2 in oil and gas reserves or saline formations. The amount and types of materials used and wastes generated would be roughly the same for construction phase and operations phase, respectively. However, the amounts of materials and wastes would generally be a function of the quantity of CO_2 and H_2S that would be placed into storage. One exception would be the possible need for one or more pipelines to collect H_2S from a sour gas field or an IGCC plant. The waste treatment and disposal systems for similarly sized CO_2 geologic sequestration facilities would be roughly the same as for a CO_2 and H_2S geologic sequestration facility handling the same volume of gas.

4.9.4 Mitigation of Potential Adverse Impacts

The following measures are recommended to mitigate potential adverse impacts of sequestration technologies due to materials used and wastes that would be generated:

4.9.4.1 Project Planning and Design

- Determine if less hazardous materials can be substituted in the construction or operation of projects.
- Prepare permit applications and secure permits for any hazardous waste that would be generated.
- If hazardous materials would be used in sufficient quantities to trigger the 112r requirements of the Clean Air Act (CAA) Amendments, confer with the local emergency planning committee early in the planning process to establish a dialogue, explain the proposed facility, and learn how the emergency plan can be amended to address the new facilities. Observe the other requirements of the EPCRA and Section 112r of the CAA Amendments and prepare a RMP as required.
- Establish an effective monitoring and alarm system to detect CO_2 leaks from pipelines, valves, and other equipment.
- Prepare a SPCC plan for any fuel or oil storage tanks that would have sufficient capacity to trigger an SPCC plan under the federal CWA.
- Prepare a plan of operations for the well drilling phase that defines the project including: how drilling mud and cuttings will be handled.

4.9.4.2 Construction

- Determine if construction materials are available that meet EPA Affirmative Procurement Guidelines. Determine if construction refuse (concrete, metal, asphalt) can be recycled.
- Provide drilling mud retention ponds.
- Install and use leak detection or monitoring system for hydraulic fluids and lubricating oils on drill rigs.
- Prepare a safety information center in the site office where employees can review material safety data sheets, and other information that will promote a safe work place.
- Provide personal protective equipment to all employees that work with hazardous materials and wastes as necessary.
- Empower all employees to stop work if unsafe working conditions are observed.
- Comply with DOE materials and waste management-related directives as they apply to the project.

4.9.4.3 Operation

- Dispose of all hazardous, solid, or industrial wastes according to federal, state and local regulations.
- Implement the CO_2 monitoring and alarm system on pipelines, valves, and equipment. The system should include a means of periodically testing the system to ensure that it is in proper working order.
- Use systems/components that recycle process water whenever feasible.
- Prepare a safety information center in the site office where employees can review site safety plans, material safety data sheets, and other information that will promote a safe work place.
- Implement a system to respond to spills of hazardous materials or waste including reporting the spill to the correct authority, providing appropriate means of cleaning up spills, and properly disposing of the resulting waste.
- Comply with DOE materials and waste management-related Directives as they apply to the project.

4.9.5 Summary of Potential Impacts

Table 4-25 provides an overall qualitative assessment of potential impacts to materials and waste management for each sequestration technology.

Table 4-25. Potential Impacts of Program Technologies on Materials and Waste Management

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H2S
Solid waste	○	·	·	·	·	·	·	·
Hazardous waste	○	·	·	·	·	·	·	·
Hazardous materials	○	·	·	·	·	·	·	·

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

4.10 HUMAN HEALTH AND SAFETY

This section describes the potential impacts to human health and safety that could occur during the implementation of carbon sequestration technologies. Baseline health and safety information as it relates to sequestration technologies are described in Section 3.10. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.10.1 Impact Considerations

Potential impacts on human health and safety have been assessed using the general criteria outlined below and the impact definitions in Section 4.1.1. Short-term impacts for human health and safety are defined as impacts occurring during the construction timeframe or the results of isolated and temporary mishaps. Localized impacts for human health and safety are defined as those occurring within the project footprint.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Conflict with federal, state, or local regulations or DOE orders for the handling, packaging, storage, transport, or disposal of hazardous and radioactive materials and/or wastes.
- Conflict with adopted emergency response plans.
- Create unsafe conditions or expose employees and the public to situations that exceed health standards or present an undue risk of health-related accidents.
- Cause an increase in hazard quotient or cancer risk to the public.

In general, impacts on human health and safety from the implementation of sequestration technologies would be related to the number of workers that would be employed during the construction and operation phases of proposed facilities and the proximity to members of the public outside the boundaries of the proposed facilities. Impacts would be different and would depend on the technologies that would be used for sequestration projects.

Another aspect of human health and safety for carbon sequestration projects would be the potential for CO_2 inhalation accidents by workers. There are numerous documented cases of industrial workers being asphyxiated (deprived of normal breathing air) due to an undetected leak in process equipment, pipeline, or gas transfer point. Severe cases are fatal while non-fatal accidents can cause permanent brain injury due to lack of oxygen being delivered to the brain.

Unlike natural gas, CO_2 is odorless, and odorizers are not commonly added to CO_2 in pipelines the way natural gas is odorized with methyl mercaptan. Also, CO_2 is heavier than ambient air and will settle into low lying areas of the terrain including basements, and below-grade work areas. The gas can remain in these areas for a substantial period of time until the CO_2 is displaced with normal air through wind action or by other ventilation.

> CO_2 is odorless and heavier than air. It will settle into low lying areas and may remain for a substantial period of time until it is displaced by wind action or other ventilation.

4.10.2 Regulatory Framework

OSHA and the Compressed Gas Association have issued guidance for the safe handling of compressed CO_2 based on experience in the workplace and by investigations of accidents.

OSHA and an industry group, the Compressed Gas Association (CGA), have issued guidance for the safe handling of compressed CO_2 based on experience in the workplace and by investigation of accidents.

Worker exposure limits for CO_2 are listed below.

- OSHA General Industry Permissible Exposure Limit (PEL): 5,000 ppm, 9,000 mg/m3 time weighted average (TWA).
- OSHA Construction Industry PEL: 5,000 ppm, 9,000 mg/m^3 TWA.
- American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH TLV): 5,000 ppm, 9,000 mg/m^3 TWA; 30,000 ppm, 54,000 mg/m^3 short term exposure limit (STEL).
- National Institute for Occupational Safety and Health Recommended Exposure Limits (NIOSH REL): 5,000 ppm TWA; 30,000 ppm short term exposure limit.

Threshold Limit Values (TLVs) are determinations made by the American Conference of Governmental Industrial Hygienists. They represent the opinion of the scientific community that has reviewed the data described in the documentation, that exposure at or below the level of the TLV does not create an unreasonable risk of disease or injury.

Pipeline transportation of CO_2 became subject to the U.S. Office of Pipeline Safety in 1988 when an amendment to the Hazardous Liquid Pipeline Safety Act of 1979 (Pub. L. 100-561; October 31, 1988), gave DOT authority to regulate pipeline facilities that transport CO_2.

4.10.2.1 CO_2 Risk to the Public

Another human health risk is for members of the public to be exposed to CO_2 due to a rapid release of a large quantity of CO_2. Such a rapid release is considered to have a very low probability of occurrence based on the following considerations.

- Siting criteria for future geologic storage of CO_2 would include geologic conditions that are less likely to have leaks develop due to the confining layers above the formation that would receive the CO_2
- Siting criteria for future geologic storage of CO_2 would require the facility be located in a remote area, separated from cities or towns by many miles
- Monitoring and verification of operational geologic storage facilities would be conducted on a scheduled basis to detect leakage long before it would reach the earth's surface and potentially displace atmosphere essential for human life
- Real-time monitoring of CO_2 at the surface above geologic storage facilities so that an evacuation of personnel and nearby residents could be initiated if conditions warrant such action.

DOE's plan for managing risk at CO_2 geologic storage facilities is more fully explained in the fact sheet, *Risk Assessment for Long-Term Storage of CO_2 in Geologic Formations* (DOE, 2005a). Historic releases of CO_2 that caused hundreds of lives to be lost, the most notable example being the one at Lake

Nyos in Western Africa, are rare and have been due to natural processes related to recently active volcanic geologic formations. Recently active volcanic formations would not be considered suitable for CO_2 storage.

CO_2 exposure standards for the general public have not been developed.

CO_2 pipelines have been operating with few accidents for more than a decade. Although the safety record is good, with no reported accident-related injuries or fatalities (see Section 2.7), some safety guidelines are available for the public to help them identify and report a leak and help promote CO_2 pipeline safety, as listed below:

- Call the pipeline owner before digging near a pipeline;
- Listen for hissing or a roaring sound;
- Look for a white cloud, fog, or ice, or unusual blowing of dirt of dust;
- Observe dying plants amid healthy ones;
- Notice persistent bubbles in water; and
- Leave the area of a potential leak and call the pipeline company at the number provided on the pipeline marker. (Kinder Morgan, 2005)

More detailed information about CO_2 pipeline safety can be found at the Kinder Morgan website, www.kindermorgan.com/ehs/pipeline_safety/. Kinder Morgan is a company that operates a CO_2 pipeline in New Mexico and Texas.

4.10.2.2 CO_2 Risks to the Natural Environment

Potential risks to the environment include injury to vegetation or wildlife. One example of a direct impact to vegetation is the possible release of CO_2 into the soil before it would reach the atmosphere. The porous nature of many soil types enables the soil to absorb large volumes of CO_2 that otherwise would be occupied with gases from the atmosphere. This condition can cause trees and shrubs to die from lack of oxygen supplied through the root system. Such a condition was documented at the Mammoth Lakes area of California in 1989 in which a stand of trees more than 100 acres in size was found to have died due to CO_2 displacement of oxygen in the soil. Although the Mammoth Lakes phenomenon was caused by a natural release of CO_2, a similar release of CO_2 could potentially occur due to leakage from a geologic repository (DOE, 2005a).

> Naturally-occurring CO_2 releases have contributed to both plant and animal mortality.

An incident in Yellowstone National Park of injury and death to wildlife by naturally-occurring release of CO_2 and H_2S gases was documented in 2004 (Heasler and Jaworowski, 2004). Five bison were found to have been exposed to fatal levels of CO_2 and H_2S from a release of gases at the Norris Geyer Basin. The release of these gases, combined with extreme cold and lack of wind that limited the dispersion of the gases, created a hazardous atmosphere. Although this instance of injury to wildlife is from a volcanic area, the possibility of similar injury to wildlife is conceivable at a sequestration facility if a catastrophic release of CO_2 and H_2S were to occur.

4.10.2.3 Human Health Risks of Associated with a H_2S Release

Hydrogen sulfide (H_2S) is a toxic gas that sometimes occurs naturally in coal beds along with methane. H_2S is a component of uneconomic natural gas deposits known as "sour gas." H_2S has an odor of rotten eggs. The smell is pronounced at first exposure, but the gas quickly suppresses the sense of smell.

Exposure Limits

- OSHA Permissible Exposure Limit (PEL) for General Industry: 29 CFR 1910.1000 Z-2 Table -- Exposures shall not exceed 20 ppm (ceiling) with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes.

- OSHA Permissible Exposure Limit (PEL) for Construction Industry: 29 CFR 1926.55 Appendix A -- 10 ppm, 15 mg/ m^3 TWA.

- OSHA Permissible Exposure Limit (PEL) for Maritime: 29 CFR 1915.1000 Table Z-Shipyards -- 10 ppm, 15 mg/ m^3 TWA.

- American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV): 10 ppm, 14 mg/ m^3 TWA; 15 ppm, 21 mg/ m^3 STEL.

- National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL): 10 ppm, 15 mg/m^3 Ceiling (10 Minutes).

The most likely exposure scenario is for H_2S to be encountered during well drilling and the gas reaching the surface as well fluids circulate. Another, less likely scenario, would be for a large buildup of pressure in a geologic formation that would cause a well blowout during drilling and release of H_2S. The conditions for either release of H_2S are rare and would present a risk to workers at the drill rig. H_2S is heavier than air, like CO_2, so that it is likely to pool in low lying areas or basements of buildings. H_2S accumulation in tanks or confined spaces is a distinct hazard that warrants special procedures for safe entry if H_2S is suspected.

Several DOE directives would relate to human health and safety aspects of carbon sequestration projects as listed in Table 4-26.

Table 4-26. DOE Health and Safety Directives

Directive Number	Title	Purpose
DOE O 231.1A	Environment, Health and Safety Reporting	To ensure timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that the DOE and National Nuclear Security Administration (NNSA) are kept fully informed on a timely basis about events that could adversely affect the health and safety of the public or the workers, the environment, the intended purpose of DOE facilities, or the credibility of the Department.
DOE P 411.1	Safety Functions, Responsibilities and Authorities Policy	The DOE has the responsibility to ensure that operations at its facilities are conducted safely. The purpose of this policy and the associated manual is to define the DOE safety management functions, responsibilities and authorities to ensure that work is performed safely and efficiently. This policy statement succinctly defines the Department's expectation regarding DOE employees' responsibilities for safety management. It does not establish any new requirements.

Directive Number	Title	Purpose
DOE O 440.1A	Worker Protection Management for DOE Federal and Contractor Employees	To establish the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE federal and contractor workers with a safe and healthful workplace.
DOE O 450.1	Environmental Protection Program	To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by DOE operations and by which DOE cost effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, and DOE requirements.
DOE 5480.4	Environmental Protection, Health, Safety and Health Protection Standards	To specify and provide requirements for the application of the mandatory ES&H standards applicable to all DOE and DOE contractor operations, to provide a listing of reference ES&H standards; and to identify the sources of the mandatory and reference ES&H standards.

Source: DOE, 2005.

Compliance with these DOE directives may be required as part of the cost-sharing agreement between DOE and the project proponent even though the facilities would not be owned by DOE nor staffed by DOE or contractor employees.

One element of protection of the public health and safety is the development of emergency response plans in local communities. Such plans define how an emergency would be handled by fire departments, police, and workplace emergency responders should a large emergency situation arise, such as an industrial fire, unexpected release of chemicals, or explosion that would place the community at risk. At this early stage of planning, the locations of proposed facilities are not known and the status of a site-specific emergency response plans cannot be determined. However, it is assumed that the proposed facility management would initiate a dialogue with local community leaders and amend the local emergency response plan to address the new facility.

Information about hazardous materials used at any work site would be made accessible to workers and members of the pubic through the posting of MSDS that explain the hazards that are posed by use of the material, personal protective equipment that should be worn when the material is used, and other precautionary measures.

4.10.3 Generalized Construction and Operational Impacts of Technologies

4.10.3.1 Post-combustion Capture

Post-combustion capture projects would be retrofitted to existing, or added to proposed, fossil fuel combustion facilities or comparable industrial processes. The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries, such as the power generation industry (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

Most processes available for post-combustion CO_2 capture, such as the use of sorbents or separation membranes, would not introduce features that have unknown or substantially more hazardous materials when compared to the features of an existing or proposed combustion power plant. Wastes that would be produced such as spent carbon from amine filter beds and disposable filter cartridges can be disposed of safely without unusual risk to workers or members of the public.

4.10.3.2 CO_2 Compression and Transport

The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The gas compression component of the project presents risks to workers from a possible catastrophic failure of the compressor. Several injuries and fatalities have been reported in compressor stations that are used to convey gases in pipelines. This is more of a concern when corrosive gases are being compressed and transported in a pipeline such as some types of natural gas before being processed in a gas sweetening plant. However, the purity of CO_2 must be maintained because CO_2 can combine with water to form carbonic acid and create a corrosive compound.

Similarly, the CO_2 storage tank and piping component of this project includes certain risks to workers due to the operations of equipment under high pressure conditions. The equipment is part of a category know as pressure vessels (OSHA, 2005). Several instances of catastrophic failure or pressure vessels have resulted in injuries to workers and in some cases fatalities. Pressure vessel accidents are rare.

Over a 10-year period (1995-2005), 12 incidents were reported for CO_2 pipelines. The sample size for CO_2 pipelines was small compared to those for natural gas and hazardous-liquids transmission, and it is reasonable to suggest that, statistically, the number of incidents involving CO_2 should be similar to those for natural gas transmission (Barrie et al., 2004).

As described in Section 2.5, CO_2 can be transported from compression facilities to sequestration sites via compressed gas pipeline or via commercial refrigerated tank trucks. It has been assumed that a cost-effective commercial scale project would likely provide conveyance by pipeline. However, CO_2 could be transported in tank trucks instead of a pipeline. Truck transportation would present an additional risk of traffic accidents during the transportation of the gas.

Human health risks to the general public would primarily be in the form of a potential pipeline accident that would create a release of CO_2 into the air at a location away from the compressor station. These risks would be greatly reduced through adopting safety and operating procedures commonly in place for gas processing facilities and pipelines. Controls on the pipeline operation would be used to detect a sudden loss of pressure to identify a large leak. Small leaks could be detected and prevented by periodic pipeline inspection and monitoring.

4.10.3.3 Sequestration in Coal Seams

The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The construction phase would consist of drilling wells into coal seams for injection of CO_2. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews. Safety practices that would help to minimize worker injuries and impacts to the environment are listed in Section 4.10.4.

As with other drilling operations, there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as CH_4. Precautions would be taken to avoid a well blow-out or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed. During the test, increasing pressures of CO_2 injection would be applied and the results would be measured in the surrounding monitoring wells and the injection well.

Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig that would pose a potentially unsafe condition for workers.

The operational phase of coal seam sequestration would require fewer workers and would pose a lower hazard than the construction phase. As with the CO_2 transportation project, one safety concern would be to maintain a pure stream of CO_2 so that carbonic acid would not form that could lead to pipe corrosion and potential catastrophic failure of the injection system.

Tracers are sometimes injected into the CO_2 stream so that measurements can be made about its transport within the formation. Tracer levels are measured in monitoring wells to determine their distribution in area and time. The compounds used as tracers are typically nontoxic and will degrade within the formation over time. Common tracers include fluorescein sodium dyes, ammonium nitrate or fertilizer, ammonium thiocyanate, and lower molecular-weight alcohols such as methanol and isopropanol. The specific tracer(s) to be used, if any, would be evaluated and addressed during the site-specific NEPA process.

4.10.3.4 Sequestration in Depleted Oil and Gas Reserves

The mechanics of sequestration in depleted oil and gas reserves or EOR are similar to that of coal seam sequestration - both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation. The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The construction phase would consist of drilling wells into depleted oil deposits or reworking existing wells if they are deemed suitable to support the injection of CO_2. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews. Safety practices that would help to minimize worker injuries and impacts to the environment are listed in Section 4.10.3.

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as methane. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed. During the test, increasing pressures of CO_2 injection would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig that would pose a potentially unsafe condition for workers.

The operational phase of sequestration would require fewer workers and would pose a lower hazard than the construction phase. As with the CO_2 transportation project, one safety concern would be to maintain a pure stream of CO_2 so that carbonic acid would not form that could lead to pipe corrosion and potential catastrophic failure of the injection system.

4.10.3.5 Sequestration in Saline Formations

The mechanics of sequestration in a saline geologic formation is similar to that of sequestration in coal seams. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation. The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The construction phase would consist of drilling wells into a saline geologic formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as CH_4. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed. During the test, increasing pressures of CO_2 injection would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig that would pose a potentially unsafe condition for workers.

The operational phase of saline formation sequestration would require fewer workers and would pose a lower hazard than the construction phase. As with the CO_2 transportation project, one safety concern would be to maintain a pure stream of CO_2 so that carbonic acid would not form that could lead to pipe corrosion and potential catastrophic failure of the injection system.

4.10.3.6 Sequestration in Basalt Formations

The mechanics of sequestration in a basalt geologic formation is similar to that of sequestration in coal seams. They both consist primarily of a network of wells and piping systems for injecting CO_2 into a geologic formation. The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The construction phase would consist of drilling wells into a basalt geologic formation. Monitoring wells would also be drilled into the formation to measure the concentrations of CO_2, CH_4, and water. This would be similar to well drilling activity in the oil and gas industry. Standard safety precautions would be observed by the work crews.

As with other drilling operations there would be a potential of drilling into a pressurized formation that could contain a flammable gas such as CH_4. Precautions would be taken to avoid a well blowout or venting dangerous gases in work areas. After the injection well is completed, tests would be conducted on the formation where the well is completed. During the test, increasing pressures of CO_2 injection would be applied and the results would be measured in the surrounding monitoring wells and the injection well. Under high pressure, equipment could fail and allow a sudden release of CO_2 at the drill rig that would pose a potentially unsafe condition for workers.

The operational phase of basalt aquifer sequestration would require fewer workers and would pose a lower hazard than the construction phase. As with the CO_2 transportation project, one safety concern would be to maintain a pure stream of CO_2 so that carbonic acid would not form which could lead to pipe corrosion and potential catastrophic failure of the injection system.

4.10.3.7 Terrestrial Sequestration

As described in Sections 2.5, terrestrial sequestration projects generally would entail efforts to reclaim and restore degraded landscapes through the establishment of trees and grasses that will convert CO_2 into biomass. The projects would entail work activities similar to those of the agricultural and forestry industries. Work related injuries are generally higher among agricultural and forestry workers than the U.S. private workforce in general.

The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

Herbicides and pesticides may be used during clearing and site preparation to eliminate invasive plant species and insects that would reduce the chances of success for the tree and shrub planting. The particular herbicides and pesticides have not been identified at this early stage in the planning process. Human health impacts to workers would be limited by workers receiving training in the proper use and storage of the chemicals, using personal protective equipment, and proper disposal or recycling of unused chemicals.

4.10.3.8 Co-Sequestration of H_2S and CO_2

Impacts on human health and safety associated with the co-sequestration of CO_2 with H_2S from sour gas fields or IGCC plants generally would be similar to those described for geologic sequestration in oil and gas reserves or saline formations. The number of workers would be roughly the same although the potential hazards faced by workers would be greater for co-sequestration due to the presence of H_2S in the process stream. Workers would need to be prepared to protect themselves against the toxic effects of H_2S and the oxygen displacing effects of CO_2 should a leak occur.

The frequency of injuries for construction and operations workers can be estimated based on accident and injury rates in similar industries (BLS, 2004). Occupational hazards can be can be minimized when workers adhere to safety standards and use appropriate protective equipment.

The estimated rate of worker injuries would be higher for the co-sequestration of CO_2 with H_2S from IGCC plants than from sour gas fields due to a larger workforce during operations. For co-sequestration projects, corrosion of pipes and components may become an important factor for potential equipment failure that historic accident data for the general work industry does not recognize.

Equipment preventative maintenance is always important to help establish a safe working environment. Maintenance procedures become even more important when corrosive process chemicals or products are used.

4.10.4 Mitigation of Potential Adverse Impacts

The following measures are recommended to mitigate potential adverse impacts of carbon sequestration technologies on human health and safety:

4.10.4.1 Project Planning and Design

- Prepare a comprehensive safety program that addresses the construction and operations phases of the project. Ideally that plan would include a training plan, regular safety meetings, and an employee safety-awareness program.

- Confer with the local emergency planning committee early in the planning process to establish a dialogue, explain the proposed facility, and learn how the emergency plan can be amended to address the new facilities. Observe the other requirements of the EPCRA and Section 112r of the CAA amendments.

- Since the sudden release of a large quantity of CO_2 can have ground-level impacts on nearby flora, fauna, and humans, monitoring for leaks in and around pipelines and around injection points is an important consideration of any system design. Transmission piping and wells should be located to allow for adequate dispersion of CO_2 (away from populated areas) in the event of an accidental release.

> Transmission piping and wells should be located to allow for adequate dispersal of CO_2 away from populated areas in the event of an accidental release.

- Design an effective monitoring and alarm system to detect CO_2 leaks from pipelines, valves, and other equipment.

- Prepare a Risk Management Plan (RMP) if any of the facilities would use chemicals in quantities sufficient for the facility to become subject to the risk management provisions of Section 112r of the CAA amendments.

4.10.4.2 Construction

- Establish a culture of safety at the work site including daily safety meetings and a site safety plan that focuses on construction activities.

- Prepare a safety information center in the site office where employees can review site safety plans, MSDS, and other information that will promote a safe work place.

- Provide personal protective equipment to all employees that is appropriate for the hazards that would be encountered in the workplace.

- Empower all employees to stop work if unsafe working conditions are observed.

- Encourage workers to notice unsafe work practices and make improvements that will lead to a safer work site.

- Comply with OSHA requirements and DOE safety-related directives as they apply to the project.

- For drilling operations, adhere to guidelines for safe drilling practices including: avoidance of overhead power lines and other energized electrical components, assurance that emergency shut-down devices are in proper working order, observance of precautions on MSDS for drilling fluids, usage of personal hearing protection when sound levels justify such precautions, detection of hazardous gases (including CO_2 and H_2S), and reporting unsafe working conditions to the rig supervisor and discontinuing operations until safe conditions are restored.

4.10.4.3 Operation

- Prepare and apply a safety plan that a focuses on the operational aspects of the facilities.

- Implement a CO_2 and H_2S monitoring and alarm system on pipelines, valves, and equipment. The system should include a means of periodically testing the system to ensure that it is in proper working order.
- Implement a reservoir monitoring and data collection process to evaluate: formation pressures, leaks to overlying groundwater aquifers, seismic activity, well-bore integrity and surface leaks.
- Prepare a safety information center in the site office where employees can review site safety plans, material safety data sheets, and other information that will promote a safe work place.
- Provide personal protective equipment to all employees that is appropriate for the hazards that would be encountered in the workplace.
- Empower all employees to stop work if unsafe working conditions are observed.
- Encourage workers to notice unsafe work practices and make improvements that will lead to a safer work site.
- Comply with OSHA requirements and DOE safety-related directives as they apply to the project.

4.10.5 Summary of Potential Impacts

As stated above, human health and safety would be a primary consideration at all of the sites. A site-specific risk assessment for CO_2 releases and a comprehensive safety program for workers and the community should be performed during the project planning phase.

Table 4-27 provides an overall qualitative assessment of potential impacts to human health and safety for each sequestration technology. Because of the inherent uncertainty related to the probability of a large scale CO_2 release at a site, these impact levels do not take into consideration a large and sudden leak/release of CO_2 from a geologic reservoir.

Table 4-27. Potential Impacts of Program Technologies on Health and Safety

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Toxic and hazardous materials	○	·	·	·	·	·	·	⦿
Operational hazards	○	○	·	·	·	·	·	⦿

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

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4.11 SOCIOECONOMICS

This section describes the potential impacts in terms of socioeconomics that could occur during the implementation of carbon sequestration technologies. Baseline information on these subjects is provided in Section 3.11. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.11.1 Impact Considerations

The general criteria outlined below have been used as a basis for evaluating potential adverse impacts of carbon sequestration projects on socioeconomics.

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Displace existing population on a site selected for project.
- Substantially alter projected rates of population growth directly or indirectly in the area of influence.
- Cause demolition of existing housing on a site selected for a project.
- Adversely affect housing demand directly or indirectly in the area of influence.
- Displace existing businesses on a site selected for a project.
- Adversely affect local businesses and the economy directly or indirectly in the area of influence.
- Displace existing jobs on a site selected for a project.
- Adversely affect local employment or the workforce directly or indirectly in the area of influence.
- Adversely affect community services (police, fire, health care, schools) directly or indirectly in the area of influence.
- Conflict with local and regional management plans for community services.
- Create the potential for significant and disproportionate adverse effects on low-income populations in the area of influence.

4.11.2 Regulatory Framework

Potential socioeconomic and environmental justice impacts of a project are generally the subject of federal NEPA documents and are not governed by laws or regulations. Executive Order Number 12898 provides that "*each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations*" (The White House, 1994). In its guidance for the consideration of environmental justice under NEPA, the CEQ defines a "minority" as an individual who is American Indian or Alaskan Native, Black or African American, Asian, Native Hawaiian or Pacific Islander, Hispanic or Latino (CEQ, 1997). The statistics on minorities presented in Chapter 4, Section 4.11 are based on this definition. The CEQ also defines a "minority population" as one where either the percentage of minorities in the affected area exceeds 50 percent, or the percentage of minorities in the affected area is meaningfully greater than the percentage of minorities in the general population or other appropriate unit of geographic analysis (CEQ, 1997).

The CEQ guidance further recommends that low-income populations in an affected area should be identified using the U.S. Census Bureau's Current Population Reports, Series P-60 on Income and Poverty (CEQ, 1997). The individual poverty rates included in Chapter 4, Section 4.11 were obtained from data (Census 2000 Summary File 3) consistent with that source.

The basic steps for evaluating the environmental justice impacts of a Proposed Action under NEPA, consistent with the CEQ guidance and DOE recommendations (DOE, 2004), are the following:

- Determine whether the proposed action or an alternative would have a significant adverse impact on the affected area. Consider all potential impacts (e.g., health effects, air quality, water quality, cultural resources, cumulative impacts).
- Determine whether low-income or minority populations exist based on a comparison of the percentages of these individuals in the affected area of the proposed action with the percentages in the wider geographic area or representative general population.
- Determine whether there would be any significant adverse impacts to minority and low-income populations that would appreciably exceed impacts to the general population or other appropriate comparison group. Consider whether minority and low-income populations would have different ways than the general population of being affected by a proposed action or alternative.

> Because utility costs generally represent a greater proportion of non-discretionary expenditures for low-income consumers, increases in average monthly electric bills associated with the cost of carbon sequestration activities may affect these consumers adversely and disproportionately.

Most direct socio-economic impacts from the implementation of sequestration technologies would be related to the siting, construction, and operation of proposed projects and facilities within regions, states, and local communities. Indirect or induced impacts may result from changes in national, regional, state, and local economies caused by the implementation of sequestration technologies. Most potential impacts on environmental justice would be associated with the site selection process. However, impacts on local economies and utility costs caused by the implementation of sequestration technologies could have implications for environmental justice.

The GCCI calls for an 18 percent reduction in the carbon intensity of the U.S. economy by 2012. In the process of attaining this goal, the President and DOE intend that technologies and projects implemented under the Program would result in less than a 10 percent increase in the cost of energy services for advanced power systems and less than a 20 percent increase for traditional combustion facilities. If energy providers implementing sequestration projects were to pass the full costs of the technologies on to consumers, the average monthly electric bills for their customers could potentially increase by 10 to 20 percent after the technologies were implemented. Based on the national average monthly electric bills in 2002, customers could experience increases on average comparable to those summarized in Table 4-28.

Table 4-28. Potential Increase in Average Monthly Electric Bill by Sector to Pay for Carbon Sequestration Technologies (2002 Baseline)

Customer Sector	National Average Monthly Bill*	Average Increase in Monthly Bill (10%)	Average Increase in Monthly Bill (20%)
Residential	$76.74	$7.67	$15.35
Commercial	$478.41	$47.84	$95.68
Industrial	$6,647.01	$664.70	$1,329.40

Source: EIA, 2002.

Because utility costs generally represent a greater proportion of non-discretionary expenditures for low-income consumers than for higher income consumers, increases in average monthly electric bills by 10 to 20 percent as indicated in Table 4-28 may affect these consumers adversely and disproportionately. On the other hand, some economists predict that the future costs associated with global warming and adaptation impacts would be higher than the costs of implementing sequestration projects. But, whether such costs might affect low-income populations disproportionately would depend on how the free market or the government responds to the increased demands on energy and economic systems caused by climate change and adaptation requirements. Therefore, sponsors of specific projects to implement sequestration technologies should carefully evaluate the manner in which the local share of project costs would affect customers in the service area and determine whether the method of distributing these costs would have a disproportionate adverse impact on low-income populations.

4.11.3 Generalized Siting and Operational Impacts of Technologies

4.11.3.1 Post-combustion Capture

A post-combustion capture project would typically be located within the site boundary of an existing power plant or other industrial source facility. Therefore, adding a CO_2 capture process to an existing industrial site would not affect local population growth, displace housing or businesses, cause job losses, require expansions in community services, or otherwise affect demographic and socioeconomic conditions. An exception might occur if the new process required a significant expansion of the facility property or would otherwise introduce features (increased air emissions, noise, hazardous materials, etc.) that would adversely affect adjacent housing, businesses, and community services. In such case, or in the event that a post-combustion capture process would be associated with a proposed new industrial facility, the environmental review for the new facility should address all site-specific impacts on socioeconomic resources based on criteria in Section 4.11.1.

Most processes available for post-combustion CO_2 capture, such as the use of sorbents or separation membranes, would not cause an increase in the demands on local fire and emergency response services when compared to the features of an existing or proposed fossil-fueled power plant. Therefore, the contributions of a CO_2 capture process to air emissions, hazardous materials, safety hazards, and other features already associated with a power plant or comparable industrial process would have negligible additional impacts on adjacent housing, businesses, and community services.

As further indicated in Section 2.5, additional manpower requirements for the operation of a representative CO_2 capture facility would be minor relative to the existing workforce. The addition of these positions would have a small beneficial effect on local employment and the economy in most communities.

Construction of required facilities would require a relatively large though short-term workforce. Hence, such projects would have beneficial short-term impacts on local economies.

4.11.3.2 CO_2 Compression and Transport

Generally, the addition of CO_2 compression facilities to an existing or proposed industrial site would not affect local population growth, displace housing or businesses, cause job losses, require expansions in community services, or otherwise affect demographic and socioeconomic conditions. An exception might occur if the new process required a significant expansion of the facility property or would otherwise introduce features (increased air emissions, noise, hazardous materials, etc.) that would adversely affect adjacent property owners and communities. In such case, or in the event that a post-combustion capture process would be associated with a proposed new industrial facility, the environmental review for the new facility would address all site-specific impacts on socioeconomic resources using criteria in Section 4.11.1.

Assuming that a cost-effective commercial-scale project would likely provide conveyance by pipeline, the principal aspect of a CO_2 compression and transport project that would affect housing, businesses, and community services is the potential need for easements and rights-of-way for underground CO_2 pipelines and access roads. Where practicable, these impacts can be minimized by utilizing easements already established for other utility pipelines and power transmission lines. Otherwise, new easements would be required, which would necessitate an assessment of site-specific impacts on local property owners and communities based on criteria Section 4.11.1. In the event that tank trucks would transport CO_2, the principal impacts on surrounding communities would be related to the numbers of trucks entering and leaving the respective compression and sequestration sites on a daily basis.

Because CO_2 is an inert, non-toxic gas, the establishment of easements for pipeline corridors would not necessarily impose significant restrictions on property owners and communities affected by the easements. However, the easements would generally require that the corridors remain cleared of large trees and be accessible for inspection and maintenance of the pipelines, that permanent structures may not be built within the easements, and that subsurface excavation may not occur. Appropriate negotiation of easements with property owners would ensure that they are compensated for the resulting limitations on the beneficial use of their properties.

The operation of CO_2 compression and transport facilities would create a small number of additional jobs at the facility. The addition of these positions would have a small beneficial effect on local employment and the economy in most communities.

Construction of pipeline facilities would require a relatively large though short-term workforce. Hence, such projects would have beneficial short-term impacts on local economies. Projects that would transport CO_2 by truck would have a negligible impact on local employment.

4.11.3.3 Sequestration in Coal Seams

Suitable coal seams closest to existing fossil-fueled power plants or other CO_2 sources would be the most promising candidates for the application of a pilot- or commercial-scale project initially. A host of economic considerations could affect site selection, including the feasibility of enhanced CBM recovery and the potential for future coal extraction from the seam by the holder of the mineral rights, the nature of the terrain, the accessibility of a proposed site, and the availability of suitable rights-of-way for conveyance corridors. A suitable coal seam must also have adequate containment capacity, including a sufficiently impervious caprock, to prevent the migration of injected CO_2 beyond the site boundary and its release above the ground surface in concentrations that could potentially affect adjacent property owners. The objective of storing CO_2 in a seam indefinitely may also preclude mineral extraction on adjacent properties. An appropriate method of MM&V should be selected to monitor the potential release of CO_2 beyond the target coal seam, including mechanisms and procedures to protect local residents in the event of unanticipated releases of CO_2. Hence, before selecting a suitable location for a coal seam sequestration project, an assessment of site-specific socioeconomic impacts would be required.

The most promising initial candidate sites for coal seam sequestration would include suitable coal seams in areas that have already been disturbed by activities during previous coal mining operations. It is anticipated that the siting of coal seam sequestration projects generally would not occur in urban jurisdictions. Therefore, sites chosen for coal seam injection and associated MM&V facilities most likely would not affect local population growth, displace housing or businesses, cause job losses, or require expansions in community services. Revenues from enhanced coalbed methane recovery associated with projects involving coal seam CO_2 sequestration may have a net beneficial impact on the local economy.

There would be some additional manpower required for the operation of a coal seam sequestration project. These operational manpower requirements would have a negligible effect on local employment and the economy. The construction of required facilities would have a beneficial short-term impact on local economies.

4.11.3.4 Sequestration in Depleted Oil and Gas Reserves

The most promising candidate locations initially for pilot-scale and commercial-scale sequestration would include depleted oil and gas reserves that are situated within close proximity of fossil fuel-fired power plants or other large CO_2 sources. A key factor that may influence the siting of sequestration projects in depleted oil reserves is the economic incentive offered by EOR. A suitable oil or gas reservoir must also have adequate containment capacity, including a sufficiently impervious caprock, to prevent migration of injected CO_2 beyond the site boundary and prevent its release above the ground surface in concentrations that could potentially affect adjacent properties. The objective of storing CO_2 in the reservoir indefinitely may also preclude mineral extraction on adjacent properties. An appropriate array of MM&V should be selected to monitor the potential release of CO_2 beyond the target reservoir, including mechanisms and procedures to protect local residents in the even of an unanticipated release of CO_2 at unsafe concentrations. Hence, before selecting a suitable location for an oil and gas reservoir sequestration project, an assessment of site-specific socioeconomic impacts would be required.

It is assumed that candidate sites will be situated on lands that have been substantially disturbed during years of oil and gas production and that the siting of sequestration projects generally would not occur in urban jurisdictions. Therefore, sites chosen for sequestration and associated MM&V facilities most likely would not affect local population growth, displace housing or businesses, cause job losses, or require expansions in community services. Revenues from EOR associated with CO_2 sequestration projects may have a net beneficial impact on the local economy.

Additional manpower would be required for the operation of an oil or gas field sequestration project. These operational manpower requirements would have a negligible effect on local employment and the economy. The construction of required facilities would have a beneficial short-term impact on most local economies.

4.11.3.5 Sequestration in Saline Formations

Although the surface facilities needed for sequestration in saline formations would be similar to those for sequestration in coal seams and depleted oil and gas reserves, saline formations would not necessarily involve lands that have been disturbed during prior resource extraction. A suitable saline formation must have adequate containment capacity, including a sufficiently impervious caprock, to prevent migration of injected CO_2 beyond the site boundary and its release above the ground surface in concentrations that could potentially affect adjacent property owners. An appropriate array of MM&V should be selected to monitor the potential release of CO_2 beyond the target reservoir, including mechanisms and procedures to protect local residents in the event of an unanticipated release of CO_2 in unsafe concentrations. The objective of storing CO_2 in the formation indefinitely may also preclude mineral extraction on adjacent properties. Hence, before selecting a suitable location for a saline sequestration project, an assessment of site-specific socioeconomic impacts would be required. Because saline sequestration projects generally would not occur in urban jurisdictions, such projects most likely would not affect local population growth, displace housing or businesses, cause job losses, require expansions in community services, or otherwise affect demographic and socioeconomic conditions.

These operational manpower requirements would have a negligible effect on local employment and the economy. The construction of required facilities would have a beneficial short-term impact on most local economies.

4.11.3.6 Sequestration in Basalt Formations

Although the surface facilities needed for sequestration in basalt formations would be similar to those for sequestration in coal seams and depleted oil and gas reserves, basalt formations would not necessarily involve lands that have been disturbed during prior resource extraction. A suitable basalt formation must have adequate containment capacity, including a sufficiently impervious caprock, to prevent migration of injected CO_2 beyond the site boundary and its release above the ground surface in concentrations that could potentially affect adjacent property owners over the short-term. Over the long-term, mineralization of the CO_2 is expected to reduce the chance of a CO_2 release from the formation. An appropriate array of MM&V should be selected to monitor the potential release of CO_2 beyond the target formation, including mechanisms and procedures to protect local residents in the event of an unanticipated release of CO_2 in unsafe concentrations. The objective of storing CO_2 in the formation indefinitely may also preclude mineral extraction on adjacent properties. Hence, before selecting a suitable location for a basalt sequestration project, an assessment of site-specific socioeconomic impacts would be required. Because basalt sequestration projects generally would not occur in urban jurisdictions, such projects most likely would not affect local population growth, displace housing or businesses, cause job losses, require expansions in community services, or otherwise affect demographic and socioeconomic conditions.

The additional operational manpower requirements associated with a project would have a negligible effect on local employment and the economy. The construction of required facilities would have a beneficial short-term impact on most local economies.

4.11.3.7 Terrestrial Sequestration - Reforestation

Terrestrial sequestration projects sponsored or supported by DOE generally would most likely involve efforts to reclaim and restore degraded landscapes through reforestation and afforestation that would convert CO_2 into biomass. The reclamation of degraded lands would have a net beneficial effect on demographic and socioeconomic conditions in most communities by improving open space utilization and potentially enhancing property values. Such projects generally would not alter local population growth, displace housing or businesses, cause job losses, or require expansions in community services, because candidate sites would include lands that have been degraded by prior extraction operations and that have not been developed for residential housing or businesses. If, however, a potential project were to alter a property in a manner that would adversely affect adjacent communities, an assessment of site-specific socioeconomic impacts would be required.

> Reclamation of degraded lands by reforestation is expected to have a net beneficial effect on socioeconomic conditions in most communities, by improving open space utilization and potentially enhancing property values.

Reforestation projects would not require fulltime personnel for continuous operation, because they would not create any industrial facilities. The activities involved in land reclamation and tree planting for such projects would employ small numbers of workers for less than a year, which would have a negligible impact on most local economies.

4.11.3.8 Co-Sequestration of H_2S and CO_2

Co-sequestration of H_2S and CO_2 generally would be similar to sequestration of CO_2 in coal seams, oil and gas reserves, and saline formations. The facilities and infrastructure would be comparable, however, different materials for pumps, compressors, and pipelines would be used to guard against the corrosive nature of the sour gas. Revenues from EOR associated with sequestration projects may have a net beneficial impact on the local economy. As with the aforementioned model projects, sites chosen for co-sequestration facilities most likely would not affect the local population, displace housing or businesses, cause job losses, require expansions in community services, or otherwise affect demographic and socioeconomic conditions. The construction of required facilities would have a beneficial short-term impact on most local economies.

4.11.4 Mitigation of Potential Adverse Impacts

The following measures are recommended to mitigate potential adverse socioeconomic impacts of carbon sequestration technologies:

4.11.4.1 Project Planning and Design

- Closely consider the extent to which the local share of costs for a proposed project would increase the cost of energy services to consumers. If the proposed project would result in greater than a 10 percent increase in the cost of energy services for customers of advanced power systems or greater than a 20 percent increase for customers of traditional combustion facilities, the cost increases might exceed the intentions of the President and DOE regarding the costs of attaining the GCCI goal. Substantial increases in energy costs to local consumers may affect low-income populations adversely and disproportionately, because utility costs often constitute larger percentages of the incomes and living expenses of such individuals.

- Determine whether the service area that would incur the increased cost of energy services to support the proposed project constitutes a low-income or minority population by the definitions and analyses described in Section 4.11.1. If so, determine whether these populations would be affected adversely and disproportionately by the increased cost of energy services to support the proposed project.

- Consider alternatives for distributing the anticipated increases in utility costs to support the proposed project, to mitigate the potential for adverse and disproportionate impacts on low-income populations.

- Plan for efficient use of the property and consolidation of infrastructure requirements as practical. Integrate site design elements with surrounding communities and provide appropriate buffer areas to minimize impacts on adjacent housing, businesses, and community services.

- If the project (e.g., post-combustion capture) would be located at an existing industrial facility, determine whether adequate, suitable space is available to accommodate new facilities without affecting established buffer areas or encroaching on adjacent properties.

- If the project will require the acquisition of new sites for facilities, avoid locations that may cause displacement of population, residential housing, or local businesses. Avoid locations that may adversely affect the range and capacity of community services (fire, emergency response, law enforcement, etc.).

- Determine whether low-income or minority populations exist in the area affected by a proposed project. If so, determine whether these populations would be adversely and disproportionately affected by the siting of project facilities and components as described in Section 4.11.1.

- Confer with local and regional authorities early during the site selection process to identify goals, plans, and policies pertaining to community services (fire, emergency response, law enforcement, etc.) that may be affected by the proposed project. Ensure that community services will be adequate to address the requirements of the project without adversely affecting the local tax base.

- Determine whether rights-of-way would be required for pipeline corridors, access roads, or other facilities. Identify established easements that may be available to accommodate additional pipelines or access roads in the proposed transmission corridor and minimize the need for new easements. If new rights-of-way will be required, ensure that all of the preceding recommendations are followed during planning for corridor alignments.

4.11.4.2 Construction

- Adhere to site plans and minimize the footprint of land area disturbance required for a proposed project, including permanent structures, roads, temporary structures, staging areas, and other features.

- Maintain buffer zones to minimize construction impacts on adjacent housing, businesses, and community services.

- Limit trucking operations for deliveries and removals to non-peak periods, while avoiding noise-sensitive times of day, to minimize traffic impacts on adjacent housing, businesses, and community services.

- Restrict construction activity to the least noise-sensitive times of day in accordance with local ordinances to minimize noise impacts on adjacent housing, businesses, and community services.

- Locate stationary construction equipment as far as practicable from property boundaries and adjacent housing, businesses, and community services.

- Require the implementation of noise suppression equipment and BMPs to reduce noise to acceptable levels at property boundaries of adjacent communities. For example, require sound-muffling devices on construction equipment that are no less effective than as provided on original equipment and ensure that devices are properly maintained.

- Implement BMPs for control of construction-related air emissions, erosion and sedimentation control, and habitat protection as described for other respective resources to minimize adverse impacts on adjacent housing, businesses, and community services.

- Reclaim and restore disturbed areas expeditiously in accordance with established landscaping plans for the project site upon completion of construction phases.

4.11.4.3 Operation

- Conduct facility operations within established local ordinances, as well as federal and state regulations, to minimize impacts on adjacent housing, businesses, and community services.

- Limit trucking operations for deliveries and removals to non-peak periods, while avoiding noise-sensitive times of day, to minimize traffic impacts on adjacent housing, businesses, and community services.

- Limit noise-emitting operations to the least noise-sensitive times of day in accordance with local ordinances to minimize noise impacts on adjacent housing, businesses, and community services.

- Require the implementation of noise suppression equipment and BMPs to reduce noise to acceptable levels at property boundaries of adjacent communities. For example, require sound-muffling devices on operational equipment that are no less effective than as provided on original equipment and ensure that devices are properly maintained.

4.11.5 Summary of Potential Impacts

Table 4-29 provides an overall qualitative assessment of potential impacts on socioeconomics for each sequestration technology. Construction and operation of sequestration facilities generally would have negligible to minor adverse impacts on demographic and socioeconomic conditions. Revenues from enhanced CBM recovery and EOR associated with sequestration in coal seams and oil reserves may cause net beneficial impacts for respective projects. Most projects would also have slight beneficial impacts on local employment resulting from construction and operation of required facilities.

Table 4-29. Potential Impacts of Program Technologies on Socioeconomics

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Population	·	·	·	·	·	·	·	·
Housing	·	·	·	·	·	·	·	·
Business and Economy	·	·	+	+	·	·	+	+
Employment	+	+	+	+	+	+	·	+
Community Services	·	·	·	·	·	·	·	·
Low-income population	O	O	·	·	O	O	·	·

Key: · Negligible Impact, O Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact

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4.12 UTILITY INFRASTRUCTURE

This section describes the potential impacts to utility infrastructure that could occur during the implementation of carbon sequestration technologies. The utility infrastructure that could be affected by sequestration technologies are described in Section 3.12. Possible measures for avoiding or mitigating potential adverse impacts are also presented in this section.

4.12.1 Impact Considerations

A project or technology would be considered to have an adverse impact on the natural or human environment if any of its features or processes would:

- Adversely affect the capacity of public water utilities directly or indirectly.
- Require substantial extension of water mains involving offsite construction for connection with a public water source.
- Insufficient water supply capacity for fire suppression demands.
- Cause excessive fuel requirements.
- Adversely affect the capacity and distribution of local and regional energy suppliers.
- Require substantial extension of telecommunications utilities involving offsite construction for connection with the network.
- Adversely affect traffic volumes compared to existing capacities and traffic loads on roadways in the area of influence.
- Cause substantial alteration of traffic patterns or circulation movements.
- Conflict with local or regional transportation plans.
- Adversely affect rail traffic compared to existing capacities and loads on railways in area of influence.
- Conflict with regional railway plans.

In general, the implementation of sequestration technologies would be related to the infrastructure needs during the construction and operation phases of proposed facilities. Impacts would depend on the technologies that would be used for sequestration projects, size of the facilities, and location.

4.12.2 Regulatory Framework

Project developers should take into account federal, regional, and State environmental laws and regulations, Executive Orders, and Policy that may apply to the carbon sequestration projects. Some of these that relate to the utility infrastructure include:

- Safe Drinking Water Act (SDWA) of 1974 (42 USC § 300(f)) - This Act specifies a system for the protection of drinking water supplies through the establishment of contaminant limitations and enforcement procedures. The Act requires each state to adopt a program to protect wells within its jurisdiction from contamination. States have the primary responsibility to enforce compliance with national primary drinking water standards and sampling, monitoring, and notice requirements.

- UIC program (40 CFR Parts 144-147) – The UIC program was promulgated under the SDWA and regulates the injection of fluids in the subsurface. The regulations establish minimum requirements for UIC programs. Each state must meet these requirements in order to obtain primary enforcement authority for the UIC program in that State.

While federal and state highways and other roads, as well as freight railroad lines, could be utilized for a potential carbon sequestration project, it is too early in the planning process to specify which highways or railroads would be utilized. Therefore, particular requirements and potential impacts on transportation infrastructure would be determined during the site-specific planning and development stage for potential projects. Qualitatively, on a national and regional basis, potential carbon sequestration projects are anticipated to have negligible impacts on highways and railways. Such projects are not anticipated to require frequent and substantial shipments of materials or waste products by truck or rail during normal operations, and they are not expected to employ large numbers of workers in proximity to urban commuting areas.

While no new railroad lines would likely be developed for potential projects, the need for new access roads might arise in the course of detailed planning and site layout.

4.12.3 Generalized Siting and Operational Impacts of Technologies

4.12.3.1 Post-combustion Capture

Post-combustion capture projects require steam, electricity, water, and chemicals during operation. Since these projects would be built adjacent or in close proximity to existing industrial facilities that may already be generating and/or utilizing these utilities, the incremental impacts on the existing utility infrastructure would be minimal. Post-combustion capture technologies would be used to treat the exhaust from utility or industrial size boilers. Process steam requirements can be met by extracting steam at the required temperature and pressure from existing steam turbines as is typical in cogeneration applications. As described in Section 2.5, the electricity power requirements of the capture project are extremely small (< 5 MW) in comparison to either the host facility's generation capacity (e.g., 300 MW on commercial scale) or electricity available from the power grid. Therefore these projects are not expected to require any significant changes to existing or future electric transmission infrastructure. However, the parasitic energy requirement for CO_2 capture and compression would be a concern to the energy provider in terms of meeting their required output levels and the extra cost to consumers. The energy requirement would be a function of the type of power plant, capture process and extent of capture.

Water requirements for the project are primarily for washing the treated flue gas exiting the absorber. Although the impact on existing water supply would be site specific, the required volumes are not expected to cause a significant adverse impact. For example, power plant feed-water flow rate for a 300 MW power plant is about 5,000 gpm, which is more than an order of magnitude greater than the estimated requirement for the project (see Section 2.5).

Solid and liquid wastes would be trucked offsite for disposal. On-site treatment of wastewater is not expected. Since the capture projects would be built close to existing industrial facilities, adequate road and/or rail infrastructure required for bringing in chemicals and other materials and for removing solid and liquid wastes are already expected to exist. Although traffic volume would increase, it is not expected to cause significant alterations in traffic patterns and rates, or cause conflicts with existing local and regional transportation plans.

4.12.3.2 CO_2 Compression and Transport

The compression and transport of CO_2 to a sequestration site requires the use of electricity and/or fuel to operate electric motors or engines that drive the compressors. Fuel is also required to operate the dehydrator. Other utility needs include cooling water for engines and wastewater and oil disposal.

Electricity required to compress CO_2 to injection pressures for a commercial-scale sequestration project would be obtained from the local power grid. Since the compressor station would be located in the vicinity of the capture site, existing electricity transmission infrastructure can be used to meet the power requirements.

If gas-fired engines would be used to drive the compressor motors and natural gas is not already available at the host facility, then access to a supply of natural gas would be required. The additional fuel use is not significant to adversely impact the supply and distribution of natural gas to the local markets. For example, a typical gas-fired CO_2 capture host facility boiler would consume about 3,000 MMBtu/hr which is about 20 times greater than the requirement for the CO_2 compressor facility (see Section 2.5).

Wastewater, which is mainly condensate from the compressed gas stream, and used lubricating oil are expected to be disposed of either in UIC Class II injection wells at the sequestration site or trucked for off-site disposal in approved wastewater treatment and disposal facilities.

Since the capture projects would be built close to existing industrial facilities, adequate road and/or rail infrastructure required for removing liquid wastes is already expected to exist. Increased traffic volumes would be minimal and would not be expected to cause significant alterations in traffic patterns and rates, or cause conflicts with existing local and regional transportation plans.

4.12.3.3 Sequestration in Geologic Formations

CO_2 sequestration projects require fuel and electricity during operation. Additionally liquid wastes (e.g., produced water and used lubricating oils) and solid wastes (e.g., well cuttings) that are generated during project construction and operation require proper disposal.

Fuel is required for injection well heating typically for coal seams and saline formation sequestration projects. If natural gas is already available at the site, it can be used as the fuel source. Alternatively, diesel-fired heaters can be used. In these cases diesel would be trucked to the site and stored in approved tanks or containers. Based on heating requirements, fuel usage rates are small and are not expected to disrupt local fuel supply and distribution.

Electricity demands at the sequestration sites are also minimal. Since these projects do not involve CO_2 compression (CO_2 is assumed to be compressed and delivered at injection pressures in the CO_2 transport project), electricity usage is limited to producing and handling produced fluids and re-injection. For example in EOR sequestration projects, electricity is required to operate pumps used to remove fluids from production wells, separate and treat the produced fluids, and inject produced water to enhance EOR. Electric-drive pumps can be used to dispose of fluids produced in sequestration projects by re-injection in underground injection wells. The electricity demand for these operations is small and can be supplied either by the CO_2 capture project's host facility (if the sequestration site is located close to a capture host facility) or by the local utility grid without significant impact to electricity transmission capacity margins. Electricity usage for basalt sequestration projects are expected to be similar to those of EOR sequestration projects. Based on availability, natural gas-fired internal combustion engines can also be used as prime movers for the pumps.

Wastewater produced at the site would be disposed of either in injection wells at the sequestration site or trucked off-site for disposal. The sequestration site is expected to have UIC Class II injection wells that allow such disposal. Solid wastes including well cuttings generated during the construction phase from injection and monitoring wells would be disposed of in a nearby landfill. The volumes generated are not expected to affect local landfill capacities significantly.

For sequestration in saline formations, there is a possibility of contamination of underground water reservoirs caused by subsurface leakage of the formation fluids. However, proper control of injection pressures coupled with continuous monitoring of the reservoirs, using MM&V technologies prior to, during, and for extended time periods following injection, can significantly reduce this risk.

4.12.3.4 Terrestrial Sequestration – Reforestation

Utility requirements for reforestation projects include fuel (e.g., diesel) required by heavy machinery that would be used to prepare and plant areas to be reforested. The fuel would be brought on site by road and stored in above ground tanks. The fuel requirements are not expected to adversely affect the supply and distribution of fuel in the area. Since the reforested areas may be remotely located, proper access roads would be required to bring in fuel and other materials (e.g., pesticides and fertilizers). Wastes including used lubricating oil and sanitary wastes would be collected and trucked off-site for disposal.

The fuel and waste removal rates are not expected to adversely affect local traffic patterns or volumes in the affected areas.

4.12.3.5 Co-Sequestration of CO_2 and H_2S in Depleted Oil and Gas Reservoirs, and Saline Formations

Utilities required for the co-sequestration of CO_2 and H_2S include steam, electricity, and water. Supplies of chemicals and other materials, as well as the disposal of solid and liquid wastes, are also required during operation.

During capture and separation of the acid gas stream from a commercial scale IGCC project, steam would be required which can be met by extracting steam at the required temperature and pressure from existing steam turbines at the facility (as is typical in cogeneration applications). The electricity power requirements would be small in comparison to the host facility's generation capacity. For acid gas streams obtained from sour gas processing facilities, incremental steam requirements would be negligible, and net electricity usage is expected to decrease when compared to typical sour gas processing requirements. Electricity requirements during compression, transport, and sequestration would be similar to those for pure CO_2 gas streams. Based on those electricity requirements, the co-sequestration of acid gas streams is not expected to require any significant changes to existing or future electric transmission infrastructure.

Incremental water requirements would be primarily for washing the treated flue gas exiting the absorber. Although the impact on existing water supply would be site-specific, the required volumes are not expected to cause a significant adverse impact. For example, the power plant feed-water flow rate for a 300 MW power plant is about 5,000 gpm (see Section 2.5), which is an order of magnitude greater than the estimated requirement for the model project.

For sequestration in saline formations, there is a possibility of contamination of underground water reservoirs caused by subsurface leakage of the formation fluids. However, proper control of injection pressures coupled with continuous monitoring of the reservoirs, using MM&V technologies prior to, during, and for extended time periods following injection, can significantly reduce this risk.

Significant rail and/or road infrastructure is required for delivery and handling of coal, chemicals, and other raw materials to an IGCC facility, as well as for the removal of by-products and wastes from the facility. These issues would be considered during project siting. However, the incremental infrastructure needs for the acid gas capture and separation operations would be minimal in comparison to the host facility. Therefore co-sequestration operations are not expected to require significant additional infrastructure over that required by the host facility.

Incremental solid and liquid wastes from the capture and separation operations would be trucked offsite for disposal. No on-site treatment of wastewater is expected. Wastes generated during transport and injection phases of the operation (e.g., condensed or produced wastewater, oils, etc.) would be trucked off-site or re-injected in approved UIC Class II injection wells that may be located at the sequestration site. Although traffic volumes would increase to meet incremental supply and disposal needs, it would not be expected to cause significant alterations in traffic patterns and volumes, or cause conflicts with existing local and regional transportation plans.

4.12.4 Mitigation of Potential Adverse Impacts

The following measures are recommended to mitigate potential adverse impacts of sequestration technologies on the utility infrastructure.

4.12.4.1 Project Planning and Design

- Identify utilities required and determine whether the available local utility infrastructure can adequately meet requirements.
- Identify alternatives if local infrastructure is inadequate. For example, if access to natural gas pipelines is unavailable, then the project design should include electric motors instead of gas-powered engines to drive compressors and pumps, or vice versa.
- Determine existing utility ROW for new CO_2 pipeline construction and identify potential barriers for alternative utility ROW.

4.12.4.2 Construction

- Identify whether adequate access roads are available to handle the volume and frequency of construction traffic to and from the proposed site.
- Discuss transportation plans with local authorities, especially during the movement of oversize loads, including construction equipment, drilling rigs, process equipment modules, and other heavy machinery.
- Develop a plan to reduce impacts of construction crews' traffic by proper scheduling and rotation of personnel.
- Create plans to handle and dispose of increased volumes of industrial and sanitation wastes generated during construction periods.

4.12.4.3 Operation

- Develop project-specific energy management plans to minimize materials and utilities usage.

- Identify opportunities for waste reduction to minimize wastewater and solid waste disposal volumes.
- Align schedules for delivery of materials (e.g., diesel fuel or chemicals) and for off-site waste disposal with host facility to minimize traffic to-and-from the project area.

4.12.5 Summary of Potential Impacts

Table 4-30 provides an overall qualitative assessment of potential impacts to the utility infrastructure for each sequestration technology.

The majority of impacts of all program technologies on the utility infrastructure would be negligible with a few impacts qualified as minor. In general, the primary needs of program technologies include energy sources (electricity or fuel), periodic supplies of raw materials, and periodic removals of wastes. Based on the relative energy demands and quantities of materials transported (supplies and wastes), the incremental impacts on the utility infrastructure would not be significant.

Impacts on water and wastewater infrastructure would be related to the size and distribution of potential facilities and/or region-specific issues affecting the ability to obtain a sustained supply of water or dispose of treated wastewater. Because volumes would be relatively small, the impacts are expected to be negligible or minor. Saline formation sequestration and co-sequestration of acid gas would have minor impacts on water resources based on the potential for contamination of underground water supplies caused by subsurface leakage of saline water. However, the use of MM&V technologies and proper control of injection pressures during operation would significantly reduce this risk.

Table 4-30. Potential Impacts of Program Technologies on Utility Infrastructure

Resource Criteria	Postcom Capture	Compr & Trans	Coal Seq	EOR Seq	Saline Seq	Basalt Seq	Terr Refor	Co-seq H_2S
Water supply and distribution	○	·	·	·	○	·	·	○
Wastewater treatment and disposal	○	○	○	○	·	○	·	○
Energy supply and distribution	·	·	·	·	·	·	·	·
Telecommunications	·	·	·	·	·	·	·	·
Roadways and traffic	·	·	·	·	·	·	·	·
Rail access	·	·	·	·	·	·	·	·

Key: · Negligible Impact, ○ Minor Adverse Impact, ⦿ Moderate Adverse Impact,
● Significant Adverse Impact, + Beneficial Impact