Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Matthew H. Mead, Governor **Todd Parfitt, Director**

July 3, 2014

Mr. Douglas Minter, Acting Chief
Underground Injection Control Program
US EPA Region 8
1595 Wynkoop Street
Denver, CO 80202

Re: Linc Energy: Underground Coal Gasification Demonstration Gasifier #6 Project; Groundwater Re-classification to Class V (Mineral Commercial)

Dear Mr. Minter:

In accordance with the 1983 Underground Injection Control (UIC) program Memorandum of Agreement (MOA) between the State of Wyoming and the United States Environmental Protection Agency (US EPA), the Wyoming Department of Environmental Quality (WDEQ) is providing the results of the public hearing process relating to the re-classification of groundwater and the proposed aquifer exemption associated with Linc Energy's Gasifier #6 Project. The results of the public participation process (attached) are described below and include:

Attachment 1:	WDEQ letter to commenters and Responses to Comments (oral and written) received between Feb. 24, 2014 and prior to WDEQ's public hearing in Wright, WY on March 26, 2014.
Attachment 2:	Official transcript of oral comments received at WDEQ's public hearing in Wright, WY on March 26, 2014.
Attachment 3:	Comments (written) received at WDEQ's public hearing in Wright, WY on March 26, 2014.
Attachment 4:	Comments (written) received via mail between Feb 24, 2014 and the close of the public comment period at 7PM, March 26, 2014.
Attachment 5:	Mar. 26, 2014 public hearing 'Sign-in Sheet' and mailing list.
Attachment 6:	Feb. 24, 2014 Publisher's Affidavit (and public notice) of the public hearing in Wright, WY on March 26, 2014.
Attachment 7:	Jan. 28, 2014 letter from EPA Region 8 Administrator (McGrath) to WDEQ Director (Parfitt).
Attachment 8:	Jan. 24, 2014 WDEQ response to Oct. 21, 2013 comments from Wyoming Outdoor Council and Sierra Club.
Attachment 9:	Jan. 9, 2014 Findings of Fact, Conclusions of Law and Order. Before the Environmental Quality Council IN RE Linc Energy Operations, Inc., TFN 5 5/128, Docket # 13-4804.

Attachment 10:	Transcript of Hearing Proceedings, Volume II, Before the Environmental Quality Council IN RE Linc Energy Operations, Inc., TFN 5 5/128, Docket # 13-4804.
Attachment 11:	Transcript of Hearing Proceedings, Volume I, Before the Environmental Quality Council IN RE Linc Energy Operations, Inc., TFN 5 5/128, Docket # 13-4804.
Attachment 12:	Oct. 25, 2013 Interim Response letter from EPA Region 8 Asst. Regional Administrator (Watchman-Moore) to WQD Administrator (Frederick).
Attachment 13:	Oct. 21, 2013 Comments on groundwater re-classification and proposed aquifer exemption from Wyoming Outdoor Council and Sierra Club.
Attachment 14:	Oct 18, 2013 Powder River Basin Resource Council Objections and Request for Hearing before the Environmental Quality Council.
Attachment 15:	Sept. 23, 2013 Publisher's Affidavit (and public notice) of re-classification of groundwater and proposed aquifer exemption.

The "Aquifer Reclassification Justification Statement of Basis" (SOB) for WQD's re-classification of groundwater within the mining unit to Class V (Mineral Commercial) was provided to you via letter dated August 29, 2013 and reflects DEQ's findings regarding the current use of the affected aquifer as a water source and the presence of commercially producible minerals within that aquifer.

In accordance with the MOA, please review these materials for conformance with Wyoming's groundwater classification criteria and US EPA's regulations at 40 CFR 146.4.

Please contact me at 307-777-5985 if you have any questions. We look forward to your review and response.

Sincerely,

Kevin Frederick

Kevin Frederick
Wyoming Department of Environmental Quality
Administrator
Water Quality Division
KF/rm/14-0580

attachments: *Results of Public Participation (Attachments 1 – 15): Linc Energy: Underground Coal Gasification Demonstration Gasifier #6 Project; Groundwater Re-classification to Class V (Mineral Commercial)*

c: Todd Parfitt, WDEQ Director (w/o attachment)
Nancy Nuttbrock, LQD Administrator (w/o attachment)
Don Fischer, WQD/GPC District Supervisor, Sheridan (w/o attachment)
Jeremiah Williamson, Asst. Attorney General, WY Attorney General's Office (w/o attachment)
Brian Deurloo, General Manager, Linc Energy Operations, PO Box 789, Glenrock, WY 82637 (w/attachment)

ATTACHMENT 1

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Wyoming Department of Environmental Quality
Water Quality Division/Groundwater Section
Underground Injection Control Program
Review Comments: Plans/Specifications/Proposals/Reports

Project Type:	**Response to Public Comments: Statement of Basis, Wyodak Coal Aquifer Exemption**
Facility Name:	**Underground Coal Gasification R&D License Application**
Facility Operator:	**Linc Energy Wyoming**
Facility Location:	**Campbell County, Wyoming NW1/4, Section 36, Township 44 North, Range 74 West**
Date:	**June 24, 2014**

INTRODUCTION: The Wyoming Department of Environmental Quality, (WDEQ) Water Quality Division (WQD) conducted a public hearing in Wright, WY on March 26, 2014 to collect public comments on the "Statement of Basis, Wyodak Coal Aquifer Exemption" (License Application Section 13.14 Appendix D-12) that was submitted to the US Environmental Protection Agency (EPA) for approval. The WQD responses to the oral and written public comments that were received by the department are addressed below. The WQD responses have been grouped into major topics based upon the environmental concerns presented.

Topic 1: Pre-Mining Groundwater Quality:

Example of Comments:

"DEQ failed to consider groundwater quality before making a decision."

"DEQ's groundwater classification process is not clear."

"And then I was confused as to the exemption and the requirements after reclamation that they'll reclaim to the same class prior. Does that mean that they reclaim to the class that's been exempted?

"Water is currently used as stock wells proximal to project".

WDEQ Response to Comments on Pre-Mining Groundwater Quality:

40 CFR §146.4, Criteria for Exempted Aquifers states: "An aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in §146.3 may be determined under §144.7 of this chapter to be an "exempted aquifer" for Class I-V wells if it meets the criteria in paragraphs (a) through (c) of this section. Class VI wells must meet the criteria under paragraph (d) of this section:

(a) It does not currently serve as a source of drinking water; and

(b) It cannot now and will not in the future serve as a source of drinking water because:

(1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

The licensee has met the requirements of the state regulations for a mineral commercial groundwater reclassification and the WDEQ has submitted the request for the aquifer exemption to EPA for approval.

Based on the groundwater data submitted to date, the pre-discharge use suitability of the groundwater has been determined by WDEQ to be Class III (livestock use). This classification is based upon the WDEQ groundwater classification process stated in Wyoming Water Quality Rules and Regulations (WQRR) Chapter 8, Section 4. The groundwater was then re-classified to Class V (mineral commercial) based upon data submitted in the license application and applicable state and federal regulations and guidance.

In accordance with WQRR, Chapter 8, Groundwaters of the State are classified in order to apply standards to protect water quality. The groundwater classifications are Class I (domestic use), Class II (agricultural), Class III (livestock), Class IV (industrial), Class V (mineral or hydrocarbon commercial), and Class VI (unsuitable for use).

No domestic water supply wells are located within ¼ mile of the proposed aquifer exemption boundary. No water supply wells are located within the aquifer exemption boundary.

Even though the aquifer may be exempted by the EPA, state regulations, specifically WQRR Chapter 8 Section 4(d)(viii)(B), require restoration of the groundwater: "A discharge into a Class V (Mineral Commercial) Groundwater of the State shall be for the purpose of mineral production and shall not result in the degradation or pollution of the associated or other groundwater and, at a minimum, be returned to a condition and quality consistent with the pre-discharge use suitability of the water."

Topic 2: Groundwater Monitoring during Operations

Examples of Comments:

"Linc has not demonstrated that contamination will remain within the proposed exemption area."

"How do they control excursions?"

"Linc's monitoring plan is insufficient to detect excursions resulting from the proposed UCG process."

"Linc's monitoring program does not include a broad enough list of parameters."

"Linc and WDEQ's proposed groundwater monitoring plan is too limited."

"Linc's proposed groundwater monitoring plan does not consider dangerous contaminants likely to be mobilized by the UCG process, including carcinogens such as benzene and polycyclic aromatic hydrocarbons (PAH)."

WDEQ Response to Comments on Groundwater Monitoring during Operations:

A total of 20 trend wells and 17 excursion wells will be used to monitor the groundwater. Overburden and underburden trend wells are located immediately surrounding the cavities to ensure horizontal and vertical groundwater movement is consistently towards the gasifier and to identify excursions. The WDEQ has determined that the Groundwater Monitoring Program described in the Statement of Basis, Wyodak Coal Aquifer Exemption will provide protection of the underground source of drinking water.

The primary focus of the monitoring plan is to monitor potentiometric levels, temperature and specific conductance in the Wyodak, overburden, and underburden trend wells to ensure horizontal and vertical groundwater movement is consistently towards the gasifier and to quickly identify excursions should they occur.

In the case that potentiometric data or conductivity data indicate the possibility of an excursion, during the operational or decommissioning phase, a groundwater sampling program will be initiated. The possibility of an excursion will be determined on the basis of one or more of the following conditions:

1) If a cavity-directed hydraulic gradient is not maintained in the Wyodak aquifer or anomalous heads are observed in Overburden or Underburden aquifers during gasifier operation;
2) If down-hole conductivity instrumentation in a trend well detects a change in conductivity greater than 80 umhos/cm over a 24-hour period; and,
3) If water temperature increases by more than 1 degree C over a 24-hour period.

If any of these conditions is met in one or more trend or excursion wells, groundwater samples will be collected from the closest two excursion wells in the same aquifer of the suspected excursion within two days following receipt of the in-situ detection. The samples will be analyzed for the four upper control limit parameters: phenol, ammonia, conductivity and benzene.

The process is discussed on pages 13.14-19 through 22 of the Statement of Basis, Wyodak Coal Aquifer Exemption.

Topic 3: Long Term Contamination Potential

Examples of Comments:

"Historically, the UCG resulted in long-term aquifer contamination and Linc, specifically, has been unable to demonstrate successful decommissioning after operations cease, especially at the scale required for commercial operations."

"Why not wait until the process in Australia is done? Linc has a pilot project in Australia and should demonstrate successful aquifer cleanup and decommissioning."

"In your response to comments, please explain why the WQD believes that Linc's project proposal will be different than past UCG projects that have contaminated groundwater."

"If you believe Linc's project will not contaminate groundwater, please explain the justification for this opinion, especially given the experimental nature of Linc's project and findings of the ISP report related to Linc's and other companies' projects in Australia."

WDEQ Response to Comments: Long Term Contamination Potential:

Based on WDEQ's evaluation of the technical provisions within the Linc license application, the WDEQ found the operational controls to be sufficient to protect the underground source of drinking water outside the proposed exempted area and restore groundwater after operations cease within the proposed exempted area in accordance with Water Quality Rules and Regulations. Hydraulic containment of the project is discussed in the Statement of Basis, Section 13.14.7.2.3 and the Groundwater Monitoring Plan is discussed in Section 13.14.7.2.4. Groundwater restoration of the project is found in Section 17.2 of the license application.

Topic 4: Decommissioning of the Burn Cavity

Examples of Comments:

"While Linc claims that its project here in Wyoming will be successful because it plans to use a clean-up process modeled after the Rocky Mountain 1CRIP cavity decommissioning process, there is very little public information available about the Rocky Mountain 1 project. In your response to comments, please fully explain the following: 1)Decommissioning process used by Rocky Mountain 1 and why it was allegedly more successful than any other UCG test project, including Linc's Australia projects. 2) Please also explain the similarities and differences between Linc's proposed project here and the Rocky Mountain 1 project, including characteristics such as coal quality, depth, formation thickness, overburden and underburden thickness, availability of fresh water and saturation of the coal seam, and monitoring and regulatory requirements. 3) Please also explain whether the Rocky Mountain 1 process is similar or different to any of Linc's decommissioning processes for its projects in other parts of the world, including Australia."

WDEQ Response to Comments: Decommissioning of the Burn Cavity:

The specific questions concerning the decommissioning of the burn cavity are not addressed in the Statement of Basis, Wyodak Coal Aquifer Exemption that was submitted to the USEPA and are therefore outside of the purview of the aquifer exemption public hearing process. Section 17.0 of the license application contains the Reclamation Plan.

Topic 5: Mineral Commercial Designation of the Aquifer

Examples of Comments:

"The formation does not contain commercially producible minerals.....there are no commercially producible minerals in the aquifer which would allow an aquifer exemption.

"Linc hasn't shown that commercial quantities of a mineral exist in the Wyodak aquifer."

WDEQ Response to Comments: Mineral Commercial Designation:

The licensee has met the state and federal rules and regulations administered by WDEQ and EPA for a mineral commercial exemption of an aquifer and has submitted the necessary application materials provided in guidance by WDEQ and EPA (Ref: Guidance for Review and Approval of State UIC Programs and Revisions to Approved State Programs, GWPB Guidance 34).

Topic 6: Procedural Concerns about the Aquifer Exemption Action Under State and Federal Regulations

Examples of Comments:

"According to EPA's regulations, EPA or delegated state cannot issue an aquifer exemption if the aquifer is currently being used as a drinking water source or has the potential to be used in the future as a drinking water source."

"The depth, location, yield, and existing groundwater quality do not prevent it from being a future drinking water source."

"The aquifer in question does not legally quality for exemption and granting such an exemption would violate the Safe Drinking Water Act (SDWA)."

"Groundwater is a vital, limited resource in the Powder River Basin and removing protections is not in the public's interest."

"The Fort Union is an important and commonly used regional water supply."

"the depth, location, yield and existing groundwater quality of the Wyodak aquifer do not prevent it from being a future drinking water source."

"It is our understanding that the WQD made its final decision on the aquifer exemption before any public process. To our knowledge, the WQD has not rescinded it August 29, 2013 letter to EPA with plans to issue a new letter reflecting a new or reaffirmed decision, after the public comment period. The fact that the letter was mentioned in WQD's public notice for the hearing implies that the letter is still in effect." ……."In other words, WQD and EPA, is still violating the rules before today's public hearing and before considering any data or views offered by members of the public during this public comment process."

WDEQ Response to Comments: Procedural Concerns about the Aquifer Exemption Action Under State and Federal Regulations

A mineral commercial basis for groundwater reclassification and subsequent federal aquifer exemption is not a violation of the SDWA as stated above in 40 CFR §146.4.

The notice of intent to issue the license and aquifer reclassification was published once a week for four consecutive weeks in the Gillette News Record newspaper, beginning on September 6, 2013. The Administrator of the Land Quality Division, Wyoming Department of Environmental Quality accepted objections to the proposed operations for 30 days following the day of last publication. A formal hearing was held before the Wyoming Environmental Quality Council on November 14 and 15, 2013. As stated in the Findings of Fact, Conclusions of Law and Order before the Environmental Quality Council, State of Wyoming, docket No. 13-4804:

> No. 23. All notice requirements have been met.
>
> No. 32. Linc Energy's R&D license is complete. The license application complies with all statutory and regulatory requirements.

In addition to this public participation process, the WDEQ held a public hearing in Wright, WY on March 26, 2014 in order to take additional public comments on the Statement of Basis, Wyodak Coal Aquifer Exemption.

The Wyoming WDEQ cannot authorize an aquifer exemption. The aquifer exemption proposal in question is considered a non-substantial revision to the state's program. The authority for approval of non-substantial revisions is delegated to the US EPA Regional Administrator.

Topic 7: Protection of Public Water Supply (Town of Wright)

Examples of Comments:

> *I run the Wright Water and Sewer District for the town of Wright. My concern is just because it's in the Fort Union aquifer. Our wells are drilled at 3,000 feet. Our first screens are at 1200 feet. You're going to 1100 feet, according to what I can see on the thing……We're only a hundred feet deep to getting our water. So that's one question I'd like answered from the EPA or the WDEQ or both of them."*

WDEQ Response to Comments: Protection of Public Water Supply (Town of Wright)

If approved, the research and development project will be located over ten miles west of the Town of Wright's wellfield in the NW1/4, Section 36, Township 44 North, Range 74 West. The aquifer proposed for exemption is an 80 acre section of the Wyodak coal, which is one of the coal seams in the Tongue River member of the Fort Union formation. The actual cavities to be gasified will cover less than an acre combined. Based on WDEQ's evaluation of the technical provisions within the Linc license application, the WDEQ found the operational controls will provide protection of the underground source of drinking water outside the exempted area and restore groundwater after operations cease inside the exempted area.

Topic 8: Precedent for Future Development

Examples of Comments:

"Issuing Linc's requested aquifer exemption sets a dangerous precedent for the state's interpretation and implementation of the SDWA"

WDEQ Response to Comment: Precedent for Future Development

The WDEQ interpretation and implementation of the groundwater reclassification and subsequent aquifer exemption request process is consistent with federal regulations under the Safe Drinking Water Act, federal guidance on aquifer exemptions, and state regulations. While federal and state regulations afford protection for the non-exempted aquifer during and after mining, WDEQ regulations also require restoration of the exempted aquifer to its predischarge class of use suitability after mining ceases.

Topic 9: General Informational Questions

Examples of Comments:

"The aquifer itself, what is the impact area?"

"What size of seam are they going into there?"

"Are there test monitoring wells proposed?"

"Baseline information, is that part of the project?"

WDEQ Response to Comment: General Informational Questions

If approved, the project will be located over ten miles west of the Town of Wright's wellfield in the NW1/4, Section 36, Township 44 North, Range 74 West.   The aquifer proposed for exemption is an 80 acre section of the Wyodak coal, which is one of the coal seams in the Tongue River member of the Fort Union formation.   The actual cavities to be gasified will cover less than an acre.

The Wyodak coal seam is from 24 to 30 feet thick in the project area.

A total of 20 trend wells and 17 excursion wells will be used to monitor groundwater in the vicinity of the gasifier.

Background water quality was collected for a full suite of groundwater classification parameters.

Topic 10:   Stratus Consulting Report

Examples of Comments:

There are a number of technical issues with respect to Linc's calculations in the aquifer exemption application and correspondingly, WDEQ's statement of basis. (e.g., hydraulic properties, rising water table, methods used to analyze pump tests, hydraulic communication *between aquifers, estimation of yield, water wells into Ft Union could span multiple aquifers (yield question)*

WDEQ Response to Comment: Stratus Consulting Report

The WDEQ/WQD received the memorandum titled "Review of Linc Energy Wyoming's Proposed Wyodak Coal Aquifer exemption" (Stratus report) during the public hearing held at the Town of Wright Wyoming from the Powder River Basin Resource Council (PRBRC).

In the report, Stratus Consulting reviewed and commented on the geology and hydrogeology of the application. Wyoming Statute § 33-41-102 states: (viii) "Practice of geology before the public" means the performance of geological services or work including consultation, investigation, evaluation, planning, preparation of geologic reports and maps, the inspection of geological work and the responsible supervision of geological services or work, the performance of which is relevant to public welfare or the safeguard of life, health, property and the environment, unless exempt under this act.

Wyoming Statute § 33-41-104 Prohibited Acts and Conduct states:(a) Unless duly licensed in accordance with the provisions of this act, no person in this state shall: (iii) Practice, continue to practice, offer or attempt to practice geology or any subdiscipline or part thereof before the public as defined by this act.

The report by Stratus Consulting was not submitted by a licensed Wyoming Professional Geologist in accordance with state statutes.

The WDEQ/LQD reviewed the Stratus report. Presented below are the comments on the Stratus report findings. The WDEQ/LQD review comments are grouped into four broad categories.

- **Category 1 – Incomplete review**: WDEQ/LQD comments addressing the Stratus report questions that appear to have resulted from the incomplete review conducted by Stratus on the Linc R&D license application.

- **Category 2 – Reasonably Conservative Estimates:** WDEQ/LQD comments that address and clarify the environmentally conservative approach taken by WDEQ in evaluating the proposed aquifer exemption. The general intent of the WDEQ approach is to protect the underground source of drinking water outside the proposed exempted area and restore groundwater after operations cease inside the proposed aquifer exemption area in accordance with WDEQ Rules and Regulations.

- **Category 3 – Gasifier Inward Hydraulic Gradient Control:** WDEQ/LQD comments clarifying the proposed operational and restoration plan presented in the Linc R&D license application.

- **Category 4 – Clarification on the Proposed Aquifer Exemption:** WDEQ/LQD comments clarifying the proposed aquifer exemption area and the criteria it is applied under.

Category 1: Incomplete review

Page 1 of the Stratus report states "*The Powder River Basin Resource Council (PRBRC) has requested that Stratus Consulting conduct a technical review of the aquifer exemption request, based on a review of the following sections of Linc's UCG Research and Development (R&D) Permit Application (Linc, 2013):*

- *Section 13.14, Appendix D-12 – Statement of Basis, Wyodak Coal Aquifer Exemption*
- *Section 13.7 – Geology*
- *Section 13.8 – Hydrology*

In addition, we have reviewed aquifer exemption-related public comments and Linc's responses to these comments. We have also cited selected literature, reports, and documents that are relevant to our comments."

The Stratus review report does not mention if they reviewed the other critical sections in Linc's R&D license application. A complete review of the entire Linc R&D license application would have addressed several of the questions raised by the Stratus report. It appears that there are several critical sections that were not reviewed by Stratus including:

- Section 14 - Mineral Extraction Plan
- Section 15 – Research and Reporting
- Section 16 – Determination of Upper Control Limits and
- Section 17 – Reclamation Plan

The review comments 1 through 9 are intended to serve as examples to note where the answer to a question that was raised by the Stratus report exists in Linc's R&D license application. However, this is not a comprehensive list of questions that were raised in the Stratus report caused by the incomplete nature of the review conducted on the Linc R&D license application.

Review Comment 1: Page 3 of the Stratus report under the heading 'Summary of Key Findings' states, "*The proposed groundwater monitoring program is too limited [e.g., it does not consider contaminants such as polycyclic aromatic hydrocarbons (PAHs) and benzene, which are likely to be mobilized by the UCG process]."*

Please reference the below sections in the Linc R&D license application for details on the groundwater monitoring program.

- Section 14.3.7.4 - Groundwater Contamination and Parameters Monitored
- Section 14.4 - UCG hydrology
- Section 14.5.2 - Groundwater Monitoring Plan – Excursion and Trend Wells

- Section 16 - Determination of Upper Control Limits
- Section 17.2 - Reclamation Plan – Groundwater Restoration and
- Section 17.8 - Bond Reclamation Procedures and Monitoring

Review Comment 2: Page 3 of the Stratus report under the heading 'Summary of Key Findings' states, "*Hydraulic communication between the Overburden, Wyodak, and Underburden aquifers exists under current conditions and may become more pronounced as the UCG process proceeds because of the effects of the operations on the local hydrogeologic system*."

Please reference Section 13.8.2.4.2 on the existing groundwater flow system and Sections 13.8.2.5.1, 13.8.2.5.2, 13.8.2.5.3 and Addendum 13.8-D for the leakage analysis between the different geologic units.

Please reference Sections 14.3, 14.4, 14.5 and 14.6 for the hydraulic controls, monitoring and the operation plan to protect the underground source of drinking water outside the proposed exempted area.

Please reference Section 17.2 on the groundwater restoration plan to restore groundwater after operations cease inside the proposed aquifer exemption area.

Review Comment 3: Page 5 of the Stratus report under the heading '4 Geology of the Project Area and Relevance to UCG Operations' states, "*Available borehole logs provide additional information on the degree of heterogeneity within the Tongue River Member in the project area. The Wyodak is described as "24 to 30 feet thick and laterally continuous within the Project Area." However, Linc also notes that "The exception is within the northeast portion [of] the Project Area where it [is] about 12 feet thick" (Linc, 2013, p. 13.14-4). Based on this existing characterization, the thickness of the Wyodak therefore varies by more than 100% over length scales of less than 1 mile*."

Please reference Section 14 for the location of the proposed gasifier within the permit area. The proposed gasifier for the Linc R&D license project is not located in the northeast portion of the project.

Review Comment 4: Page 12 of the Stratus report under the heading '5.4 Groundwater Classification Based on Current and Future Use' states, "*It is unclear how Linc has estimated the yield of the Wyodak Coal aquifer. The technical basis for this yield is not provided, nor does Linc provide the spatial area of the Wyodak over which they assume this yield applies***."**

Please reference Section 13.8.2.5.2 and Addendum 14-F for the yield estimate of the Wyodak Coal aquifer.

Review Comment 5: Page 16 of the Stratus report under the heading '6.2.1 Excursion well distance' states, *"While considering experience and knowledge gained from other sites is good practice, monitoring plans and well configurations should be based on site-specific conditions, including the local hydrogeologic properties and site-specific operating conditions. It is difficult to assess whether the 600-foot distance will be sufficient for this site, based solely on experience at different sites that likely had different hydrogeologic and operating conditions"*

Please reference Addendum 14-F Excursion and Trend Well Placement Evaluation in the Linc R&D license application for a description of the other site-specific conditions considered in addition to the experience at different UCG sites. In addition to the excursion wells, please note that 20 trend wells will be used to monitor groundwater.

Review Comment 6: Page 16 of the Stratus report under the heading '6.2.1 Excursion well distance' states, " *Linc states that they conducted contaminant fate and transport analysis in the Wyodak, Overlying, and Underlying aquifers of chloride and benzene, to assist in determining the size of the exemption area (Linc, 2013, p. 13.14-16). For chloride, they report that a concentration of 25 mg/L chloride (emanating from a continuous 500 mg/L source) is estimated to travel 200 feet from its source in the Wyodak aquifer in 5.8 to 10.8 years; in 31.8 to 187 years in the Overburden aquifer, and 9.4 to 26.2 years in the Underburden aquifer. These results would suggest that the aquifer exemption area will adequately encompass any area that would be contaminated if an excursion were to occur. However, Linc does not provide any information on their calculations, input parameters, nor the values for input parameters. This makes it difficult to assess the reported travel times for contaminants*."

Please reference Addendum 14-F Excursion and Trend Well Placement Evaluation in the Linc R&D license application for a description on the contaminant fate and transport calculations, input parameters and the results.

Review Comment 7: Page 16 of the Stratus report under the heading '6.2.2 Overburden and Underburden excursion wells' states, "*All of the wells that form the excursion well perimeter are screened in the Wyodak. The only excursion wells that are screened in the Overburden and Underburden aquifers are those located to the northwest of the oval. It is unclear why the Overburden and Underburden aquifer excursion wells are only placed in one area of the site.*"

Please note that a total of 20 trend wells and 17 excursion wells will be used to monitor groundwater. In addition to the overburden and underburden excursion wells, there are five overburden trend wells and six underburden trend wells within the excursion well perimeter. The overburden and underburden excursion wells are located downgradient from the proposed gasifier.

Please reference Addendum 14-F Excursion and Trend Well Placement Evaluation in the Linc R&D license application.

Review Comment 8: Page 19 of the Stratus report under the heading '6.3 Calculation of Area beyond the Excursion Wells to be Included in the Exemption Areas' states, "*As a result of this anisotropy, flow is unlikely to be radial in this setting. Instead, contaminants may preferentially flow in one direction, and/or follow narrow, fracture-controlled preferential pathways that could pass between excursion wells. Such pathways could allow contaminants to travel much faster and reach much greater distances before detection than would be otherwise predicted assuming homogeneous, isotropic, radial flow. Therefore, Linc's calculations could significantly underestimate the distance a contaminant could travel beyond the excursion wells, prior to being detected at a well."*

Please reference Section 13.7.4 on the existing groundwater flow regime.

Please reference Section 13.8.2.5 on the aquifer properties and anisotrophy

Please reference Addendum 14-F Excursion and Trend Well Placement Evaluation in the Linc R&D license application.

Review Comment 9: Page 10 of the Stratus report under the heading '5.2.1 Wyodak Hydraulic Properties' states, "*It does not appear that Linc's analysis of the aquifer test considered the rising water levels in the Wyodak as these wells recover from CBM depletion. No mention is made of the rising water levels in the sections of the document that describe the pumping tests, although increasing water levels are evident in many observation wells in early monitoring times. For example, water levels in observation well OW-30 were increasing at a rate of approximately 2 ft/day from January 27, 2012 through January 29, 2012, and then they began to decline, probably in response to pumping at TR44 that was initiated on January 27, 2012 (see Linc, 2013, Addendum 13.8-D1). Because analysis of the aquifer testing is based on water level changes in observation wells, ignoring the regional groundwater level rise during the pumping test could cause Linc to inaccurately estimate the transmissivity and hydraulic conductivity of the aquifer. This propagates into the aquifer exemption calculations because the estimated hydraulic conductivity is used to estimate both groundwater flow rates and the distance contaminants can be transported by the groundwater over a given time period*."

Based on the WDEQ/LQD review of Addendum 13.8-D1, the Stratus report determination, "*water levels in observation well OW-30 were increasing at a rate of approximately 2 ft/day from January 27, 2012 through January 29, 2012"* is not correct. It is not clear how the 2 feet per day recovery rate was calculated by Stratus.

Category 2 – Reasonably Conservative Estimates

Page 3 of the Stratus report under the heading 'Summary of Key Findings' states, "*Significant heterogeneity is present in the Wyodak and surrounding geologic units. This heterogeneity has implications for calculations of groundwater travel times and the size of the aquifer exemption area. Heterogeneity between these units also has implications for hydraulic communication between aquifers, and for Linc's ability to maintain hydraulic control of UCG operations."*

Almost all aquifers will exhibit heterogeneity. Therefore, it is reasonable to consider the range of estimated aquifer properties and then apply the aquifer properties that would minimize the aquifer exemption area and maximize the protection of the underground source of drinking water outside the proposed exempted area. In other words, the general intent is to minimize the proposed aquifer exemption area while using the possible range of scientifically credible aquifer properties.

Please reference Section 14, Section 15, Section 16 and Section 17 for the protective measures in place during the operation and restoration of the proposed UCG project.

Review Comment 10: Page 10 of the Stratus report under the heading '5.2.1 Wyodak Hydraulic Properties' states, "*Literature studies of the Wyodak aquifer hydraulic properties indicate that the hydraulic conductivity values obtained from the site pumping test are lower than mean values obtained from other aquifer tests. A U.S. Geological Survey report (Bartos and Ogle, 2002) summarized three previous studies that evaluated the hydraulic conductivity of the coal bed aquifers in the PRB using results from hundreds of aquifer tests. All three studies found that the data were logarithmically distributed, with geometric means of 0.5 ft/day (Peacock, 1997); 0.8 ft/day (Martin et al., 1988), and 0.9 ft/day (Rehm et al., 1980). Furthermore, Linc cites regional groundwater studies that indicate that the Anderson Coal aquifer (the coal aquifer is often referred to as the Wyodak-Anderson coal zone) has a hydraulic conductivity of 3 ft/day (Linc, Table 13.8-5). This information suggests that the hydraulic* *conductivity of the Wyodak aquifer may be an order of magnitude higher than indicated by Linc's analysis of a single pumping test in their proposed demonstration project area. An order of magnitude higher hydraulic conductivity would result in an order of magnitude faster travel time, which means that contaminants could potentially travel much farther than estimated by Linc in their transport analysis for the exemption area*"

- The references listed in the Stratus report summarize the hydraulic conductivities for coals that are typically less than 500 feet deep. The coal seam of interest for the proposed Linc R&D project is about 1,100 feet below land surface.
- It is difficult to make a direct comparison of the different coal seams in the Powder River Basin because of the variations in nomenclature.
- Even when compared against shallower coals, the hydraulic conductivity presented in the Linc Energy R&D license application is within the range of hydraulic conductivities reported for the shallower coal seams.
- Given the differences in the depth of the coal seams and the availability of site-specific test, it is prudent to provide more weightage to the site-specific estimate of the hydraulic conductivity of the coal.
- The arguments presented in the Stratus report are for the application of a higher hydraulic conductivity and faster travel times. Selecting a higher hydraulic conductivity from the range of estimates and applying this higher hydraulic conductivity to the aquifer exemption area estimation will result in an aquifer exemption area bigger than the proposed aquifer exemption area. This is contrary to the WDEQ's environmentally conservative approach to minimize the aquifer exemption area.

Review Comment 11: Page 14 of the Stratus report under the heading '6.1 Aquifer(s) included in the Exemption' states, "*Based on our review, the Overburden and possibly the Underburden aquifers should be included in the exemption*."

Please note that including the overburden and underburden will increase the aquifer exemption area. In other words, this will remove the federal protection for the overburden and underburden units.

Category 3 – Gasifier Inward Hydraulic Gradient Control

Review Comment 12: Page 2 of the Stratus report under the heading 'Summary of Key Findings' states, "*There are a number of technical issues with respect to the calculation of the aquifer exemption, including:*

- *The aquifer exemption calculations contain inappropriate assumptions for key parameters, including the distance to excursion wells and the hydraulic gradient used to calculate flow velocities.*

- *The aquifer exemption calculations do not sufficiently consider uncertainty. Single values were used in aquifer exemption calculations, ignoring the range of parameter values that would be representative of this natural system."*

Please reference Section 14.3 and 14.4 for the details on the proposed operational and monitoring controls. One of the key requirements of the proposed UCG process is to maintain an inward hydraulic gradient towards the gasifier. The gasifier will act as a groundwater sink during operations and restoration. Please note that the aquifer exemption calculations are carried out with an assumed absence of this inward hydraulic gradient towards the gasifier.

Review Comment 13: Page 20 of the Stratus report under the heading '*6.3.3 Calculation of the distance an excursion could travel from the time of detection until recovery operations begin' states, "It is not clear why a gradient that was measured during a pumping test was used in a calculation to predict travel distances during the UCG demonstration project. A more appropriate approach would be to predict gradients that would exist during the UCG test and, during cavity flushing, use those gradients in the calculation to predict the distance an excursion might travel during the test*."

Please reference Section 14.3 and 14.4 for the details on the proposed operational and monitoring controls. One of the key requirements of the proposed UCG process is to maintain an inward hydraulic gradient towards the gasifier. The gasifier will act as a groundwater sink during operations and restoration. Therefore, if the operations are conducted according to the proposed operation plan presented by Linc in the R&D license application, the hydraulic gradient will be towards the gasifier and not towards the excursion well ring boundary.

Category 4 – Clarification on the Proposed Aquifer Exemption

Review Comment 14: Page 2 of the Stratus report under the heading 'Summary of Key Findings' states, "*Linc Energy is requesting an aquifer exemption that would allow them to contaminate groundwater in and around the Wyodak Coal aquifer, which is part of the Fort Union Formation. The Fort Union is an important and commonly used regional water supply aquifer in Wyoming. Linc alleges that the depth, location, low yield, and (or) the existing groundwater quality of the Wyodak aquifer preclude future use as a drinking water supply. We disagree.*"

Please note that Linc is applying for aquifer exemption under the criteria "Aquifer is not a source of drinking water and will not serve as a source of drinking water in the future because it is mineral, hydrocarbon, or geothermal energy producing, or can be demonstrated by a permit applicant as a part of a permit application for a class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible." The arguments presented by Stratus are not the criteria used in this Linc's proposed aquifer exemption (Please review: Aquifer Exemption Summary Sheet, Don Fischer, WDEQ/WQD, August 28, 2013).

Review Comment 15: Page 3 of the Stratus report under the heading 'Summary of Key Findings' states, "*The aquifer exemption request is unclear about which aquifer is being proposed for exemption, and whether this includes the Wyodak aquifer only, or the Wyodak and Overburden aquifers*."

The proposed aquifer exemption is only for the Wyodak aquifer that is within the proposed aquifer exemption boundary.

END OF DOCUMENT

ATTACHMENT 2

(Copies can be obtained by contacting Wyoming Reporting Service, Inc. at 1-800-444-2826)

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2601 Central Avenue
Cheyenne, WY 82007

Ph 307.635.0331

WYOMING MINING
ASSOCIATION

Mailing Address
PO Box 866
Cheyenne, WY 82003

Fx 307.778.6240

Comments
Wyoming Mining Association
Re
Linc Energy Underground Coal Gasification Project

My name is Marion Loomis and I am the Executive Director of the Wyoming Mining Association. The Wyoming Mining Association (WMA) represents bentonite, coal, trona (which is processed into soda ash), uranium, and rare earth mineral producing companies. This includes companies like Linc Energy that want to develop new ways to produce Wyoming's abundant mineral resources. Wyoming leads the nation in the production of bentonite, coal, soda ash and uranium. We may soon be a leader in the production of rare earth minerals.

I want to lend the WMA's support for the Linc Energy underground coal gasification project. Wyoming is blessed with tremendous reserves of coal. We also have additional coal resources that might someday be reclassified as a reserve. I am sure you know the difference between a reserve and a resource, but for the record I would like to provide some background on the difference. A reserve is the amount of mineral that is in the ground that can be recovered by existing, economic methods. A resource on the other hand includes all of the reserves, but it also includes those minerals that are in the ground that cannot be recovered economically or those where the technology does not exist to recover the mineral. Wyoming has about 45 billion tons of coal reserves. That will last us 100 years. Half of that coal reserve can be mined by open pit mining. The other half will have to be mined using underground equipment. Our resource on the other hand exceeds 1.3 trillion tons. Those of us in the mining industry have long wished for a way to move some of those resources into the reserve category. With the development of new and more efficient use of existing technologies, we have managed to do so. However, most of the resource still is out of reach. Developing in situ coal gasification holds promise that may allow us to reclassify some of those resources into reserves, and the potential benefits to the state are significant.

The current economic impact of coal for Wyoming is huge. Revenues from coal to state and local governments are exceeded only by natural gas production. Revenues from minerals are the primary reason Wyoming has not seen the need for a state income tax. Coal mining generates almost 7,000 direct jobs with an estimated payroll of 700 million dollars. Wyoming's share of the taxes and royalties from coal mining exceed 1 billion dollars per year. As the economic limits of surface mining are reached, it will be important for Wyoming to have options to continue to develop our coal resources in order to continue this necessary funding stream for schools, highways and general government expenses. It will be important that some of this revenue be picked up by other commodities 50 years or more in the future. In situ coal gasification could be a major part of a new revenue source.

Development of synfuels could promote new value added products in Wyoming. Opinion leaders have long talked about how to add value to the minerals we produce. In situ coal gasification could be the stimulus to build those value added projects in Wyoming rather than just shipping our raw products out of state for refining in other states.

The coal formation Linc Energy wants to develop is 1,100 feet below the surface. The water quality does not meet Class I water quality standards for iron, manganese, or total dissolved solids. The formation is bounded by tight shale both above and below the formation where they want to develop. This is a pilot project to show that the technology will work and the area impacted can be restored to the standards set out by the Department of Environmental Quality (DEQ). DEQ has reviewed the permit and found that it does comply with the standards adopted by the state.

Linc Energy's technology is proven. They have demonstrated their technology successfully for 14 years in Australia while meeting environmental compliance.

In summary Linc Energy's use of in situ mining of the coal could greatly expand the reserve base of our coal resources. It could lead to develop of a whole new industry in Wyoming, contributing needed funding to state and local governments. The company will have to prove that the groundwater can be restored to the class of use for which the water was suitable prior to development. The aquifer exemption that Linc Energy submitted to the DEQ & EPA meets all federal and state requirements to be approved.

Thank you.

TREC, Inc.
Engineering & Environmental Management

A Woodard & Curran Company

900 Werner Court, Suite 150
Casper, WY 82601

Phone (307) 265-0696
Fax (307) 265-2498

March 24, 2014

WDEQ / Water Quality Division
122 West 25th Street
Herschler 4W
Cheyenne, Wyoming 82002
Attention: Kevin Fredrick, Administrator

RE: Linc UCG Gasifier 6 Project

Dear Mr. Frederick:

This letter is written to urge approval of Linc Energy's (Linc) application for a proposed Underground Coal Gasification (UCG) pilot in northeastern Wyoming. Linc has developed and submitted to WDEQ a detailed Research and Development application for the UCG pilot in accordance with WDEQ guidance and input. In one of the most rigorous and well-vetted applications review processes that TREC has been involved in, Linc's application has undergone eight rounds (16 months) of review by highly qualified WDEQ staff and consultants. Generally, this level and length of review exceeds efforts usually reserved for a traditional mine application. Therefore, I have the upmost confidence that Linc and WDEQ have conducted a very thorough evaluation of the technical and environmental facets of this project.

There have been a number of successful UCG trials in the State of Wyoming, and Linc has unrivaled experience in UCG with development of multiple generations of gasifier technology and 50 years of operational experience to draw from. Linc's comprehensive investigation in their site selection and experience makes this R&D project a valuable asset in Wyoming's energy strategy that balances energy development with environmental issues and mitigates potential environmental impacts. Furthermore, energy research and development efforts are a positive approach that can buffer the traditional cycle of boom and bust in Wyoming's energy economy. UCG can add value and diversity to Wyoming's energy portfolio while responsibly adding jobs and tax revenues.

Sincerely,

Ray DeLuna

Ray DeLuna,
Deputy Regional Manager
TREC, Inc.

My name is Peter Wold. I live in Casper, Wyoming and am a member of the Powder River Basin Resource Council. I ranch Southwest of Kaycee, Wyoming at the Hole in the wall and am in the oil and gas business here in the Powder River Basin.

I appreciate this opportunity to address the issue of Linc Energy's UCG aquifer exemption. I did have the opportunity to make comments to the Wyoming Department of Environmental Quality during the public comment period between September 6 and October 23 of that year. I understand I also could have read the 1200 pages or so of Linc's Underground Coal Gasification Gasifier 6 Research and Development License that was in the Gillette courthouse during that time. I didn't get around to that but do appreciate my time now.

Good quality water is critically important to all of us that live here, raise our families here, run our cattle here or produce our energy here. That's why when I heard that Linc Energy was going to apply for a UCG permit to build a plant here in the basin, I wanted to learn as much as possible about the company and the process. Two years ago I traveled to Australia to see my son who was in college in Brisbane. While there I went to Linc's Headquarters and quizzed the management about UCG. They encouraged me to drive to their field operations in Chinchilla Australia where they have a full fledge UCG gasifier running and a refining facility converting the produced syngas to diesel. While that project was not at a commercial stage yet, it was impressive, clean and a source of pride for everyone in the area.

From my studies, I was surprised to find there have been 33 such tests in the U.S., 17 in Wyoming, mostly in the 1970-80's. One did cause H_2O contamination and subsidence but the DOE and industry learned from that one and the many other successful tests. One of the most recent tests was the Rocky Mountain #1 test near Hanna. That UCG test was very successful, recovered gas, restored the water to its same class of use, decommissioned the site, and was released from its bond by the DEQ.

Contained in Linc's 1200 page application, I am told are sophisticated scientific chemical and mineralogical studies modeling this Powder River Basin test. They have complied with every request from numerous state and federal agencies and answered every detail in the many regulatory requirements to get to this point. Linc is coming here with this project from a thoughtful, carefully planned approach that includes geologic, hydrologic, and engineering studies. They are doing this in other places in the world and they have the information gleaned from the 33 other tests previously done here in the U.S.

I am encouraged by my research at the potential this technology can bring to this region, to Wyoming and our nation. In our efforts to become a nation independent of Middle East oil UCG can tap a proven resource in an environmentally responsible way while providing jobs here and not sending dollars to our foreign enemies. I encourage the EPA to sign off on the aquifer exemption that our WDEQ already has done.

Thank you -

Peter Wold
139 W. 2nd St Ste 200
Casper, Wy 82601

Pwold@woldoil.com

JOHN S. WOLD
GEOLOGIST

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139 WEST SECOND STREET
CASPER, WYOMING 82601-2462

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E-mail: wopl@trib.com

Department of Environmental Quality/ Water Quality Division
Attn: Kevin Fredrick, Administrator
122 West 25th St, Herschler 4W
Cheyenne, WY 82002

March 25, 2014

Dear Mr. Fredrick;

I, John Wold, was the first professional geologist ever to serve in the U. S. Congress. As the "Member from Wyoming", I served on the House Interior Committee and was the original author and sponsor in the House of Representatives of the National Mining and Minerals Policy Act of 1970. I was chairman of a large variety of responsible development programs in the Powder River Basin natural resources.

In 1968, I was chosen by the Associated Press and United Press as "Wyoming Man of the Year", in 1978 chosen as "Wyoming Mineral Man of the Year", and in 1999 was elected by the American Heritage Foundation of the University of Wyoming as Wyoming's "Oil, Gas, and Mineral Man of the 20th Century".

I hold a B.A. degree from Union College and St. Andrew's University Scotland, a M.S. degree in Geology from Cornell University, and an honorary L.L.D. from the University of Wyoming.

While my principal business interest has been oil and gas, in the 1970's I managed coal exploration and acquisition programs on a nationwide basis with Peabody and Consolidation Coal Company that introduced Exxon, Mobil, Sun, and other major players to the coal resources of the Rocky Mountains.

Based on a lifetime (76 years) of experiences in the energy field and particularly in the underground coal gasification process, I strongly support the established tedious decision of the judicial system with respect to license #18RD from the Wyoming Department of Environmental Quality on January 14, 2014.

I appreciate your diligence, persistence and understanding of the situation you now consider.

Sincerely,

John Wold

John Wold

JSW:as

Jill Morrison, PRBRC, 934 N Main, Sheridan, WY 82801
DEQ policy & purpose ? R&D application issues –

According to the Wyoming Water Development Office, State Water Plan for Northeast Wyoming Water Basin completed in 2002:

"Groundwater is the major and in many cases, the only source of water in the Basin Plan Area."

The Gillette Area Water Master Plan states:

The Fort Union Formation is one of the most prolific Tertiary-age fresh water aquifers in the arid western half of North America. Certainly within the state of Wyoming, and the Powder River Basin in particular, people and industry are highly dependent on this seemingly inexhaustible and exceptional quality ground water. This is especially true when the almost total lack of surface water supplies in this area is considered (WSEO, 1995, p. 3-1).

The state reports also document the population served by individual domestic systems reliant on groundwater from the Fort Union formation in the PRB is estimated to be around 14,000.

In the NE Planning area there were over 2700 domestic wells averaged from 1 gpm to 1325 gpm with an average of 18 gpm. There are nearly 7,000 permitted stock wells 1 gpm to 1,600 gpm with an average of 14 gpm.

Further, the Fort Union is the source for approximately 14 municipal and public water supply systems including the City of Gillette and Wright and adjacent Districts, Joint Powers Boards and Privately Owned Water Systems and Water Users Associations in Campbell County. The City of Gillette mixes Fort Union Formation water with that from the Madison and Fox Hills/Lance system for municipal / public water supply.

DEQ fails to justify and support anywhere in the application that this aquifer will not be used in the future because it contains minerals. The primary aquifers that provide several thousand domestic and livestock wells in the area also contain coal. If DEQ permits an aquifer exemption for good quality water in this case Class 1 water quality – simply because it contains coal – that is a precedent for exempting groundwater aquifers all over the Basin that contain minerals.

We know from the independent scientific panel and report from Australia where Linc has operated for years that they have **not** demonstrated they can clean up and reclaim an UCG site. We also know the bond they've provided to ensure they will clean up contamination is not inadequate.

Experts we hired who analyzed the Linc application found errors in Linc's analysis for assuring confinement of the contamination from the area and/or from the overburden aquifers.

The proposed aquifer exemption does not meet the legal requirements since this is good water and it can be used. Finally, sacrificing precious groundwater for an unproven experiment is bad policy. We ask that you deny this aquifer exemption and protect our dwindling groundwater resources for current and future generations.

Public Comment on Proposed Water Classification change in the Powder River Basin.

Wright Wy

3/26/14

The public should have full and complete access to all required monitoring of the ground water. If there is truth in the comments that the Powder River Basin Resource Council made about certain chemical contaminants that are common in this process are not going to be monitored they needed to be added to the requirements. All monitoring information should be uploaded to public access without any human intervention in real time. There should be levels established that will trigger automatic notification of contaminations. In the world we live in today you can't argue that this would be cost prohibitive. If cost is the limiting factor this should not be allowed to proceed. Anyone that has water wells within 10 miles should be provided monthly reports on water quality changes from the monitoring wells. The Wright Water and Sewer District depends on this water there doesn't seem to be any record of contact with the district of this proposal. The applicant should pay the cost of State Employee's to monitor the whole operation, and there should be a required minimum of inspections established. Oversight on this project is of the utmost importance.

Roger Rasmussen

PO. Box 125
Wright Wy. 82732

schlad@vcn.com

3-26-14

To Whom it may Concern:

As a resident of Campbell County that recently attended the public comment period in Wright WY for the Linc Energy Project, my only comment after listening to a multitude of questions by those in attendance would be to encourage Linc Energy to provide another Q&A Session to address the technical comments that were asked today.

Two additional recommendations:

1) Put a copy (additional from the one on file in Gillette) of the application at the Wright Library or Town Hall for review by the general public.
2) Make sure that the Wright newspaper is copied on all news releases.

Sincerely
Brenda K. Schladweiler

ENCOURAGING RESPONSIBLE DEVELOPMENT TODAY ~ FOR TOMORROW

934 N. MAIN ST. SHERIDAN, WY 82801 (307) 672-5809 FAX (307) 672-5800
INFO@POWDERRIVERBASIN.ORG WWW.POWDERRIVERBASIN.ORG

POWDER RIVER BASIN
Resource Council

Via hand-delivery

March 26, 2014

Department of Environmental Quality
Water Quality Division
Attn: Kevin Frederick, Administrator
122 West 25th Street, Herschler Bldg. 4W
Cheyenne, WY 82002

RE: WQD's re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.'s proposed underground coal gasification research and development testing project

Dear Mr. Frederick,

Thank you for the opportunity to provide these comments on the Department of Environmental Quality (DEQ) Water Quality Division's (WQD) proposed re-classification and exemption of groundwater for Linc Energy Operation, Inc.'s (Linc) proposed underground coal gasification (UCG) research and development project in Campbell County, Wyoming. These comments are submitted on behalf the Powder River Basin Resource Council and the Western Organization of Resource Councils and our members.

As you know, our organizations remain very concerned about WQD's proposed aquifer exemption, and we believe that there are strong procedural and substantive reasons for rejecting Linc's aquifer exemption request. As discussed in detail below, the reclassification and exemption of the proposed aquifer would violate the Safe Drinking Water Act (SDWA), EPA's regulations implementing the SDWA, and corresponding state laws and regulations.

If Linc's project is allowed to go forward, we ask that the WQD treat it similarly to the way you treated microbial coal conversion projects, by not granting aquifer exemptions and UIC Class III wells, but instead by permitting the projects with UIC Class V wells and no aquifer exemption.[1] A Class V UIC permit without an aquifer exemption could be designed to protect the aquifer during production and to ensure it is restored after decommissioning of the project. In other words, the permit would protect this underground source of drinking water (USDW) rather than allowing for its contamination through an exemption. **If Linc's project cannot proceed without an aquifer exemption, then Linc's project should not proceed**.

[1] In establishing that regulatory framework, EPA, DEQ, and the Oil and Gas Commission concluded that aquifer exemptions could not be obtained for the Fort Union Formation because of the presence of drinking water wells in the formation and because of the quality of the aquifer as a source of drinking water. We do not see any difference here.

Introduction

In the arid Powder River Basin, ranches, homes, and local governments obtain water from the ground. Locally, there is no surface water supply available in sufficient quantities and qualities for drinking and livestock water. *See* Wyoming State Engineer's Office, *Background: Time Limited Water Haul Permits from the Fort Union Formation in Campbell County*, April 9, 2008 ("The City of Gillette and all other water users in the vicinity of Gillette depend solely on ground water for their water needs."). As reported in numerous geological and hydrological reports, in the Powder River Basin "[g]roundwater for domestic consumption is derived predominantly from the Wasatch and Fort Union aquifers." The geology and relatively good water quality make the Fort Union Formation a preferred source of groundwater for domestic and livestock purposes in the Powder River Basin. Both the sandstone aquifers and the coal-bearing aquifers of the Fort Union Formation are produced for domestic and livestock water, and in some locations, the coal-bearing aquifers are preferred. As explained by Dr. John Bredehoeft, a retired USGS scientist:

> The coal beds are not very porous; the porosity is thought to be 0.4 percent. However, the coal beds are reasonably permeable because of the fractures (cleats) within the coal. The coals often contain better quality water than the surrounding sand aquifers; in places the coal beds are the most permeable aquifers. For these reasons the coal beds are often the preferred aquifers for groundwater development.

John Bredehoeft, *Comments on Wyoming and Montana Final Environmental Impact Statement on the Development of Coal-Bed Methane, available at* http://www.powderriverbasin.org/assets/Uploads/files/final/expertfeisjohnbredehoeft.pdf.

For these reasons, our organizations' members and many other landowners across the Powder River Basin rely on the coal-bearing aquifers of the Fort Union Formation for drinking and livestock water.

In addition to wide use by private landowners for domestic and livestock watering purposes, the Fort Union Formation also provides significant water resources to municipalities and water districts. *See e.g.*, HKM Engineering, *Northeast Wyoming River Basins Water Plan*, Appendix E, *available at* http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html (showing that most municipalities and water districts in Campbell County use water from Fort Union wells); *see also* Wyoming State Engineer's Office, *Background: Time Limited Water Haul Permits from the Fort Union Formation in Campbell County*, April 9, 2008 (noting that the Fort Union Formation is "a drinking water resource for both the City of Gillette and numerous subdivisions in the Gillette area."). Some of these municipal wells are in relative close proximity to Linc's project.

The Fort Union Formation is also a water source with dwindling supply, making preservation of the formation's various aquifers even more important. Because of population and industrial growth and ongoing drought, the Wyoming State Engineer's Office determined that "[u]se of a quality, declining ground water resource for use in construction, oil and gas activities, etc. is not in the public's water interest." *Id.* As a result, the agency limits the amounts and types of water permits that can be received from the formation. *Id.*

As explained below, Linc's proposed UCG project will irreversibly damage a portion of the Fort Union Formation and will contaminate this source of good quality water. The portion of the Fort Union Formation where Linc proposes its project has good quality groundwater, with TDS measurements barely above drinking water standards. Equally important, approval of Linc's request to reclassify and exempt this portion of the Fort Union Formation will set a dangerous precedent and basically commit DEQ to permitting future contamination from UCG and other industrial projects in the Powder River Basin,[2] threatening the viability of this regional aquifer as a continued source of water.

Concerns about the Underground Coal Gasification Process

Linc proposes to carry out an experimental UCG project on a state section of land in Campbell County. UCG converts coal to a synthetic gas through chemical reactions underground. The process oxidizes the coal, igniting it and converting it into a syngas that is transported to the surface through a production well. Linc plans to flare off all gas produced from the project.

The UCG process is fraught with risk. Past projects have resulted in the long-term contamination of aquifers. As explained in a report to the Wyoming Business Council, "The major concerns with the UCG process are excessive subsidence, groundwater influx, mixing of aquifers (or water bearing strata), and groundwater contamination." Gas Tech, *Viability of Underground Coal Gasification in the "Deep Coals" of the Powder River Basin, Wyoming*, June 2007, at 3. Of particular note, the Hoe Creek I, II, and III projects carried out in the Powder River Basin by the Department of Energy were considered failures and led to the contamination of groundwater. *Id.* at 8, 18-19; *see also* Linc Application at 14-6 to 14-7.

In 1986, the Department of Energy issued a technology status report on UCG. In the report, the DOE looked at past UCG projects in the United States and largely found that most projects resulted in significant problems including roof collapse, gas loss, and contamination of aquifers in and/or adjacent to the coal seam being gasified.

It is highly likely that Linc's project will irreversibly damage the aquifer used during the UCG process. Linc has not demonstrated that the UCG process is safe and effective. Linc admits that its process is not fully refined and that through the pilot project, Linc plans to "refine techniques and procedures to establish hydraulic control" of the gasifier with the goals of learning how to maintain groundwater flow and pressures. *Id.* at 14-29. In other words, Linc must carry out this experimental project before it can assure regulators and the public that groundwater flow and pressures can be controlled.

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[2] As discussed below, the precedent-setting nature of this exemption is particularly relevant given Linc's coal leases across the Powder River Basin.

For over a decade, Linc has tested its process in Australia; however, significant questions still remain about whether the process and its contamination can be adequately controlled and whether facilities can be safely decommissioned. These questions have led the Australian government to restrict Linc's activities, which has led the company to announce that they are leaving the country. We have attached a comprehensive report from an Independent Scientific Panel that was commissioned by the Queensland Government. Queensland Independent Scientific Panel for Underground Coal Gasification, *Report on Underground Coal Gasification Pilot Trials*, June 2013, available at http://mines.industry.qld.gov.au/assets/legislation-pdf/isp-final-report-cs-review.pdf, attached (hereafter "ISP report"). Please consider its findings in your review of this project and provide a review of the report in your response to public comment. This report questioned the maturity of Linc's technology and ultimately found that Linc's Australian project should not be expanded until critical findings can be made, including the ability to safely operate and decommission the project without contamination of groundwater. The report found that if contaminants are left, they could migrate out of the exemption area after Linc's project is decommissioned.

The ISP report states:

> Both companies have demonstrated capability to commission and operate a gasifier. Neither company has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. The ISP remains open to the possibility that the concept is feasible. However sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. Important work has been undertaken but more is yet to be done.

Id. at Executive Summary; *see also id.* at 23 ("Linc Energy manages a site that is clearly an experimental facility . . .").

The contamination left in the aquifer after decommissioning is of particular concern to our organizations. Linc's permit application states that ungasified components such as "ash, char, fine grained sediment, and other mineralogy associated with coal deposits" will be present in the cavity after the gasifier is shut down. The presence of char indicates incomplete gasification or coal pyrolysis, which also implies the presence of condensable hydrocarbons (i.e, coal tars). The ISP report found that "[t]he UCG process involves pyrolysis, combustion and gasification that will inherently produce contaminants such as benzene, toluene, ethylbenzene, xylenes (commonly referred to together as BTEX), various phenols, polycyclic aromatic hydrocarbons (PAHs) and other toxic compounds." *Id.*; *see also id.* at 34 ("During cooling there is an inherently high probability of formation of potentially contaminating chemicals."). The lighter components are highly water soluble, with the heavier, higher-boiling-point components having lower solubility and higher viscosities. Even multiple water flushes may not be enough to remove these heavier hydrocarbons and eliminate subsequent exposure of the cavity to groundwater contamination. BTEX and PAHs are known carcinogens and are not currently present in the aquifer in detectable amounts.

While Linc claims that its project here in Wyoming will be successful because it plans to use a clean-up process modeled after the Rocky Mountain 1CRIP cavity decommissioning process, there is very little public information available about the Rocky Mountain 1 project. In your response to comments, please fully explain the decommissioning process used by Rocky Mountain 1 and why it was allegedly more successful than any other UCG test project, including Linc's Australia projects. Please also explain the similarities and differences between Linc's proposed project here and the Rocky Mountain 1 project, including characteristics such as coal quality, depth, formation thickness, overburden and underburden thickness, availability of fresh water and saturation of the coal seam, and monitoring and regulatory requirements. Please also explain whether the Rocky Mountain 1 process is similar or different to any of Linc's decommissioning processes for its projects in other parts of the world, including Australia. Please also disclose whether EPA issued an aquifer exemption for the Rocky Mountain 1 project.[3] If EPA did not issue an exemption, please explain why Linc and WQD are able to rely upon the results of Rocky Mountain 1 project to issue this aquifer exemption.

In your response to comments, please explain why the WQD believes that Linc's project proposal will be different than past UCG projects that have contaminated groundwater. If you believe Linc's project will not contaminate groundwater, please explain the justification for this opinion, especially given the experimental nature of Linc's project and findings of the ISP report related to Linc's and other companies' projects in Australia. If you believe Linc's project will not contaminate groundwater, please explain why you have proposed an aquifer exemption in this case.

Procedural Concerns Related to the Aquifer Exemption

Federal regulations require "notice and opportunity for a public hearing" *before* the state can identify "exempted aquifers." 40 C.F.R. § 144.7(b)(3). Additionally, the Memorandum of Agreement between Wyoming and EPA related to state implementation of the Underground Injection Control (UIC) program of the Safe Drinking Water Act requires a "public participation process" for all proposed aquifer reclassifications and exemptions. Public participation is a key aspect of our nation's environmental laws, allowing those most impacted by a decision to participate in the decision-making process. Public comment allows parties to present data and views that agencies must consider during their decision-making process.

Unfortunately, DEQ's first attempt at a "public hearing" before the EQC was not very "public" as only parties that had gone through the burdensome process of objecting to the decision were allowed to participate in the contested case hearing. DEQ and the EQC did not afford opportunities for other members of the public to participate, either in writing or orally.

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[3] Our organization submitted a FOIA request to EPA for copies of all EPA Region 8 approvals of aquifer exemptions for UCG projects and EPA Region 8 produced only one set of documents – approval of an exemption for the Carbon County UCG project. Other UCG projects may have been merely grandfathered into SDWA requirements because they predated the aquifer exemption process.

Although we appreciate that DEQ is offering a new public comment hearing to address some of these procedural concerns, we still have grave questions about whether DEQ and EPA are following the correct procedure even now.

It is our understanding that the WQD made its *final* decision on the aquifer exemption *before* any public process. To our knowledge, the WQD has not rescinded its August 29, 2013 letter to EPA, with plans to issue a new letter reflecting a new or reaffirmed decision, after the public comment period. The fact that the letter was mentioned in the WQD's public notice for this hearing implies that this letter is still in effect.

Raising further concern for us is DEQ's contention that this August 29, 2013 letter is a final agency action. During the EQC proceeding, we argued that the August 29, 2013 letter should be viewed solely as a preliminary recommendation to EPA because EPA has final decision-making authority over aquifer exemptions and because DEQ had not yet held a public comment opportunity and hearing. However, DEQ was adamant that the August 29, 2013 letter "...represents DEQ's final action on this issue..." DEQ Brief, Nov. 12, 2013 at 7.

WQD's decision was affirmed by the January 9, 2014 order of the Environmental Quality Council, which is another *final* agency action of the state.

In other words, WQD – and in turn EPA – is still violating the rules because the state made its decision to reclassify and exempt the aquifer *before* today's public hearing and *before* considering any data or views offered by members of the public during this public comment process. Particularly telling is WQD's use of past tense in its public notice, demonstrating that the agency believes it has already made a decision: "WQD believes that the area of the aquifer *re-classified* by WQD meets EPA's criteria for exemption." WQD Public Notice (emphasis added).

We hope that WQD will earnestly address the concerns, comments, and questions raised through this public comment period, but we remain unconvinced that the state will change its opinion. Until we are shown otherwise, we believe that any responses to public comments will be drafted to justify a decision already made as rather than to inform a decision that is still pending before the agency.

We continue to call upon EPA to hold its own public comment period and to ensure that any public comments received by EPA or DEQ, including any data or views offered by members of the public, are fully considered and addressed during the federal agency's decision-making process.

EPA – and WQD – Cannot Legally Grant an Aquifer Exemption in this Case

The primary purpose of the SDWA, as carried out through its implementing regulations, is to protect underground sources of drinking water. 42 U.S.C. § 1421(b)(1)(B); SDWA § 300h(b); H.R. Rep. No. 93-1185, 120 Cong. Rec. 6454, 6480 (1974); *Western Nebraska Resources Council v. EPA*, 793 F.2d 194, 195-196 (8th Cir. 1986). The Act's requirements for protecting underground sources of drinking water are found in Section 300h. Specifically, the Act provides that drinking water programs have requirements that, at a minimum, assure that no underground sources of drinking water will be endangered by any underground injection of fluids and chemicals. SDWA §§ 300h(b)(1), 3(C). Therefore, EPA or state programs cannot permit injections that will endanger drinking water sources. 42 U.S.C. § 1421(b)(1)(B).

This general principle is embraced by EPA's regulations governing aquifer exemptions. According to EPA's regulations, EPA or a delegated state cannot approve an aquifer exemption if the aquifer is currently being used as a drinking water source *or* has the potential to be used in the future as a drinking water source.

The regulations clarify that exempted aquifers "are those which would otherwise qualify as 'underground sources of drinking water' to be protected, *but which have no real potential to be used as drinking water sources.*" 40 C.F.R. § 144.1(g) (emphasis added); *see also* 45 Fed. Reg. 33,290, 33,328, 33,330 (May 19, 1980) (an exempted aquifer is an aquifer or portion of an aquifer that would otherwise qualify as a USDW, but has no actual potential for providing drinking water).[4]

According to the public notice for this comment period, WQD is proposing to exempt the aquifer in question because the aquifer "cannot now and will not in the future serve as a source of drinking water because" the formation contains minerals that considering their quantity and location are expected to be commercially producible. *See* 40 C.F.R. § 146.4(b)(1).[5] However, none of these criteria have been met.

1. The Formation Does Not Contain Commercially Producible Minerals

First, the formation does not contain commercially producible minerals. During cross-examination at the EQC hearing, Linc and WQD testified that the mineral they are considering to be commercially producible is coal,[6] because the ultimate product of syngas is not naturally occurring within the aquifer. Coal at the depth and location of the coal-bearing aquifer at issue here is not commercially producible. The coal cannot be mined and brought the surface economically using any mining technique currently in practice. Unlike aquifer exemptions granted for uranium mining – where uranium is the product that is extracted from the aquifer – here, the mineral in question is admitted to be non-producible. Linc will not be producing coal through its project. Therefore, **there are no commercially producible minerals in the aquifer**

[4] In passing the SDWA, Congress recognized the balance between aquifer protection and energy production but ultimately came down in favor of groundwater protection. *See, Phillips Petroleum Co. v. U.S. Environmental Protection Agency*, 803 F.2d at 560 (concluding that if a requirement on injecting activities is necessary to assure that underground sources of drinking water are not endangered, whether that requirement impedes mineral recovery is irrelevant because the "clear and overriding concern" of Congress in passing the Act was to assure the safety of "present and potential sources of drinking water").

[5] WQD's public notice states: "WQD believes that the area of the aquifer re-classified by WQD meets EPA's criteria for exemption because groundwater within this portion of the aquifer is not being used as a source of drinking water, and it cannot now, nor in the future serve as a source of drinking water because it contains minerals that are expected to be commercially producible, considering their quantity and location."

[6] *See also* DEQ's Public Notice for this comment period.

which would allow an aquifer exemption. This is a straightforward legal issue that the WQD and EPA should resolve in favor of denying the aquifer exemption.

However, even if WDQ considers the syngas product to be the "mineral" that will be produced – which the agency should not because of Linc and DEQ's admission that the mineral they are basing their aquifer exemption on is coal – the research and development project proposed by Linc will not produce syngas in commercial quantities.

While the company *estimates* that "approximately one million standard cubic feet per day (MMscfd) of synthesis gas or 'syngas'" will be produced during the demonstration project, Linc Application at 13.14-3, all syngas will be flared and not commercially sold. Linc has not demonstrated that an amount of one MMscfd is production in commercial quantities. In fact, one of the main purposes of the research and development scale project is to evaluate the economic viability of the process in the Powder River Basin and determine whether commercial projects are even a possibility in the future. In its application, Linc did not present any information demonstrating that production of syngas from its project would be commercially viable.

As further evidence of the trial, non-commercial, nature of this project, Linc will not pay royalties on its state lease during the research and development project. *See* Wyoming Office of State Lands and Investments, *Consideration of Royalty Valuation of Coal Extracted During Underground Coal Gasification (UCG) Production and Other Lease Terms for Linc Energy*, Dec. 6, 2012, at 2, available at http://slf-web.state.wy.us/osli/boardmatters/2012/1212/f-7.pdf. The State Land Board authorized royalty free disposition of the coal extracted during the R&D "demonstration project," because only "1000 tons of coal will be extracted during the demonstration; no product will be sold." If no product will be sold, Linc has explicitly admitted that no commercial product will be produced from its project.

While EPA's guidance on aquifer exemptions speaks to test projects being used as a basis for assessing whether commercially producible minerals are present in the aquifer, the guidance does not speak about the case here – where Linc does not yet have results from a test project. At this time, Linc has no basis for asserting that minerals present in the aquifer are expected to be commercially producible. WQD's Statement of Basis (part of Linc's permit application) contains only general descriptions of the UCG process and does not speak specifically to the commercial production potential of the minerals present in *this* coal-bearing aquifer. *See* Statement of Basis at 2-3.

As further evidence of the lack of proof of the commercial viability of UCG, the Linc representative at the EQC hearing testified that at this time the company has no plans to develop a commercial-scale project at this location or anywhere in the Powder River Basin.

No previous UCG projects – including Linc's own multi-year projects in Australia[7] – have reached commercial scale. As admitted by Linc and DEQ during the EQC hearing, UCG is still an unproven technology and questions remain regarding its commercial and economic

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[7] See Statement of Basis at 3, which refers to Linc's Chinchilla project as a "demonstration facility."

feasibility, especially with new market conditions such as the glut of natural gas in the U.S. of much higher quality than the syngas that will be produced by UCG.

According to UCG reports, previous projects have – at most – produced 350 Btu/cf gas. Most projects, especially those using subbituminous coals like Linc is proposing to use here, produced from 150 to 250 Btu gas.[8] In contrast, shale gas formations typically produce over 1,000 Btu/cf gas, with minimal processing and remediation costs.[9] It is telling that past UCG test projects in the United States were carried out before the shale gas boom. If gas is the "mineral or hydrocarbon" used as the basis for the aquifer exemption, Linc must demonstrate that its gas product will be commercially producible. Here, Linc cannot make that demonstration, especially given competing nearby shale and tight sands gas production that is already being produced at commercial scale ancillary to unconventional oil wells in the Powder River Basin. Locally, Linc's project would also be competing with coalbed methane gas production, a source that demonstrates how difficult it is for lower quality gas to compete with the higher quality unconventional gas resources on the market today.

Although Linc apparently hopes that produced syngas might become commercially economic when it is used in a downstream application, such as converting it to liquids,[10] merely producing the syngas is clearly not economic at a commercial scale. Linc cannot use a further converted product as the basis for its commercial demonstration because that product is not present in the aquifer in commercially producible quantities any more than is syngas. Regardless, after over a decade of work in Australia, Linc has still not demonstrated that liquids conversion technology is economically viable at a commercial scale.[11]

Therefore, Linc has not demonstrated – and WQD cannot determine – that there are "minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible" from the aquifer. This is a basic requirement of the aquifer exemption and is not met in this case.

2. The Formation Does Contain Water Capable of Being a Future Source of Drinking Water

Equally important is that the mineral in question – coal – does not prevent the aquifer from being a future source of drinking water. As discussed above, because the Safe Drinking Water Act prevents contamination of underground sources of drinking water, an aquifer exemption can be approved only if the aquifer has no real potential to serve as a drinking water

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[8] For instance, Arco Coal Company's 1978 test project 45 miles southeast of Gillette produced 200 Btu/scf syngas.

[9] *See* http://www.pipelineandgasjournal.com/shale-gas-measurement-and-associated-issues?page=show; http://www.eia.gov/dnav/ng/ng_cons_heat_a_epg0_vgth_btucf_a.htm

[10] *See* http://www.lincenergy.com/data/info_sheets/Syngas_in_the_Modern_Energy_Mix.pdf; *see also* Statement of Basis at 3, discussing the commodity products that can be produced, such as fuel products.

[11] Linc's gas-to-liquids plant at the Chinchilla site is still operating at a pilot scale. *See* http://www.lincenergy.com/underground_coal_gasification.php.

source. See 40 C.F.R. § 144.1(g). Stated another way by David Murry, a Senior Geologist and Project Manager with the Texas Commission on Environmental Quality:

> Until the quality of the ground water is restored and the exempt status is removed, *water will not be used for drinking because of its mineral or geothermal character*, its depth or location, or its pre-existing contamination renders it impractical for treatment to make it fit for drinking.

David Murry, *Class III In Situ Uranium Injection Wells and Aquifer Exemptions in Texas: Multiple Levels of Permitting Protection for USDW Protection*, available at http://www.gwpc.org/sites/default/files/event-sessions/Murry_David.pdf (emphasis added).

Federal regulations use the word "because" not "if." 40 C.F.R. § 146.4(b). Therefore it must be demonstrated that the aquifer cannot be used as a future drinking water source *because* the aquifer contains minerals.[12]

Here, WQD cannot demonstrate that cause/effect relationship because it does not exist. The proposed aquifer exemption should be denied because the aquifer can be used in the future as a source of drinking water and the presence of coal does not render the aquifer unusable. To the contrary – coal-bearing aquifers are regularly used – and are sometimes preferred – as drinking water sources.

In fact, during testimony at the EQC hearing, WQD staff admitted that the quality, quantity, and location of the water all make the aquifer a potential future drinking water source. According to WQD's own statement of basis for the aquifer exemption, **the aquifer could be classified as a Class I drinking water aquifer**. To our knowledge, no aquifer of this quality has ever been exempted in Wyoming.

While some minor constituents (iron, manganese, and TDS)[13] slightly exceed drinking water standards, overall "WDEQ can classify the water as Class I based on the technical practicability and economic reasonableness of treating ambient water quality to meet use suitability standards." Linc Application at 13.14-6. The aquifer actually has a lower TDS concentration than many other portions of the Fort Union Formation that are currently used for drinking water purposes.

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[12] While one could read the regulation the opposite way to conclude that an aquifer is not a future source of drinking water merely *because* minerals are present, that reading would frustrate the purpose of the SDWA and the implementing regulations. The purpose and intent of the SDWA is to protect aquifers that have the potential to be used for drinking water sources.

[13] All three of these constituents have only secondary standards from EPA. Secondary standards apply to substances in water that can cause offensive taste, odor, color, corrosion, foaming, or staining but have no direct effect on health. As DEQ's statement of basis acknowledges, all three constituents are easily treated to come into compliance with the secondary drinking water standards.

As evidence of the aquifer's good quality water, the aquifer was – up until a very recent time – used for livestock watering. As identified by Linc, there are wells permitted for livestock watering purposes within the quarter mile buffer required to be evaluated by WQD and EPA. *Guidance for Review and Approval of State Underground Injection Control (UIC) Programs and Revisions to Approved State Programs #34* at 2 ("the applicant should survey the proposed exempted area to identify any water supply wells which tap the proposed exempted aquifer. The area to be surveyed should cover the exempted zone and a buffer zone outside the exempted area. The buffer zone should extend a minimum of a 1/4 mile from the boundary of the exempted area.") While these wells may currently be shut-in, Statement of Basis at 5, they are nevertheless evidence that the formation is capable of producing – and previously did produce – good quality water.

3. The Aquifer Does Have Water at a Depth, Location, and Quantity to Make it a Viable Source of Underground Drinking Water

WQD's public notice only references the 40 C.F.R. § 146.4(b)(1) criteria of commercially producible minerals and hydrocarbons. Additionally, WQD's Statement of Basis speaks only to that criteria. Statement of Basis at 1. Therefore, if WQD – or later, EPA – decides to base its aquifer exemption decision on any other criteria in 40 C.F.R. § 146.4, the agencies must reissue public notice and hold an additional comment period on the proposed other criteria.

Nevertheless, in the interest of efficiency, our organizations are providing information to the agencies which demonstrates that none of the other criteria in 40 C.F.R. § 146.4 are met. We believe this is especially important in light of the EQC's order that bases its decision to affirm the aquifer exemption based on a different criterion: that "The aquifer in the license area will not in the future serve as a source of drinking water because it is not economically feasible." EQC Order at 6.[14] However, DEQ, the EQC, and Linc have not proffered any information that demonstrates this criterion is met.

First, the aquifer is located at a depth of 1,100 feet. Statement of Basis at 4. This is a relatively shallow formation for the Powder River Basin and it is both economically and technologically practicable to produce drinking water from this depth. Nearby domestic and municipal wells are drilled at comparable depths or at even greater depths.

Second, the location of the formation does not render it economically infeasible to produce for drinking water purposes. As Linc is well aware, the state section is located immediately adjacent to a county road with easy access to the area. If a grazing lessee or nearby landowner (or municipality) wanted to lease the area and permit a domestic or livestock well, the location would not create any barriers.

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[14] Although it was not specified in the EQC's Order, we assume the EQC was applying the 40 C.F.R. § 146.4(b)(2) criteria: "[the aquifer] is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impracticable."

Third, the quantity of the water is sufficient to be produced for drinking water purposes.[15] Testimony for WQD staff at the EQC hearing referred to EPA guidance that holds that water in the quantity present in the aquifer can be used as a USDW.

While Linc claims that water in the formation has been significantly reduced because of previous coalbed methane development, Linc has not demonstrated that this drawdown renders the aquifer unsuitable for future drinking water purposes. Notably, Linc did not include any information in its application about the possibility of groundwater recharge after coalbed methane development ends

The Wyoming State Geological Survey published an updated report on groundwater levels in the Powder River Basin in 2013. The report, <u>2012 Coalbed Natural Gas Regional Groundwater Monitoring Update: Powder River Basin, Wyoming, Open file report 2013-01</u>, documents the groundwater drawdown and recovery rates in the coal-bearing aquifers in the Fort Union Formation. The report at page 166 documents a monitoring well close to the Linc project in Section 14 of 44N R72W. The report documents recovering groundwater levels in this monitoring well after CBM dewatering. This particular monitoring well shows some of the greatest recovery rates with groundwater levels in the Wyodak coal rising 167.37 feet in the 2010 to 2012 monitoring period, after significant declines caused by CBM. (Over the 1998 to 2012 monitoring period, water levels in this well declined 548 feet.)

Because the permeability of Fort Union coal seams is widely accepted, the potential for recharge should be acknowledged. Current groundwater levels and pressures (presumably impacted by recent CBM activities) do not necessarily reflect conditions in the distant future. Even of no further recharge occurs, groundwater levels are presently sufficient to constitute a viable underground source of drinking water.

In your response to comments, please fully disclose whether DEQ or EPA will consider depth, location, and quantity issues in assessing whether the aquifer contains water that can be economically and technically produced. If you are relying on any of those criteria, please reissue the public notice disclosing that and accept additional public comment on that issue.

At the very least, WQD must fully assess current production capabilities of the aquifer and future capabilities, given recharge of the aquifer over the long-term.

Linc Has Not Demonstrated that Any Contaminated Water Will Remain Within the Exempted Area

Even if WQD believes the criteria for an aquifer exemption have been met – which they have not – WQD should deny the aquifer exemption because neither Linc nor WQD has affirmatively ensured that contamination from the project will remain within the exempted portion of the aquifer.

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[15] EPA's aquifer exemption criteria does not mention formation yield. *See supra* note 14. However, Linc's expert at the EQC hearing inferred that the formation yield would make it impractical to use for drinking water purposes.

EPA's guidance documents make it clear that in evaluating whether the aquifer "does not currently serve as a source of drinking water . . . [i]f the exemption pertains to only a portion of an aquifer, a demonstration must be made that the waste will remain in the exempted portion." EPA, *Guidance for Review and Approval of State Underground Injection Control (UIC) Programs and Revisions to Approved State Programs #34*, Attachment 3 at 3, available at http://www.epa.gov/ogwdw/uic/pdfs/guidance/guide-memo_guidance-34_review_state_prog.pdf.

The Statement of Basis speaks generally to "Hydraulic Containment," page 13-14, but does not go into great detail. As discussed above, establishing that hydraulic containment can happen during UCG operations is a key component of the test nature of this project. As Linc states, "One of the research and development objectives of the project is to refine techniques and procedures to establish hydraulic control." Statement of Basis at 13.

Because of the experimental nature of its project and the inherent risks and unknowns of the UCG process, as explained above, Linc has not definitively shown that contamination will remain in the exempted portion of the aquifer.

Linc's Monitoring Program Is Not Sufficient

About a third of the Statement of Basis is devoted to describing Linc's proposed groundwater monitoring plan. Statement of Basis at 14-22. We are concerned that Linc's monitoring program does not account for the heterogeneous nature of the coal-bearing aquifer, including fractures, cleats, and other characteristics of the Wyodak seam. This issue is more fully addressed in the report from Stratus Consulting, attached to separate comments from our organizations.

Please fully review Linc's proposed monitoring program in light of the Stratus Consulting report. We believe additional monitoring wells are needed, especially given the test nature of this project. The monitoring program must be robust enough to assure the public that the project occurred safely and without excursions or long-term contamination of the coal-bearing aquifer or overlying or underburden aquifers adjacent to the coal-bearing aquifer.

Concerns about Bonding and Financial Assurance

Our organizations are also concerned about financial assurance for this project. Bonding should be in a sufficient amount to allow a third-party contractor to come in and fulfill all of Linc's obligations related to decommissioning and restoration. Former DEQ staff members who were involved in the review of this project have told us that there was a dispute between the Sheridan DEQ Office and the Cheyenne DEQ Office about the bond amount, with the Sheridan staff recommending a much higher amount than was authorized by the Cheyenne staff.

The WQD should independently review the financial assurance obligations, with an eye towards fulfilling monitoring, decommissioning, and restoration obligations laid out in WQD's statement of basis for the aquifer exemption.

A review of the financial assurance for this project is especially necessary given Linc's corporate fluctuations. Some information we found on the internet shows that Linc had a large net loss last year and with the Australian government's efforts after the ISP Report was released, they removed their company from the Australian Stock Exchange and are now listed on the Singapore Stock Exchange.

In your response to comments please fully disclose any financial reviews of the company (especially its Wyoming or other assets that guarantee fulfillment of its monitoring, decommissioning, and restoration obligations) carried out by DEQ and explain how DEQ derived the bond amount that it did. Please explain fully why DEQ believes that bond amount to be sufficient. If it is not found to be sufficient, please raise it.

As you know, our organizations are very concerned about outstanding public financial liability for orphaned wells and other failed projects over the years in the Powder River Basin. We do not want this to be another sorry example.

This Aquifer Exemption Is Precedent-Setting and Should be Considered a Major Revision to the State's Implementation of the SDWA

Reclassification and exemption of this portion of the Fort Union Formation would set a dangerous precedent. In response to an inquiry from our organization, Don Fischer, the DEQ North District Geologic Supervisor, stated that "To the best of my knowledge, there are no aquifer exemptions for UIC Class I or III facilities in the Ft. Union Formation in Johnson or Campbell counties." Electronic correspondence from Don Fischer to Shannon Anderson, Oct. 11, 2013. Therefore, Linc's aquifer exemption would be the first of its kind in the Fort Union Formation.

If Linc is able to obtain an aquifer exemption in this case merely because of the presence of coal, the decision opens the door for future exemptions in other portions of the Fort Union Formation, which is a coal-bearing formation across the Powder River Basin. As identified by the report prepared for the Wyoming Business Council "307 billion tons of coal, or 74% of the coals deeper than 500 feet" in the Powder River Basin are viable sources of coal for UCG projects. GasTech report at 3. If Linc is successful, the entire portion of the Fort Union Formation bearing those coals could be exempt from SDWA protection.

The precedent-setting nature of this aquifer exemption is especially important given that Linc is a leaseholder of coal resources underlying 333 state sections in the Powder River Basin. Under DEQ's logic, if Linc obtains an aquifer exemption here, DEQ (or later, EPA) would be virtually prevented from denying an aquifer exemption for any of the other 332 coal-bearing aquifers, with the only exception being if there are domestic water wells in the immediate area currently producing from that formation. This is an absurd result, and one that runs contrary to the SDWA's mandates of protecting aquifers that are capable of being *future* sources of drinking water.

Additionally, the proposed reclassification of the aquifer is even more problematic, as the reclassification is not dependent on a company meeting the requirements for an aquifer exemption. Reclassifying an aquifer that has drinking water quality water (Class I water) to "Mineral Commercial" quality water (Class V water) merely because the aquifer is "closely associated with commercial deposits of minerals," Linc Application at 13.14-6, sets a particularly troubling precedent. Most aquifer formations in the Powder River Basin, and in fact across the state, have some "commercial deposits of minerals."[16] The reclassification would set a bad precedent that other industries could use to their advantage to limit the protection and restoration of aquifers. For instance, under Linc's rationale, WDEQ could reclassify all of the shallow coal seams of the Fort Union Formation that are surface mined or the deeper coal seams that produce coalbed methane. That would amount to almost the entire Fort Union Formation.

In essence, under WQD's proposal, the Fort Union Formation could be reclassified from an aquifer that is THE major source of drinking water in the Powder River Basin to an aquifer that is merely used for mineral production.

For all of the above stated reasons, WQD and EPA cannot lawfully reclassify and exempt the aquifer.

Sincerely,

R LeResche

Bob LeResche
Powder River Basin Resource Council Treasurer
Chair, Western Organization of Resource Councils Coal & Climate Task Force

Attachments: 1) Comment letter from Timothy Moore (included in the state administrative record as PRBRC Exhibit 4*); 2) Petition from Campbell County landowners (included in the state administrative record as PRBRC Exhibit 5); Comment letter from Mr. and Mrs. Gary Marquiss, *et al.* (not considered as part of the state administrative record); and 4) Queensland Independent Scientific Panel Report on Underground Coal Gasification Pilot Trials, June 2013

*Please fully consider all of the exhibits and legal filings we submitted at the EQC hearing, as well as the transcript for the proceeding, as part of the administrative record for this aquifer exemption.

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[16] As discussed above, Linc has not demonstrated that this formation contains commercially producible coal deposits. However, Linc and other companies routinely argue that any mineral reserves can be considered commercial deposits.

To Whom It May Concern:

I am a landowner adjacent to the Link Energies Project on Section 36, Township 44, Range 74 in Campbell County, Wyoming. I very strongly object to any Coal, Oil, Gas or Mineral/Energy Company being exempt from their responsibility to keep our water and environment clean and safe. Therefore, I am totally against the Aquifer Exemption they are applying for.

Sincerely,

Timothy M. Moore

Timothy M. Moore

320 A. Moore Road

Gillette, WY 82718

We, the undersigned landowners, depend upon groundwater wells in the Fort Union formation in the Powder River Basin for our livestock and domestic water wells. We recently learned that the Wyoming DEQ recommended an aquifer exemption be granted for the Fort Union formation in conjunction with a permit for an exploratory underground coal gasification project proposed by an Australian company, Linc Energy. The Fort Union formation is the most important aquifer in the Powder River Basin supplying drinking and livestock water. We oppose this aquifer exemption and believe it is a violation of the Safe Drinking Water Act and that this action will set a precedent that will lead to the contamination and loss of an important and dwindling groundwater resource in the Powder River Basin.

NAME	ADDRESS
Bernadette Barlow	1625 Buffalo cut across Gillette WY 82718
Nancy Sorenson	7241 U.S. Hwy 14-16, Arvada, Wy 82831
Leland J. Turner	606 Turnercrest, Gillette Wy 82718
Judith Leggitt	Box 4272 Gillette WY 82717
Diane Ernst	304 N. 4th St. Gillette, WY 82716
Gary Packard	2897 tippery arvada Wy 82831
Edward A. Smartz	PO Box 1539 Gillette, WY 82717
Loretta Dowling	2409 Kristan Avenue - Gillette, WY 82718
Marjorie West	628 S.A. Rd. Arvada, Wy 82831
Bill West	628 S.A. Rd. Arvada, Wy. 82831
Sandra Stewart Holcyak	P.O. Box 314 Recluse Wy 82725

We, the undersigned landowners, depend upon groundwater wells in the Fort Union formation in the Powder River Basin for our livestock and domestic water wells. We recently learned that the Wyoming DEQ recommended an aquifer exemption be granted for the Fort Union formation in conjunction with a permit for an exploratory underground coal gasification project proposed by an Australian company, Linc Energy. The Fort Union formation is the most important aquifer in the Powder River Basin supplying drinking and livestock water. We oppose this aquifer exemption and believe it is a violation of the Safe Drinking Water Act and that this action will set a precedent that will lead to the contamination and loss of an important and dwindling groundwater resource in the Powder River Basin.

NAME	ADDRESS
Robert Sorensen	7241 H/W 14-16 Arvada, Wy 82801
Claiborne K. Rowley	1709 SAGEBRUSH DR., SHERIDAN, WY 82801
Gayle J Rowley	1709 Sagebrush Dr. Sheridan, WY 82801
LeRoy Van Buggenum	246 N. Piney Rd, Story Wy 82842
Beckie Spellman	PO Box 460 Buffalo WY 82834
Bob Spellman	" " "

Environmental Quality Council
122 W. 25 Street Herschler Bldg. Rm 1714
Cheyenne, Wyoming 82002

To whom it may concern:

We write to you with very real concerns in regards to the experimental coal gasification site proposed by Linc Energy in southern Campbell County.

Our family lives and depends on the family ranch, The Little Buffalo Ranch located near this site. Our Grandfather R.B. Marquiss homesteaded this property in the early 1900's. There have been years of prosperity and many years of struggling financially but four generations of the family have been good stewards of the business and the property throughout those years. The point being, that long-held ranch properties such as this have been the foundation of Wyoming and its economy and hopefully in years to come-long after the energy boom. Such livelihoods are being threatened by potential and irreversible damage to important water sources; the Ft. Union aquifer.

The Hoe Creek project gasified about 6,500 tons of coal in 1976, 1977 and 1979. Ground water testing afterward revealed contaminants, including benzene, toluene and ethylbenzene, at the Hoe Creek site. Aquifer restoration work began in 1989 and was deemed complete in 2012 (according to the Department of Environmental Quality). The Department of Energy's estimate of cleanup costs were $10 million and it took 23 years.

Now the same Wyoming Department of Environmental Quality has deemed this application from Linc Energy ok and forwarded it to the US Environmental Protection Agency for exemption under the Safe Drinking Water Act. This is irrational and irresponsible.

A project of this magnitude with so many unknowns and risks would affect not only our ranch but many in southern Campbell County and perhaps the city of Wright. No one is able to predict how widespread the effects could be.

The very fact that this company/ entity is requesting a release of liability should be a red flag to our state and to the government agencies that are suppose to be protecting our environment and its citizens.

We are asking that you consider very carefully your decision on this matter. Know that this decision carries with it serious consequences and could effect many lives, livelihoods and Wyoming's beautiful and pristine environment.

With respect,

Mr & Mrs Gary Marquiss
Mr & Mrs Trigg Marquiss
Mr & Mrs Kerry Clark
Mr Twister Marquiss
Mr Merritt Marquiss
Ms Stephanie Anesi
Ms Stacy Marquiss
Mr & Mrs Tait Marquiss
Mr & Mrs Erick Mares
Mr Quinn Clark
Bentley Marquiss
Trigg B Marquiss
Josie Mares
Carly Mares
Mr & Mrs George Rials
Laurie M Jarina
Mr & Mrs Charles Rials
Gavin Rials

copy: Powder River Basin Resource Council

INDEPENDENT SCIENTIFIC PANEL REPORT ON UNDERGROUND COAL GASIFICATION PILOT TRIALS

June 2013

Queensland Independent Scientific Panel for Underground Coal Gasification (ISP)

Professor Chris Moran, Director, Sustainable Minerals Institute, The University of Queensland.

Professor Joe da Costa, School of Chemical Engineering, The University of Queensland.

Em. Professor Chris Cuff, C&R Consulting, Townsville Queensland.

Acknowledgements

The Independent Scientific Panel (ISP) has worked on a part-time basis to provide advice to government on the underground coal gasification (UCG) trials currently underway in Queensland. The ISP has worked with a number of government departments and the two companies, Linc Energy and Carbon Energy, to assess company data and reports and to design a process for reporting the essential outcomes of the investigations of the companies without breaching their confidentiality.

The members of the ISP would like to express their gratitude to the government officers who assisted at various stages throughout the process. They would also like to thank staff of Carbon Energy and Linc Energy who approached the reporting process with a positive attitude. At various times, the ISP, government officials and company members have been challenged with changing external context, e.g., environmental evaluation, changing staffing in government and companies and a state election.

The reports produced by Linc Energy and Carbon Energy are amongst the most thorough compilations of information on any UCG pilot trials to date. A great deal of useful information and lessons are incorporated into the reports. It is not possible to do justice to the quantity of technical information provided by each of the companies in a summary set of recommendations. No doubt, over time, the companies will see fit to release at least some of this technical information into the public domain so that others are able to make their own assessments of the merits and risks associated with UCG.

The ISP initially reported to government in confidence in November 2012. Government considered that report, consulted the two companies concerned and concluded that a review process should be undertaken. Terms of reference for the review are appended. The Queensland Chief Scientist convened a review panel consisting of Dr Steve Ward (Department of Natural Resources and Mines), Professor Paul Greenfield AO and Dr Geoff Garrett AO (as chair). Under the terms of reference the Chief Scientist also considered expert advice and input from Professor Robin Batterham AO, who had also previously provided independent scientific advice to both Carbon Energy and Linc Energy. The group was convened in June 2013 with the chair of the ISP, Professor Chris Moran and a technical representative of each of the two companies, to work towards referenced term 7. Following subsequent consultation with the ISP, this document is the result of the review process.

Executive Summary

Underground coal gasification (UCG) is a technology that has been in use in various forms for many decades. Queensland is possibly currently leading the world in UCG technology development and testing. The Queensland government needs to come to a conclusion regarding UCG in the context of its broader energy policy in the medium and longer terms. A great deal of coal that is economically inaccessible to mining (too deep or poor quality) and from which coal seam gas will have been extracted could potentially be a source of syngas in the future.

The Queensland government approved three UCG trial sites over a period of years with a view to making their own assessment. The Independent Scientific Panel (ISP) was established to assist government with these assessments. The main roles of the panel were to apply individual and collective expertise to analyse, assess and evaluate various technical and environmental factors and to report the outcomes of the trial activities including recommendations on the prospects and future management of UCG in Queensland.

The two companies that have provided pilot trial reports that are the subject of this assessment are Linc Energy and Carbon Energy. Both companies have developed versions of the controlled retracting injection point (CRIP) technology. The reporting process was designed around the combination of the operational life cycle (site selection -> commissioning -> operation -> decommissioning -> rehabilitation) and a conventional process industry risk assessment. Both companies have used their extensive technical databases, which have been gathered from experience of a number of gasifiers with evolving technologies. The integration of technical data into the necessary risk assessment is an important challenge in the process.

Both companies have demonstrated capability to commission and operate a gasifier. Neither company has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. The ISP remains open to the possibility that the concept is feasible. However sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. Important work has been undertaken but more is yet to be done. For example, neither company has gained access to a gasified cavity, sampled it and provided information on the current contents and condition of surrounding materials.

At mid-2012, neither company had completed a burn of sufficient duration to create a final cavity of the dimensions that are expected under a commercial process. Until this is done it is difficult to come to a final conclusion regarding the technology. Given this situation, the ISP believes it would be pre-emptive to consider commercial scale. However, given the considerable investment by the companies and Queensland government to date, and the undoubted future importance of UCG as a viable energy source of global significance, the ISP is of the view that the gasifiers currently operating should be permitted to continue until a cavity of significant dimensions is available for full and comprehensive demonstration. At that time, commercial scale UCG facilities could be considered. There is more work to be done on the design and environmental and operational safety for multi-panel operations.

Given the pilot project reports presented, the ISP has come to three overarching recommendations and eight (8) specific recommendations. The latter cover each of the life cycle stages (5), the interaction between CSG and UCG (1) governance (1) and the question of commercial multi-panel operations (1).

Following consideration of the materials made available to the ISP from companies and in the public domain, the ISP has come to the following overall conclusions.

- Underground coal gasification could, *in principle*, be conducted in a manner that is acceptable socially and environmentally safe when compared to a wide range of other existing resource-using activities.
- The ISP is of the opinion that for commercial UCG operations in Queensland *in practice* first decommissioning must be demonstrated and then acceptable design for commercial operations must be achieved within an integrated risk-based framework.

Consequently, the ISP makes the following three (3) overarching recommendations.

Overarching recommendation 1.

The ISP recommends that the Queensland government permit Carbon Energy and Linc Energy to continue the current pilot trials with the sole, focused aim of examining in a comprehensive manner the assertion that the self-cleaning cavity approach advocated for decommissioning is environmentally safe.

Overarching recommendation 2.

The ISP recommends that a planning and action process be established to demonstrate decommissioning. Successful decommissioning needs to demonstrate the self-cleaning process and/or any necessary active treatment. To achieve this:

1. *A comprehensive risk-based plan for decommissioning must be produced;*
2. *The Plan must take account of the fact that both companies now have connected cavities suitable for demonstration [Linc Energy is still gasifying];*
3. *The Plan must include at a minimum a conceptual model and relevant numerical models, a sampling and verification/validation strategy, and event-based milestones that, where possible, are time bound.*
   Two significant phases are recognised:
   a. *Sampling of the zone surrounding the cavity; and*
   b. *Direct cavity access.*
4. *The government must establish a process by which the plans and their implementation are assessed for adequacy.*

Overarching recommendation 3.

The ISP recommends that until decommissioning is demonstrated, as per Overarching Recommendation #2 no commercial facility should be commenced.

Specific Recommendations

Specific recommendation #1

The government together with the UCG industry and an independent advisory body, should develop guidelines and standards for site selection. The ISP recommends that site selection is a process that should be preceded and informed by appropriate geological surveys, hydrogeological modelling and an assessment of the community and environmental context. Such assessments must serve as Go / No Go gates for decision to develop or not any site for UCG operation, i.e., any limiting factor should signal No Go for the site.

Specific Recommendation #2

The ISP recommends that for each new panel, the UCG industry adopts a 'commissioning' approach rather than 'start-up' or 'ignition' regardless of size or multiplicity, to reduce the risks associated with this phase. Commissioning should involve world's best practice for risk management in process industries including HAZOP, fault tree analysis, event tree analysis, LOPA including all the controls to ensure that the inherent risks of UCG activities are minimised from the outset.

Specific Recommendation #3

If the UCG reaction has been extinguished, then restarting the panel should follow the pre-defined risk protocols. If restart is deemed unacceptable the process should proceed directly to decommissioning and rehabilitation.

Specific Recommendation #4

No further panels should be ignited until the long term environmental safety provided by effective decommissioning is unambiguously demonstrated. Evidence of the effectiveness of decommissioning must be comprehensive.

Specific Recommendation #5

The companies should immediately propose, test and establish acceptable and agreed processes and outcomes for rehabilitation.

Specific Recommendation #6

The ISP recommends that any UCG operation should be licensed on the basis that it is responsible for maintaining and controlling all its operating conditions, taking into account the conditions of the site at the time of approval, including maintenance of groundwater pressure.

Specific Recommendation #7

The government should consider establishing two new entities to support a UCG industry at the level necessary to ensure its best chance to be environmentally, socially and economically viable.

1. Queensland UCG Independent Assessment, Evaluation and Advisory Group.
2. The Queensland UCG R&D Network.

Specific Recommendation #8

A commercial operation should be designed from the outset on a foundation of well-established principles i.e. a risk-based approach from the outset in all phases of the life-cycle of multi-panel operation.

The Carbon Energy and Linc Energy sites have been operated as pilot sites. Any consideration of commercial activity should be preceded by a comprehensive, multi-panel, risk-based plan.

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1 Preamble

The Terms of Reference for the Scientific Expert Panel, Underground Coal Gasification Policy Implementation were defined in Version 1.4 of September 2010. This document stated (*inter alia*) that "While the Report will consider the benefits and costs of a potential UCG industry in relation to its environmental, social and commercial impacts, the panel will focus on the technical and environmental aspects of the UCG technology."

The Independent Scientific Panel (ISP) has examined the materials from the two pilot projects in the light of background information from international experiences. The information used on the two pilot projects included:

- Final summary reports and associated appendices;
- Company performance during the environmental evaluation process; and
- Company interactions during the ISP process development and carriage.

In this report the ISP takes the view that the UCG trials on which it has received information are *pilot trials*. This is distinguished from the term *demonstration trials* in that the latter would imply that the technology for all phases of the life cycle is well understood and that the single cavity/panel[1] trials are to demonstrate the scale-up for commercial UCG facilities. The ISP does not accept that the information supplied, the manner in which it has been supplied and the overall design of the pilot underground facilities warrants assessment as demonstration trials. As such, it is important that as many lessons as possible are drawn from the pilot trials to allow the companies the opportunity for future demonstrations to provide confidence, that an environmentally safe and socially acceptable process can be established that is economically viable.

In keeping with the individual confidentially agreements signed by each member of the ISP with the companies, this report does not necessarily include technical information and data. The technical supporting evidence for the recommendations made has been obtained from detailed consideration of the technical material provided.

[1] Throughout this report the terms "panel" and "cavity" are used to refer to the underground void created by UCG. It is recognized that a panel refers to a specific design and a cavity is a more general term. Attempts have been made to use the term panel when reference requires implied information about the design and therefore some likely features of the cavity. Otherwise the term cavity has been used. The ISP recognizes that this may be an imperfect separation of the terms and their use.

The ISP has taken a life cycle approach to its considerations. The life cycle for UCG that has been adopted is shown in **Figure 1.** The major phases of the life cycle are:

- Rehabilitation
- Decommissioning
- Production
- Commissioning
- Site Selection

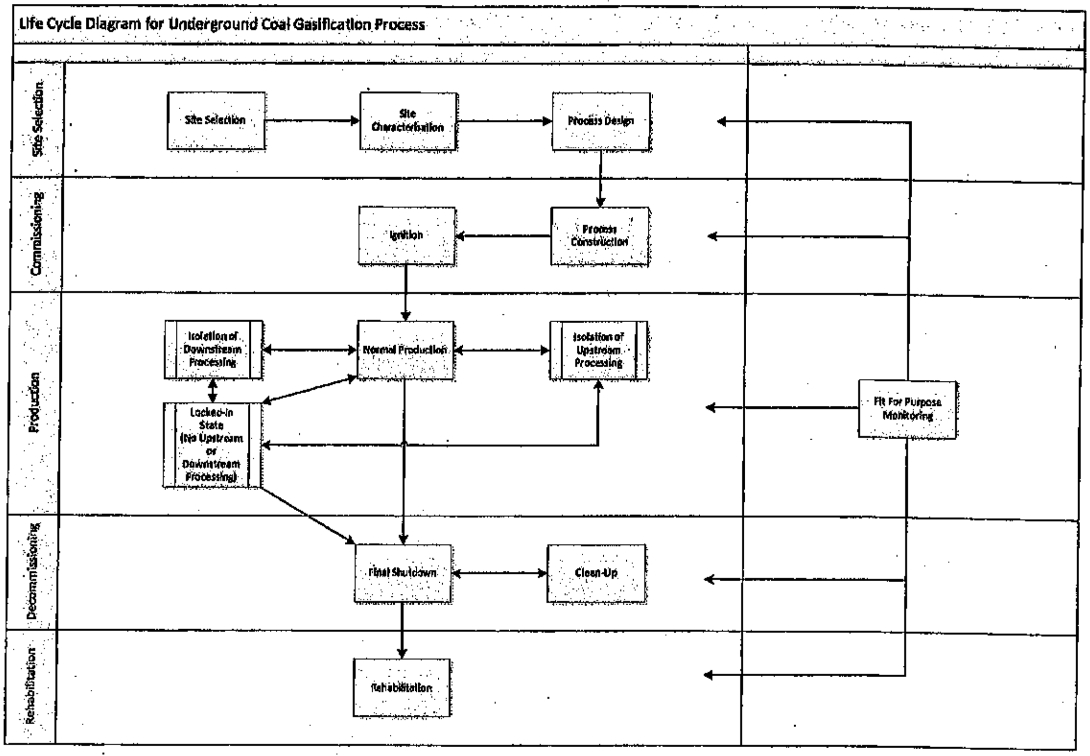

Figure 1 - Schematic of Life Cycle Stages for a UCG Plant

In assessing the pilot trials of Carbon Energy and Linc Energy it was apparent that the site selection is now historical and therefore this report deals with the critical characteristics of a site suitable for UCG and makes observations on the extent to which the Carbon Energy and Linc Energy sites meet those characteristics, i.e., a formal risk assessment approach was not considered appropriate.

For commissioning and operation, the ISP has structured its assessment around a risk assessment. The report sets out what the ISP considers to be the significant critical risks associated with these phases of the life cycle. The Carbon Energy and Linc Energy reports were assessed with regard to how well they represented and dealt with these risks and what lessons could be drawn from the experience gained to date. In general the ISP found that the company reports contained sufficient information to undertake the analyses although accessing the information was made far more difficult than it need have been because of the poor integration of data and risk assessment (see Section 4).

In contrast, for the decommissioning phase, the ISP determined that the company reports did not include sufficient information to undertake an analysis of the extent to which the proposed technologies meet the necessary risk management standards. The ISP has raised what are believed to be the major risks and outlined what would be required from the companies to demonstrate that these risks can be effectively mitigated.

No significant information has been received regarding site rehabilitation beyond general statements of similarity to other rehabilitation challenges elsewhere. Therefore, the ISP is unable to make any assessment on this life cycle stage.

Recommendations are made throughout the report and these are consolidated into a single section for ease of access. However, the ISP does not advise reading or quoting of individual recommendations out of context.

The ISP has determined that an overarching recommendation can be made regarding UCG in Queensland at this point in time and in regard to the two pilot trial sites examined herein.

The approach of using an Independent Scientific Panel to comment on the viability of pre-established and pre-approved pilot trials has been challenging for all involved. The ISP would like to acknowledge that the companies engaged in this unusual process in good faith and with cooperation at all stages. Below (Section 3) the ISP presents a critical appraisal of the reporting by the companies. It must be noted that this critique is written with respect to an ideal process. The real world is not an ideal place and the time pressures and challenges of day-to-day demands on company staff are understood by the ISP. We therefore express our gratitude for the way in which company staff worked with the ISP throughout this process.

Finally, at various times throughout the ISP process, the ISP has been challenged to understand government processes. Better integration of information flow and alignment of goals between departments would have greatly facilitated various aspects of the ISP deliberations and timeliness of reporting. The ISP understands that individuals must be given opportunities for career development as and when they arise. However, the frequent changes to the officers and secretariat supporting the ISP constrained the process from being as effective as it might otherwise have been.

The ISP is a part time role for each of the participants. We acknowledge that our inability to devote large amounts of time to the activities of the ISP has been a contributing factor in the time taken to finalise reporting. Nevertheless we accept responsibility for the shortcomings that are inevitably embedded in this report.

2 Overarching recommendations

Following consideration of the materials made available to the ISP from companies and in the public domain, the ISP has come to the following overall conclusions.

- Underground coal gasification could, *in principle*, be conducted in a manner that is acceptable socially and environmentally safe when compared to a wide range of other existing resource-using activities.
- The ISP is of the opinion that for commercial UCG operations in Queensland *in practice* first decommissioning must be demonstrated and then acceptable design for commercial operations must be achieved within an integrated risk-based framework.

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The ISP recommends that the Queensland government permit Carbon Energy and Linc Energy to continue the current pilot trials with the sole, focused aim of examining in a comprehensive manner the assertion that the self-cleaning cavity approach advocated for decommissioning is environmentally safe.

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1. *A comprehensive risk-based plan for decommissioning must be produced;*
2. *The Plan must take account of the fact that both companies now have connected cavities suitable for demonstration [Linc Energy is still gasifying];*
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   Two significant phases are recognised:
   a. *Sampling of the zone surrounding the cavity; and*
   b. *Direct cavity access.*
4. *The government must establish a process by which the plans and their implementation are assessed for adequacy.*

Overarching recommendation 3.

The ISP recommends that until decommissioning is demonstrated, as per Overarching Recommendation #2 no commercial facility should be commenced.

3 Underground Coal Gasification (UCG) – some context

UCG can be used to extract energy from coal seams that are otherwise low grade and/or too deep to economically exploit by more traditional open cut or underground coal mining methods. Injection wells from the surface supply oxidants and steam to ignite and fuel the underground gasification process. The product gas is brought to the surface via separate production wells (although one well has been used for both functions in a small number of cases). Gasification is typically conducted at a temperature between 900°C and 1200°C but may reach up to 1500°C. The process gasifies the coal and generates what is referred to as Syngas which is principally composed of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons. The proportion of these gases varies with the type of coal, the efficiency and control parameters of the gasification process. The product gas can be used for fuel for power generation, chemical feedstock, gas to liquids fuel conversion or fertiliser.

Approximately 90% of the available energy of the part of the coal seam that is incorporated by the cavity is released by the UCG process (compared to conventional open-pit technology which is ~60%).

It is important to manage oxygen flow to the coal to ensure appropriate Syngas production for the designed purpose and to avoid underground uncontrolled burning, which otherwise cannot occur because of lack of oxygen. The gasification process involves pyrolysis in various aspects of operation. Inevitably this produces chemicals that become serious contaminants if they escape the gasification cavity into the surrounding environment. The key aspect to ensuring an environmentally safe and socially acceptable UCG operation is to provide certainty of containment and/or removal of these chemicals. Therefore, an important focus of the ISP is on the decommissioning phase of the pilot UCG trials that are the subject of assessment of this report. Unambiguous evidence of clean cavities as a result of decommissioning is essential.

The ISP has not focussed on potential subsidence as this is considered to be well understood and regulated from the experiences of underground long wall coal mining.

The pilot trials in Queensland have become well known globally in the UCG community because of the longevity and quality of the work to date. The ISP has come to the view that Queensland's investment in commercial research via the pilot trials is potentially valuable to the State in the medium term.

4 Company reporting

Over the period of time the ISP has been overseeing the pilot trials and development of the pilot trial reports a great deal of change has occurred. It is clear that the companies have learned a great deal from the trials. The technical lessons are highlighted throughout this report. There has also been considerable advance in the structure and reporting of information.

However, there is more to be learned in both the technical and information areas. The ISP is firmly of the view that UCG should be treated as an industrial process and therefore operations should employ standard approaches (appropriately adapted to their particular circumstances).

Over time, each of the companies has produced information that accords with a risk-based approach. The ISP requested that pilot project reports follow the basic structure below.

1. A detailed background description of the technology (and/or technologies) being employed/tested in each trial;
2. A description of the life cycle stages of the technology;
3. An assessment of the risks associated with each stage of the lifecycle including description of hazards, pathways and receptors and proposed mitigation/control measures including levels of protection analysis. The companies were asked to supply supporting technical information to the level of detail necessary to allow the ISP to assess whether or not we were in agreement with the companies over the level of risk assigned and whether the mitigation measures were likely to be sufficient.

The ISP provided guidance to the companies in the form of a document outline and held a significant number of face-to-face meetings to assist with clarification.

The ISP was of the view that risk assessment should be used as a core integrating framework to assess the success or otherwise of the pilot trials to demonstrate the environmental and social acceptability of UCG. This is not the same as ensuring industrial quality risk assessment to operate the pilot facility. Each company took a different approach to the overall pilot risk assessment. In producing the risk assessments it is critical that headline significant risks are supported by only the information and monitoring data required to provide confidence in the mitigation and control measures proposed. The ISP found that the companies produced significant quantities of relevant information but they could have been more efficient in targeting the data provided to the threats identified. It will be important that the plans that will be delivered for decommissioning demonstrate that the integrating value of such a risk assessment has become embedded into company processes.

5 Assessment of Underground Coal Gasification Industry and Queensland Pilot Trials

5.1 Lifecycle of an Underground Coal Gasification Plant

This report is structured around the life cycle of a UCG operation. The essential stages are: site selection, commissioning, production (including temporary shutdowns for maintenance and subsequent re-starts), decommissioning and eventual site rehabilitation. Each of these stages consists of several smaller phases or operating modes, with multiple interconnections and relations as shown schematically in **Figure 1.**

5.2 Site Selection

Selection of an appropriate site for Underground Coal Gasification (UCG) operation is the single most important risk mitigation strategy and is therefore crucial to the economic and environmental viability of any UCG proponent. The site selection process should follow a structured approach that progressively analyses the characteristics of the site with the effort and expense escalating with each subsequent phase. Therefore, effort and development cost scale appropriately to reflect a site's potential. Selection of a suitable site for the operation of a UCG facility involves the investigation and consideration of the factors below:

- Target resource
- Regulatory Environment
- Social and community context
- Local land use context
- Receiving Environment
- Geological, geomorphological and hydrological parameters
- Risk

The particulars of the target resource that must be accurately assessed as part of the site selection procedure should include quality, size, geological and hydrological setting, and commercial viability of the resource. The efficiency of the combustion process and the quality of the product is partly governed by the saturation level and hydrostatic pressure within the coal seam. The *deeper the seam* the less probability there will be for operational problems e.g. uncontrolled ingress of air to the combustion chamber.

As a general guide a UCG site should operate under a rigorous risk-based approach and include, at least, the following attributes:

- Coal seam at sufficient depth to ensure that any potential environmental contamination can be demonstrated to have minimal environmental consequences. With deeper coal, there are fewer useable aquifers and, if appropriate sealing horizons are present above the gasification depth, there is a much lower probability of materials (gas or liquid) moving to the surface.
- Coal seam sufficiently thick to sustain gasification with reasonable likelihood of economic viability
- Rank of coal should be lignite to non-swelling bituminous coal.
- Hydraulic head sufficient to contain efficient gasification
- Coal seam capped by impermeable rock.
- Target coal located so that there is sufficient thickness between the target coal seam/measure and any valuable aquifer higher up the geological succession
- Sufficiently distant from rivers, lakes, springs and seeps to avoid contamination should chemical escape the cavity
- Absence of faulting or intrusions in the vicinity of the site. This is dependent on the size of the cavity
- Sufficient distance from the nearest town and/or intensive surface infrastructure, e.g., irrigation or feedlots, and areas of significant environmental value, e.g., world heritage forests or wetlands, to avoid contamination should chemicals escape the cavity and to minimise impacts of odours.

Pilot Trial Issues and Lessons Learned

The ISP recognises that much has been learned about site selection since the pilot trials were established. However, given the international experience at the time of the decision to approve the trials, the ISP was uncertain why deeper coal seams were not targeted from the outset.

Figure 1 shows that process design is considered part of site selection. This is important because it indicates that site characterisation is *not* independent of the technology to be employed (including the surface downstream processing of the Syngas). The Linc Energy site (and report) contains a number of different pilot trials each with different designs. Consequently, it is certain that site characterisation was not optimised for the process design *a priori*. This is one reason why the trials must be considered pilot trials as opposed to demonstration trials (see Section Overarching recommendation 1).

An important link between site characterisation and process design is fit-for-purpose monitoring. It is necessary to know in advance the details of technology design to ensure that monitoring is sufficient, appropriately located and robust for the process envisaged. In Section 5.4.1.2 reference is made to the failure of infrastructure and the failure of monitoring systems to adequately inform the operators of the problems. An important aspect of process design as part of site characterisation is the scale up to multiple CRIP panels for a commercial operation. Site characterisation for a single panel is not the same as for multiple panels (particularly if they are to be testing different technologies). Site-wide monitoring design must be in place at the outset to ensure sufficient baseline and site behaviour information is available as panels are gasified, is essential. Such site characterisation is yet to be tested by Linc Energy because each pilot trial has been different and no site-wide technology-specific monitoring design has been implemented. Carbon energy has a site design that envisages multiple panels. However, no full site monitoring plan has been presented. Further, the technology attempted in their first panel required design alteration to increase the probability of success in the second panel trial. On both sites, the monitoring schemes have evolved dramatically from the original designs and continue to do so over time. Overall, therefore, the pilot trials have not demonstrated successful site selection for a commercial scale operation.

The ISP does not accept the retrospective assessment by Linc Energy indicating that their site meets the requirements of a good site for UCG. The ISP remains to be fully convinced that the Linc Energy and Carbon Energy sites are sufficiently deep. Recognising that shallower sites have higher risks, demonstration of a single clean cavity at these sites is not enough to suggest *automatic* acceptability of commercial operations.

Specific recommendation #1

The government together with the UCG industry and an independent advisory body, should develop guidelines and standards for site selection. The ISP recommends that site selection is a process that should be preceded and informed by appropriate geological surveys, hydrogeological modelling and an assessment of the community and environmental context. Such assessments must serve as Go / No Go gates for decision to develop or not any site for UCG operation, i.e., any limiting factor should signal No Go for the site.

5.3 Commissioning

The initial start-up operation for a UCG panel is a complex process that incorporates elements from site selection to ignition. During the start-up sequence for a panel, there are a number of process deviations which may occur resulting in risk scenarios. These are listed below:

- Deviation of geology / hydrogeology of site from that predicted in the site characterisation and design phases
- Improper well design for a selected site
- Deviation of well construction from design
- Failure of mechanical or electrical equipment aboveground
- Blockage of the injection, ignition or production wells or the panel itself
- Failure of the control systems
- Underground explosion
- Over-pressurisation of coal seam
- Ignition failure

As with any chemical process the likelihood of a deviation occurring is greater during the start-up phase than during normal operation. This is a well-accepted fact in the process engineering industry because any operation that has not reached 'steady-state' is inherently more difficult to predict and control. To combat this increased risk, process engineering guidelines and standards dictate that a risk management based 'commissioning' approach be undertaken. Commissioning should involve world's best practice for risk management in process industries including HAZOP, fault tree analysis, event tree analysis, levels of protection analysis (LOPA) including all the controls to ensure that the inherent risks of UCG activities are minimised from the outset. It is important that this process be implemented from the beginning, across the entire operation and not applied on an *ad hoc* basis or only to specific process equipment.

It is the strong opinion of the ISP that the ignition sequence of a panel is analogous to the initiation of a new process plant. Therefore it is recommended that a commissioning approach based on risk management be utilised by all UCG proponents every time a new panel is to be commenced. The fact that the consequences of a hazard event during commissioning are predominately economic rather than environmental is not material to this recommendation. This style of risk management, from the process industry, should pervade every aspect of a UCG operation, beginning with site selection, design and commissioning. Therefore, "commissioning" is the appropriate standard term and concept from the processing industry. The ISP is of the view that this term be adopted and consistently applied in the UCG industry.

Pilot Trial Issues and Lessons Learned

The risks associated with commissioning can be minimised by proper site selection, adherence to world's best practice for UCG technology and cavity design as well as appropriate commissioning procedures. However, it is clear from the documentation provided by both proponents that the risk management approach advocated by the ISP was *not* followed from the outset. This should change in any future activities.

The ISP has formed the view that the major commissioning risk is explosion in the initiating cavity. This may adversely damage or weaken the mechanical performance of the well heads, well casings, well liners, control valves and above ground systems. Safe operating procedures (SOPs) for the ignition sequence are a critical component of risk management and part of best practice. SOP's have not been provided so it is not possible for the ISP to assess their adequacy.

Linc Energy, in their Risk Assessment Section discussed risk from high oxygen as a percursor of explosive environments. Significant work on Gasifer 5 was specifically discussed with respect to this risk and additional measures were employed to monitor this risk. The procedures during monitoring should be addressed in an SOP. It is the opinion of the ISP that it is the responsibility of Government to ensure compliance with the SOP and monitoring procedures in order to minimise risk.

Conclusions

The ISP concludes that, based on the Linc Energy and Carbon Energy pilot trials and the experience gained, that the two companies have the knowledge to establish world's best operating procedures for mitigating the significant risks during commissioning including the highest risk, i.e., underground explosion.

Specific Recommendation #2

The ISP recommends that for each new panel, the UCG industry adopts a 'commissioning' approach rather than 'start-up' or 'ignition' regardless of size or multiplicity, to reduce the risks associated with this phase. Commissioning should involve world's best practice for risk management in process industries including HAZOP, fault tree analysis, event tree analysis, LOPA including all the controls to ensure that the inherent risks of UCG activities are minimised from the outset.

5.4 Production

The production phase (see Figure 1) of a UCG plant is in principle a normal process involving non-ambient temperatures, pressures and the production of chemicals such as syngas and heavier hydrocarbons. The operation of a UCG plant should therefore be considered within the risk management ethos of any chemical or processing industry. This should include contingencies for scheduled and unscheduled maintenance on all unit operations of the UCG process and measures for emergency shut-down procedures. The major difference between UCG and other process industries is that the reactor for the UCG process is underground and it is exposed to some unknowable and uncontrollable conditions, which are not found in above ground operations. This is also the primary source of increased risk for the UCG process in comparison to other gasification processes. These uncertainties include aspects of the coal geology, hydrogeology, strata morphology and overall cavity growth.

As with its above ground analogue, coal gasification, the UCG process involves pyrolysis, combustion and gasification that will inherently produce contaminants such as benzene, toluene, ethylbenzene, xylenes (commonly referred to together as BTEX), various phenols, polycyclic aromatic hydrocarbons (PAHs) and other toxic compounds. Some of these compounds may be naturally present in coal seam aquifers. Therefore an appropriate baseline study is necessary to differentiate natural from contaminant products.

If contaminant chemical species are present then these have the potential to become environmental contaminants if they escape the controlled UCG process. In an ideal UCG process situation, everything that is produced in the underground reactor should either be extracted or remain within the cavity. Any contaminants brought to the surface should then be treated in appropriate waste facilities to reduce their inherent risks. However, as the UCG process continues, the uncertainties in the site geology ensures that there will be variations and deviations in temperature, pressure, groundwater flow and gas and vapour movement into and out of the UCG cavity. As a result there is a risk of contaminants leaving the cavity and entering the surrounding strata and aquifers. This has the potential to lead to underground water contamination or syngas egress towards the surface through the overburden via faults / fissures or high permeability regions. Detection of potential contaminants reaching the surface is a matter of compliance with an adequate monitoring programme using a spatially valid array of suitably constructed monitoring wells. All these matters fall within the jurisdiction of the Government.

UCG drilling technologies and cavity designs have evolved significantly in the last 30 years. However, the UCG process itself remains complex and the scope, scale and severity of the emissions will depend on the risk mitigation strategies adopted by the UCG proponents the aim of which is to deliver results that are environmentally, socially and economically acceptable for all stakeholders. In view of these issues, the ISP has taken that approach of Layers of Protection Analysis (LOPA) to examining the normal Production Mode. After reviewing the final summary reports and associated appendices from Carbon Energy and Linc Energy the ISP proposes a suitable LOPA (Table 1).

Table 1. Layers of protection proposed by the ISP for UCG risk management in the operation phase of the life cycle.

Layer	Description
1	Site Selection
2	Process Design
3	Process Control
4	Critical Alarms
5	Safety Instrumented Systems
6	Pressure Relief Systems
7	Physical Protection
8	Plant Emergency Response
9	Community Emergency Response

The interpretation of Table 1 is that the preference is that mitigation of any potential risk should be effective at the lowest (smallest numbered) layer possible. Risks are inherently associated with any industrial activity, and only after mitigation from a lower level is insufficient (or fails) should the rest be relied upon (needed). Nine layers of protection are considered appropriate to ensure an environmentally safe and community-acceptable UCG production mode. If the cost of implementing the layers renders the operation uneconomic, it should not proceed, i.e., compromise on layers of protection for economic viability is not acceptable.

Issue and Lesson Learned

Given retrospective knowledge of incidents that occurred during the pilot trials it is apparent that the conventional process engineering risk management based approach (LOPA - Layers of Protection Analysis) was not part of the original operating ethos of the pilot trials.

To their credit, both Carbon Energy and Linc Energy have rectified inadequate operations and improved their UCG operational management and knowhow over the course of the pilot trials. It is expected that the experience of having put in place LOPA for the pilot reporting that the companies are in a strong position with respect to operating a single cavity operation.

5.4.1 Assessment of levels of protection

5.4.1.1 Site Characterisation

Observations and a recommendation regarding site selection are provided above (Section 5.2). Sufficient site characterisation and process design is the most critical factor in identifying and controlling risks with the operational phase. A sound understanding of the variability of the various strata and their interrelationships provides significant risk mitigation. Sufficient distance from environmental and community assets of concern is key in ensuring safe operating conditions can be maintained.

Pilot Trial Issues and Lessons Learned

Linc Energy manages a site that is clearly an experimental facility (of world leading standard). Linc Energy makes no pretence that the site was selected and characterised with the risks associated with a particular commercial-ready design in mind. Therefore, it is not reasonable to expect that the site characterisation necessarily meets the optimal requirements of first layer of protection for all the designs tested to date. In this regard it is important to observe that the most recent pilot (gasifier 5) is substantially different to gasifier 4 in a number of non-trivial design respects.

Carbon Energy has managed their site with a view to scale up of their operation to multiple panels. The failure of the first panel to progress beyond a short distance before collapse of a critical underground pathway required design change for the second gasifier (which appears to be functioning more effectively). Clearly, Carbon Energy is still evolving towards a final design. Once this is achieved it will be possible to assess the site selection in terms of a multiple panel design. It is clear that both companies have learned a lot about gasifier design as would be hoped from well run pilot programmes. Optimal site characterisation (careful and comprehensive matching of site characterisation and process design) is yet to be convincingly demonstrated. The ISP is of the opinion that both companies have gained sufficient knowledge to be able to demonstrate this in selecting a new site.

5.4.1.2 Process Design

Both Carbon Energy and Linc Energy have developed their UCG technology designs to a variation of the current state-of-the-art parallel controlled retracting injection point (CRIP) design with directional drilling. This is a significant advancement from older designs utilised in international UCG experiences where vertical wells with reverse combustion linking or hydraulic fracturing were used. Parallel CRIP designs are less prone to the generation of fractures or fissures in the coal seam or surrounding strata, and are therefore useful in mitigating risks associated with syngas egress and underground water contamination.

The process and geotechnical modelling of cavity growth and UCG reaction conditions presented in the final reports of both proponents is limited. Carbon Energy do not provide any modelling on cavity growth, which should be backed by general mass and energy balances and specific data from the pilot trial for validation. A simplified example of a multi-panel site design based on long-wall coal mining software (COSFLOW) with no evidence of calibration or validation was provided. Some information is provided on cavity location and morphology for panel 1, but this is more relevant to the decommissioning phase and as such is discussed in Section 5.5.

Linc Energy presented a model of cavity growth based on computational fluid dynamics and coal reaction, consumption and gas generation. Linc Energy has therefore developed in-house expertise in modelling cavity growth. However, the model deals with ideal conditions and is not validated. It is unclear how well it would perform at forecasting variations that cannot be controlled from the surface, which may result in preferential reaction pathways occurring which in turn, will influence the cavity growth and morphology. No attempt has been made to compare modelling with actual cavity data (see Section 5.5)

There are considerable differences in the amounts of information available between the Linc and Carbon models. The most important missing information is related to the validation of the Linc model. Detailed confidential information related to cavity modelling was presented by Linc to the ISP for evaluation. This may be available to Government if formal requests are made.

Information about cavity growth and the performance of the underground reaction chamber is crucial to the process design, especially for commercial operations. The level of uncertainly in the behaviour of the cavity during operation limits the effectiveness of the process design and therefore compromises the process engineering risk management approach advocated by the ISP. This reinforces the view of the ISP that the pilot trials still remain as formal development and learning experiments and as such they do not meet the information requirements of a scaled up process.

Conclusion

Cavity growth models must be developed and suitably validated for single panel UCG operations before UCG could progress to a multi-panel design.

In this LOPA, process design also incorporates all aspects of mechanical integrity. Of particular importance are materials selection, corrosion allowances and the mechanical ability of the design to cope with high pressures, temperatures and flow rates.

Pilot Trial Issue and Lesson Learned

The pilot trials have been subject to mechanical design problems relating to the ignition, injection and production wells. Mechanical failures of the well casings and / or well heads resulting from inadequate design, selection of materials and construction have been experienced. Deviations caused by temperature and pressure resulted in weakening of the liners or lifting of the wells that subsequently failed. Whilst petroleum engineering designs were adopted, these did not account sufficiently for the higher temperatures associated with UCG operation and there is a clear need for a shift to design standards that do, such as for those associated with geothermal wells.

Carbon Energy and Linc Energy have evolved their well designs to account for UCG operations to enable operation and acceptable deviation within appropriate temperature regimes and *in situ* removal of well blockages. This greatly reduces the risk of well head failure.

Downstream processing of the syngas and associated condensates including surface water treatment is an integral part of the entire UCG operation and as such should be designed accordingly to deal with the significant variability and process deviations associated with normal production. It is observed that several issues relating the treatment of process water in the pilot trials could have been avoided if this principle was followed. For example UCG process water has exceeded piping and knock-out pot capacities resulting in minor spills directly onto soil or into local watercourses. Whilst these incidents have been thoroughly investigated by EHP (formerly DERM) and appropriate remedies taken, that they were allowed to occur in the first place leads the ISP to conclude that the original process design was not carried out using an appropriate risk management approach and/or that the necessary controls were *not* in place.

Conclusion

All downstream processing for the syngas and process water should cater for process deviations (including inherent safety factors) and unit operations should be designed and sized accordingly. Equipment should be designed to account for any corrosion that may result from the presence of syngas and water.

The flare is an integral part of the process design and is necessary for safe operation of both upstream and downstream processing facilities.[2]

The ISP recognises that should the downstream processing fail, it may not be wise to shut-down the operation of the cavity and as such systems, such as the flare, should be in place in order to safely combust the excess syngas.

Conclusion

A flare is a crucial part of the UCG operation and should be incorporated into the process design and be able to cope with process variation and deviations.

In view of the complexities associated with UCG operation, the LOPA design process requires inclusion of monitoring as an integral aspect of protection. In fact, the design of monitoring systems should be considered at the inception of the design process and must be appropriate for the site conditions and knowledge of possible deviations and indications that deviations may be occurring.

[2] Current monitoring processes are specific to each pilot and are considered, generally adequate, by the ISP. Prior to any commercialisation, detailed specific monitoring strategies should be developed for each UCG operation. Compliance with the monitoring requirements should be a Government responsibility. In principle, flares will decompose or combust hydrocarbons and condensates. Without specific strategies for removal, remaining issues would relate to H_2S, Hg, Ar, Cd, Ni and possibly silica at ppm or ppb concentrations. Industrial processes are available to assist in removal of these components.

Pilot Trial Issue and Lesson Learned

Pilot trials have corroborated conventional understanding that monitoring systems are an integral component of the UCG process design. For example, the operating pressure of the cavity should not exceed the hydrostatic pressure of the surrounding groundwater. When the hydrostatic pressure is exceeded, for a sustained period an increased presence of contaminants in the monitoring wells has been observed and reported. Carbon Energy and Linc Energy acknowledge that operating pressures greater than the hydrostatic pressure lead to gas and vapour diffusion into the surrounding strata resulting in detection of products of pyrolysis in groundwater. Therefore groundwater monitoring wells should be setup prior to the construction or drilling of any panel. The pilot trials have included monitoring wells which have been setup as regulatory and reporting requirements from the various regulatory bodies, or as deemed appropriate by the individual UCG proponents.

Carbon Energy has provided data indicating that when operating pressure dropped below hydrostatic groundwater pressure, contaminants migrated and that these could be redirected to the cavity by control of the rate of air injection and thereby internal cavity pressure. This is an important lesson of successful monitoring, deviation detection and corrective action.

Given that the pilot trials have demonstrated that flow reversal to the cavity occurs and that it can be effectively monitored, then the ISP concludes that it can be effectively monitored in practice. Monitoring the performance of the pilots on an ongoing basis as they proceed is a Government responsibility not that of the ISP. The experience of the panel indicates that this is feasible.

The evolving design of the monitoring wells has been subject to regulatory pressures, albeit to varying degrees across the UCG proponents, with several pilot trials required to install additional wells to better monitor the UCG process. To their credit all the UCG pilot trials have installed monitoring wells additional to the initial environmental licences for their own understanding and monitoring of the process.

Companies have yet to fully demonstrate the capability to design and install a monitoring network suitable for multi panel operations and that some of the groundwater data may not be representative. For example, the Linc groundwater monitoring bores are self-purging (gas lifted groundwater). This may result in the loss of volatile organic carbon contaminants during sample collection. In addition some doubts exist as to the construction of the Carbon groundwater monitoring bores which may inhibit the collection of representative groundwater samples.

It is possible that these aspects may prevent an accurate assessment of underground impacts related to chemical species transported via groundwater and/or gas. The ISP acknowledges these difficulties as do the pilot reports, particularly the Carbon Energy report. Suggestions are made for the use of improved systems. The ISP also notes that Government Departments have instigated an environmental evaluation on the basis of such monitoring.

Conclusion

The layout of groundwater monitoring wells should be integrated into process design. It is recognised that some wells are necessarily to be sacrificed as the gasifier grows. Sacrificial wells may be used to access the UCG cavity during commissioning and rehabilitation. Monitoring wells should be setup prior to commencement of any operations. The capability to design and install monitoring suitable for multi-panel operations has not been demonstrated.

5.4.1.3 Process Control, Critical Alarms, Safety Systems and Pressure Relief Systems

LOPA layers 3 through 6 cover various aspects of basic and advanced process control and automated safety systems for the UCG process and as such have been combined for the purposes of this summary. These layers of protection are commonly associated with the oil and gas processing industry. The UCG process produces syngas at moderate temperatures and pressures and therefore operates within the parameters of this industrial sector.

Pilot Trial Issue and Lesson Learned

The pilot trials suggest that many of the risk management systems adopted by the process industry for LOPA 3-6 have not been adequately implemented by any of the UCG proponents. However, the risk assessment reports provided by both Carbon Energy and Linc Energy have shown the incorporation of some of these layers of protection and discuss others that are under current consideration.

Carbon Energy has provided Piping and Instrument diagrams (P&IDs) containing pressure, temperature indicators, process control valves, pressure relief valves, flare systems among other basic and advanced control systems. The risk assessment report from Carbon Energy and R4Risk (attached as Appendix K) contains a detailed analysis of the hazard events, and specifics of the control systems with links back to equipment tags allowing full analysis of their systems. The ISP commends the content of this report, but its full value is not properly integrated into the main document (see Section 4). The R4Risk report is significantly more comprehensive than that provided by Linc Energy who provided more qualitative information regarding their control systems. Linc Energy did not provide P&IDs nor did they give expected details of specific references to the layers of protection, basic controls or advanced controls in place or under consideration.

Basic process controls form the first line of monitoring to measure deviations associated with pressure, temperature, flow rates and gas quality. These parameters can and should be monitored and controlled online in real time. However, any process deviation that causes significant environmental impacts (such as groundwater contamination) may only be detected by monitoring wells several weeks or months after the event. It is therefore imperative that operational procedures allow continuous or near continuous monitoring of these parameters. For the scope of the pilot trials this approach allows the operators and engineers the greatest opportunity to analyse the cause of a particular environmental trigger and investigate the appropriate course of remedial action.

The ISP observes that several of the incidents reported during the pilot trials came about through a lack of sufficient automatic monitoring of pressure, temperature, flow rates and gas quality. For example there is evidence in various submissions relating to the Carbon Energy pilot trial, that cavity pressures have in several instances increased beyond that of the hydrostatic groundwater pressure. This resulted in contamination plumes of greater or lesser extent in April 2010 and March 2011. In the opinion of the ISP, had appropriate control systems been in place, the risks posed as a result of the initiation of the events would have been significantly decreased. However, the monitoring records did allow Carbon Energy to identify the cause of the contamination plume and take appropriate remedial action to reduce the consequences.

For larger, commercial operations where sufficient process and groundwater modelling has been undertaken, this level of monitoring would allow operators to take immediate corrective action and thus reduce the severity or timeframe of the event and thus reduce its consequences. Basic process controls will incorporate low and high set points to address the UCG process variability. Examples include:

- The pressure difference between the cavity and the hydrostatic pressure of the groundwater to avoid gas egress and underground water contamination.
- The cavity and well temperatures that may cause well head or liner damage or increase the production of pyrolysis components.

- Injection and production well flow rates that directly relate to blockages of water and ash.
- Mass balances to check for gas losses.
- Gas quality to ensure that the UCG design is meeting syngas specifications.

Critical alarms are those devices related to independent sensors for process parameters, interlocks, isolation valves and redundancy where appropriate. Critical alarms require a quick diagnosis from the operator or engineer and a quick decision regarding the need for intervention to correct a process deviation. The documentation surrounding the pilot trials suggests a lack of critical alarms and appropriate decision-making procedures from the outset. For example on one occasion during the Carbon Energy pilot trial, backpressures on an injection well spiked to 37 bar resulting in emission of process water through the flare. This represents an injection pressure 270% in excess of the expected hydrostatic pressure. In this instance the high pressure was caused by a blockage in the well. This appears to have been noted by Carbon Energy, yet they made the decision to keep injecting under the premise that the blockage would clear itself. It is the opinion of the ISP that had this scenario been examined in an appropriate risk management culture, prior to or as part of the commissioning process, then a different decision (for example to cease injection, isolate the injection or provide pressure relief) would have been taken. More importantly, the decision taken would have followed a specific procedure designed to mitigate the risk scenario, rather than the apparent *ad hoc* decision process that took place. However, the ISP does observe that the post-deviation analysis undertaken by Carbon Energy resulted in new operating procedures being developed to avoid similar risk scenarios in the future.

Safety instrument systems (SIS) are required as part of the LOPA philosophy. SIS are advanced control systems that automatically instigate emergency shut-down procedures to safely isolate parts or the entirety of the plant.

Pilot Trial Issue and Lesson Learned

Incidents occurred during the pilot trials that indicate that sufficient safety instrument systems were not in place. One example of this may be emergency shutdown buttons for the injection compressors following over-pressurisation of the cavity and failure of pressure control systems. This may include provisions for emergency depressurisation of the cavity, sending the syngas to the flare.

The pilot trial reports do not indicate such a sophisticated level of process control. However, the risk assessment reports for both Carbon Energy and Linc Energy have indicated that the UCG proponents have learned the necessary awareness of these issues and plan to have provisions in place in the future.

Pressure relief systems are required to protect equipment which operates under pressure and which can cause environmental consequences through uncontrolled atmospheric discharge. Although the pressure of the cavity is not excessive, it is important that any depressurisation is carried out in such a way as to not instigate reaction extinction, cavity collapse or flooding. As such the pressure relief system must be designed and operated independent to other controls within the UCG process.

Conclusions

The ISP concludes that the UCG industry should adopt world's best practice for basic and advanced control systems (LOP 3 through 6) from the oil / gas and petrochemical industries.

The ISP further concludes that the basic process controls be adopted as the first line of monitoring.

5.4.1.4 Physical Protection Systems

Physical protection systems are used to mitigate the severity and prevent escalation of a risk scenario. They include systems such as physical bunds on tanks and fire curtains. There were several instances during the pilot trials for all UCG proponents when it appears that inadequate provisions were made for bunds on knock-out pots, process water/odour containment and process liquid containment. In one example, when knock-out pots overflowed or piping ruptures occurred, the spills proceeded directly onto soils or into local waterways. In another example, Linc Energy and Carbon Energy have been subject to odour complaints from local landowners.

These problems were appropriately addressed following the incident investigations, but it does once again highlight that the majority of the UCG risks have been managed on a post-incident basis.

The ISP is aware that the transport of odourous gases may occur and the degree of transport will depend upon site specific management and local weather conditions. Thus a zone beyond which no site derived odourous gases are detectable is needed. Government should develop evidenced-based guidelines as soon as possible and that the distance specified should be either appropriate to the meteorological conditions on site as ascertained by modelling or as regulated by the environmental licence of the site.

Conclusion

The ISP concludes that physical protection systems are required and should include gas detection for flammable and toxic gases, bund areas for excess process water or process liquids and fire protection systems.

5.4.1.5 Plant and community emergency response

Each site is unique in terms of geographical features, boundaries and access points. Therefore these plans should be developed in consultation with appropriate regulatory and community bodies, according to world's best practice and appropriate industry standards.

Conclusion

Plant and community emergency response plans should be developed in consultation with appropriate regulatory and community bodies, according to world's best practice and appropriate industry standards.

5.4.2 Other operating modes – Temporary Shutdown and Re-Start

Temporary shutdown and re-start are important phases of any process industry and may be associated with scheduled or unscheduled maintenance of equipment directly related to the UCG operation. The timeframe associated with temporary shutdown may be short (1-3 days) or medium term (for several weeks) depending on the scope of work. Issues relating to temporary shutdown and restarting an on-going UCG panel are very similar to those for the initial commissioning or final decommissioning phases. Long periods of temporary shut-down may lead to reduction in the cavity temperature to such a point where coal pyrolysis becomes prevalent. In these conditions the production of undesirable contaminants increases.

Pilot Trial Issue and Lesson Learned

A point of concern is if temporary shutdown leads to the extinguishment of the UCG reaction. This is the worst-case scenario, possibly leading to an inability to restart the operation, and/or associated unacceptable risks (repeated failures to reignite and possibility of explosion).

Difficulties are associated with the size of the cavity and lack of design features for such an occurrence.

The ISP observes from the pilot trial reports that the companies have learned how to successfully deal with temporary shutdowns lasting from several days to several weeks over which time the reaction was maintained as viable. Subsequently the panels were successful restarted without incident.

Specific Recommendation #3

If the UCG reaction has been extinguished, then restarting the panel should follow the pre-defined risk protocols. If restart is deemed unacceptable the process should proceed directly to decommissioning and rehabilitation.

5.5 Decommissioning

The decommissioning sequence is an important process that transitions between full production and site rehabilitation. The final shutdown sequence for a UCG panel is complex with a medium to long-term timeframe. The shutdown sequence is different to the temporary shutdowns discussed in Section 5.4.2 because the aim is to extinguish the reaction and bring the materials surrounding the final cavity into thermal equilibrium with the surrounding coal seam and over- and under-lying strata. The ISP is advocating a decommissioning approach rather than 'shut-down'. This is analogous to the risk-based 'commissioning' approach advocated during start-up and ignition.

Necessarily, the cavity must transition from gasification temperatures eventually to that of surrounding conditions. A second important change of state relates to pressure. As the cavity is cooled and the gasification is suppressed (most notably by reduction in supply of oxygen) the internal pressure decreases, which is a clear deviation from normal operating conditions. The rate of pressure decrease is important, somewhat variable and dependent on the conditions within the cavity.

During cooling there is an inherently high probability of formation of potentially contaminating chemicals (e.g., benzene, toluene, xylene (BTEX), phenols, various polycyclic aromatic hydrocrabons (PAHs) and other hydrocarbons). This is a result of the ongoing coal pyrolysis at temperatures between 250°C and 700°C, which favour their formation and so cooling of the reactor cavity will inevitably produce these unwanted chemicals. Carbon Energy and Linc Energy have appropriately highlighted these chemicals and their properties. They have also demonstrated capability in their detection and measurement.

Literature from overseas trials was reviewed by the members of the ISP and a literature review was provided by one of the proponents. There is reasonable evidence from the USA that a clean cavity may have been achieved. For information relating to the "clean cavity" concept reference should be made to the available literature. Government should seek to obtain the bibliography relating to the literature review from the company concerned.

The ISP has viewed a small core taken from one of the USA trials. Examination of the mineralogy of this core suggested a cooling pathway. It is up to the companies to design and undertake comparable sampling from the two pilots. If this is not possible, then the technology has a significantly greater degree of uncertainty than would be the case if direct mineralogical and chemical analysis of the remnant material were undertaken. Identification of the solids and liquids remaining in the cavity would reveal a greater degree of certainty for any contaminant phase transport modelling undertaken.

It is the responsibility of the companies to design appropriate sampling or measurement regimes to monitor the cleanliness of the cavity. Thus, the ISP believes, it is the responsibility of the companies to solve with the Government concerns relating to compliance with these regimes. If a "clean cavity" is not able to be demonstrated then the technology is not sufficiently well designed to be considered safe.

Carbon Energy and Linc Energy propose a "self-cleaning" approach to decommissioning (although both also note the possibility of having to actively clean the cavity if necessary). Under such a scenario the reduced pressure in the cavity is advantageous in that a local zone of low pressure draws groundwater from all directions towards the cavity. This is important because any residual chemicals from the active zone (or beyond), that are not adsorbed to the coal, are, in principle, flushed into the cavity. The residual heat in the cavity vaporises the water and contaminants which are then brought to the surface for appropriate handling and treatment. In principle, this is an attractive process if it can be demonstrated in practice in large cavities partially filled with rubble and with significant temperature gradients due to the size of the cavity and longevity of the panel gasification duration.

Pilot Trial Issue and Lesson Learned

Carbon Energy and Linc Energy both propose design panel systems of several hundred metres of length and tens of metres of width and significant height (depending on the coal seam but of order 10m). To date, there is no evidence of the capability to control the temperature and pressure changes in such large cavities because no such cavity has yet been completed. The panels currently under gasification by Linc Energy and Carbon Energy are the best opportunity to date to investigate these important issues. Extrapolation from other small cavities is inadequate as is taking analogies from overseas experiences with different designs (and also small cavities). It is simply not possible to demonstrate that self-cleaning is effective in a large cavity until a large cavity is available on which to conduct the necessary monitoring.

Linc Energy and Carbon Energy have learned the necessary monitoring and measurement capabilities to be able to demonstrate self-cleaning but to date no cavity exists upon which a convincing demonstration can be undertaken. Demonstrations on current small cavities have been unconvincing (access to cavities appears to be a very challenging design issue).

Conclusion

Several cavities (some panels) have been shut down during the pilot trials and are undergoing various stages of decommissioning and, presumably, rehabilitation. However, insufficient information has been gathered or provided regarding decommissioning during the pilot trials. A formal process model, mass and energy balances and appropriate data support were all lacking. The reliance on analogues from overseas experiences is insufficient. Therefore, the ISP is of the opinion that the best strategies have not been fully developed at this time.

5.5.1 Panel/Cavity Information and Unidentified Risks

Neither Carbon Energy nor Linc Energy provided sufficient information on the operational modelling (including morphology and growth) and decommissioning of their previous cavities or currently operating panels for the ISP to reach a recommendation of safety in practice.

The ISP decided not to review operational processes, but rather focus on the risk assessment and supporting background data.

The information provided by Carbon Energy on panel morphology and size was inconclusive. An attached consultant report (Appendix J) concluded that a new technique trialled for the purpose of mapping the decommissioned panel 1 was successful. However, the figures lacked scales and colour coding of the spatial information was not described, making independent analysis and verification by the ISP all but impossible. Indeed, one possible interpretation of the information is that the morphology of the cavity did *not* match expectations. That is, the cavity appeared as toroidal, possibly due to rubble collapsed in the centre of a more spherical cavity. Further, there appeared to be void space behind the ignition point, which would not be expected. The ISP concluded that Carbon Energy would not have presented such information if this interpretation were correct and not remark upon it themselves. Consequently, the ISP does not concur with the consultant that the technique was successfully applied to UCG. Further the ISP suggests Carbon Energy reassess the data or apply another technique to this important aspect of UCG.

The composition of the cavity following operation is important for decommissioning and rehabilitation strategies.

The plausible options for contents of a final cavity include that it is filled with:

a. rubble from gasified coal (ash and tar), collapsed overburden, interburden and disturbed underburden; or
b. underground water containing a range of constituents native to the groundwater, e.g., salts, and products of gasification and pyrolysis; or
c. syngas mixed with air and coal seam gas (methane and carbon dioxide); or
d. a mixture of all of the above.

The ISP is of the view that (d) a mixture of all of the above contents, is the most plausible and that the gas mix and water constituents are likely to vary over time.

Linc Energy provided a (partial) framework (see figures L4 and L6) in their decommissioning report. This model acknowledges that the overburden and underburden are compromised by the gasification process and that the final cavity includes "rubble-altered overburden". The ISP suggests that the critical variables of the framework be more fully elucidated and formalised into a formal engineering conceptual model. This must include a set of reference equations that can be used as a basis for statements as to the likely content of the cavity and include an appropriate conversion from 2D (as in the figures) into 3D (as exists in the real cavities). Such a model will be critical in gaining confidence that the company knows what it is dealing with. Without this, the relative quantities of water, ash, tar, rubble and gas are speculative and no mass balance or dynamic prediction models of sorption or water movement can be made with confidence. Such a model will also provide a basis to complete the picture of the cavity because measurements will always only be a partial information source for delivering the certainty required to deliver confidence that a clean cavity has been achieved.

Appendix J of the Carbon Energy report concludes that rubble-filled is the best model fit for the contents of the cavity. This conclusion means that the cavity is likely dominantly filled with material collapsed from the overburden. By comparison, Linc Energy provided a visualisation of the "material affected zone – MAZ" of gasifer 3. In that visualisation it was clear that both overburden and underburden were part of the zone, although what was intact and what was merely altered was not able to be discerned. That is, the MAZ extended above and below the coal measures and therefore the integrity of the overburden and underburden were affected by the UCG process consistent with the Linc Energy conceptual framework as presented. Surprisingly the Linc Energy decommissioning report did not make reference to this issue. Given the conclusion by the Carbon Energy consultants that their cavity is likely rubble-filled it is difficult to see how the Linc cavity would not also contain material that collapsed from the overburden (again as it was indicated in their conceptual model).

With respect to the earlier gasifers the process used to confirm that the coal has ceased to burn after decommissioning was monitoring the composition of the gas produced. There are very clear trends which indicate the shutting down of the gasification process. These include decreasing concentrations of CO, CO_2 and N_2 (which are monitored on-site) and the decline of CH_4 back to baseline. All pyrolysis will ultimately cease when the air/O_2 supply is turned off.

Once the source of oxygen is removed and at geologically suitable sites, all burning will ultimately cease and the fire will be extinguished. This is unlike underground coal fires. For example, Jharia in India has experienced a coal fire that has burned underground for approximately 100 years in spite of attempts to extinguish the fire by using nitrogen. The failure to extinguish the burn relates to failure to cut off all supply of oxygen via ventilation shafts, the numerous open pits and old mineshafts in the area. Comparably, spontaneous combustion cannot occur in UCG operations once any oxygen supply is removed.

With current Carbon and Linc gasifiers, the decommissioning is not yet complete, hence the recommendation that decommissioning trials continue (Overarching Recommendation 2). At the end of this period, a definitive statement relating to the cessation of burning should be possible. All the indirect evidence currently available indicates that burning of coal (pyrolysis and gasification) ceased soon after the injection of air or oxygen stopped.

Background information from both Carbon Energy and Linc Energy indicated that the Springbok Sandstone overlying the coal measures contains small discontinuous aquifers interspersed by dry aquicludes (lenses through which water cannot move or through which water moves so slowly as to be negligible). Carbon Energy and Linc Energy indicated that no aquifer directly overlies their reactor panels and that the tight Springbok Sandstone forms an effective seal against gas egress from the cavity. However, if the post-gasification cavity is at least partially rubble-filled, as proposed by Carbon Energy, implied by Linc Energy conceptual model and possibly MAZ visual rendering data and accepted by the ISP; then it stands to reason that the rubble is from the overburden. This implies that the integrity of the seal is potentially compromised. It is important that this risk is identified and controls articulated. It is expected that a move to commercial operation and larger cavities would increase this risk. That is, it is increasingly likely that over a length of several hundred metres gas migration pathways are formed by the collapse of the cavity roof.

A second risk is also created with respect to the final hydrological integrity of the cavity. Both Carbon Energy and Linc Energy have highlighted that the dry material overlying the cavity is an advantage because water ingress to the cavity is not important either in terms of the oxygen/water mix or the potential to drain overlying aquifers in commercial operations. However, neither Carbon Energy nor Linc Energy deal with the risk that a lack of integrity in the cavity roof may provide an escape pathway for contaminated water as the original groundwater pressure in the coal measures re-establishes following decommissioning (the local hydraulic head is above the level of the top of the cavity). Given that the overburden does not have the activated carbon or background coal capacity to adsorb pollutants (discussed further in Section 3.5.3) this is a potential pathway for their transport into the surrounding environment.

Neither of the company reports provided data to indicate that gases have been detected at the surface. All possible pathways should be examined including well and surface infrastructures to determine possible sources of any gases.

Therefore, the ISP concludes that for UCG to be safe in practice, the compromise of integrity of the overburden must pose no environmental threat. Undertaking UCG at significant depth (as per the recommendations in Section 5.2) would appear the easiest way to ensure this. An alternative would be to demonstrate that the stratum above the direct overburden is tight, not an aquifer and remains intact after gasification. There is no substitute for direct measurement coupled to a sound numerical model of the system, to demonstrate this.

5.5.2 Coal activation and pollutant adsorption

Carbon Energy and Linc Energy present information on the importance of coal as an adsorptive medium for gasification products that may assist with risk limitation during decommissioning. Linc Energy provides adsorption isotherms for coal that has been thermally altered under laboratory testing conditions. The ISP notes that the university report presented on this carried a strong disclaimer regarding the inappropriateness of the use of the experimental results for interpreting behaviour of coal in a real gasifier (although within the report there appeared to be a counter statement). Nevertheless, the ISP is of the view that laboratory heating of Macalister is not a substitute for coal sampled from the wall of an actual cavity because the complexity of alteration conditions is greater than only thermal effects.

No significant attempt was made by either Carbon Energy or Linc Energy to compare the likely available adsorptive capacity of the decommissioned cavity wall with the likely production of pollutants. This information is significant and would have demonstrated to the ISP whether contaminant load and capacity may be expected to balance. Both Carbon Energy and Linc Energy did provide either simplistic models or initial results which suggested that the contaminant plume would be restricted to within a few hundred metres of the cavity, even under worse case scenarios. However, given the lack of knowledge surrounding the final contaminant profile, cavity volume, morphology, composition, amount of water to be removed for treatment and altered ground water flows; the ISP cannot accept these conclusions without more rigorous assessment (under multiple cavity conditions) by the UCG proponents.

Evidence of the effectiveness of decommissioning must be comprehensive and include:

1. A comprehensive detailed step-wise process flow for decommissioning that can convincingly demonstrate a completed panel (as envisaged in the proposed technology for both companies) is clean and environmentally safe in the long term.
2. A conceptual model/framework for decommissioning including all material and energy flows.
3. Validated numerical models and accompanying data for the decommissioning process. This must include as a minimum:
   a. Convincing 3D estimates of the morphology and size of existing cavities;
   b. Data from the existing cavities on the material properties of the cavity walls (coal seam, overburden and underburden);
   c. Mass balance estimates of pollutant loads based on measurements;
   d. Mass loading estimates of adsorption capacity of "activated" and nearby coal, i.e., coupling of measured isotherms with adsorptive capacity and loading of a water-filled cavity;
   e. Measurements of critical pollutants and mass balances for the water and tar pollutants exiting the cavity via the production well.
   f. Measurements of critical pollutants and mass balances for the water its constituents and tar pollutants exiting the cavity via the production well.

Conclusion

For the currently operating panels, Carbon Energy and Linc Energy should establish integrated shut down and clean-up procedures to establish world's best practices for decommissioning a UCG cavity.

Specific Recommendation #4

No further panels should be ignited until the long term environmental safety provided by effective decommissioning is unambiguously demonstrated. Evidence of the effectiveness of decommissioning must be comprehensive.

5.6 Rehabilitation

Other than general definitions borrowed from the mining industry the pilot reports provided little information on rehabilitation. Therefore, this phase of the life cycle is yet to be assessed and no conclusions regarding adequacy of processes can be made.

Specific Recommendation #5

The companies should immediately propose, test and establish acceptable and agreed processes and outcomes for rehabilitation.

6 Coal Seam Gas and Underground Coal Gasification

The issue of overlapping tenure between CSG extraction and UCG was raised with the ISP. The essential issue is that CSG requires that groundwater pressure be reduced so that methane can desorb from the coal and make its way to extraction points. However, UCG requires that hydrostatic pressures be maintained at a minimum value to ensure the cavity growth is controllable and that contaminants cannot escape into the surrounding environment. Unfortunately, the minimum pressure of methane desorption is below that required to maintain a UCG gasifier.

The interaction between CSG and UCG has policy and legal issues. The ISP considers that it should *not* have the role of making a determination as to the legal situation regarding liabilities for water pressure under current legislation. Nevertheless the following observations are made.

The ISP recognises three cases for consideration of the interactions between CSG and UCG.

1. Current approved UCG trials and approved CSG overlap. The government needs to determine whether approved CSG activities will jeopardise the ability of the UCG pilots to demonstrate effective decommissioning. If so, resolution is required with respect to groundwater pressure and any potential contaminant transport from UCG cavities.
2. Potential UCG and approved CSG. The ISP is of the opinion that where it is known in advance that CSG will reduce groundwater pressure, any proposed UCG must include a risk strategy to control the groundwater pressure necessary for safe operation.
3. Greenfields. Policies to deal with such future situations are needed.

In the longer-term it should be recognised that UCG resources can be sterilised by groundwater depressurisation until recharge, which can take many decades.

Pilot Trial Issue and Lesson Learned

The ISP is of the view that no generalised buffer distance recommendation is technically sound. The distance between any active UCG gasifier and the nearest CSG well will be controlled by the details of the gasifier depth and pressure conditions and the rate of water injection required to meet the minimum pressure operating requirements.

A key issue is whether a UCG operation can be made responsible for the critical operating condition of hydrostatic pressure. Linc Energy provided information on the trialling of control of local water pressure via injection wells. Carbon Energy did not provide any information regarding design or trialling of a suitable ground water control technology. However the risk assessment conducted by Carbon Energy and R4Risk indicated that the use of injection wells to control the local groundwater pressure was a principle risk mitigation measure for multi-panel operation.

It is clear that both companies have learned the potential advantages for being responsible for hydrostatic pressure control. Control by creating a local a curtain via a series of injection wells is yet to be demonstrated. The ISP notes that the CSG industry has a large amount of coal seam co-produced water to dispose of and UCG could be one use for this water.

Specific Recommendation #6
The ISP recommends that any UCG operation should be licensed on the basis that it is responsible for maintaining and controlling all its operating conditions, taking into account the conditions of the site at the time of approval, including maintenance of groundwater pressure.

7 Regulatory Environment

The regulatory environment establishes the criteria for the approval of a proposed UCG facility, stipulates monitoring requirements and guides operational priorities. The regulatory environment also drives the site investigation. To satisfy the intent of existing legislation and the aims of the agencies that administer the legislation, consideration should be given to the identification and understanding of the Acts and other instruments of governance under which authority to explore and mine the coal, and to operate the UCG facility, is granted.

In Queensland, an application for a UCG facility is made under the *Mineral Resources Act 1989 (MRA)* and the *Environmental Protection Act 1994 (EPA)*. Although the *MRA* and the *EPA* most directly apply to the authorisation and regulation of a UCG facility, a number of other legislative instruments (such as cultural heritage and native title legislation) apply to the approval and operation of a UCG facility.

The majority of the relevant Acts are applicable to all aspects of mine related activities. These are listed below and must be understood and followed by the UCG proponent. However, a number of Acts may be confusing, misunderstood, or are considered of particular relevance to the UCG activity. These Acts will be detailed within this Guideline.

It should be noted that understanding the intent of the Legislation, and seeking clarification as necessary, will facilitate better performance, creative problem solving, success in satisfying Regulatory Authorities, and produce a proactive, rather than a reactive, approach to the problem solving situation.

7.1 Observations on policy and governance

Different parts of legislation contain sometimes conflicting or confusing definitions. An important example is *syngas*, which is petroleum under the meaning of the Petroleum Legislation and is a mineral under the meaning of the Mineral Resources Act 1989

Overlapping tenures can exist under Petroleum and Gas (Production and Safety) Act 2004 (P&G Act) and the Mineral Resources Act 1989. Existing legislative arrangements concerning rights to groundwater (e.g. dewatering) should be reviewed. An important example is that the operational parameters within the coal seam for CSG are incompatible with those for UCG. Where two different tenure applications for petroleum and mining do overlap, legislative arrangements are complex and decision-making is complicated and necessarily on a case-by-case basis. Equally, legislation can hold certain operators responsible for groundwater changes that are ultimately controlled by a separate decision regarding a different development. For example, dewatering for an approved coal mine could result in groundwater pressure changes that a CSG company had been made responsible for that a UCG company then is impacted by.

UCG is a relatively new technology to Australia and is not widely practiced globally. Professional expertise and experience is not readily available. If the UCG industry can demonstrate environmental safety and community acceptance with economic viability, the eventual establishment of a UCG industry will require significant government and technical support. Currently, it is challenging for government to develop policy and for regulators to be as effective as they might because of a limited skills base. Further, there is little non-company research being undertaken. Independent research is required to ensure broad confidence in the significant questions that remain to be answered about UCG, particularly as a commercial activity. Research is also the foundation of a tertiary education institution's ability to effectively educate the necessary workforce for a new industry. The government should establish two new entities to ensure that if it is deemed acceptable to establish a UCG industry that it can be supported at the level necessary to ensure its best chance to be environmentally, socially and economically viable.

The Government needs capability and capacity to effectively deal with the issues surrounding a potential UCG industry. Given the challenges of building internal capacity in a short time the government could consider appointing Queensland UCG Independent Assessment, Evaluation and Advisory Group[3] of persons with understanding of (a) the science behind the UCG process, (b) sufficient knowledge to predict problems that may occur, and (c) sufficient knowledge to discern solutions to unforeseen problems. Suggested components of terms of reference for the group are below.

- Reviews and monitors risk related issues (environment; safety etc) for UCG operations.
- Provides policy, legislative and regulatory information support for government.
- Neutral broker between industry and government.
  Identifies research problems/targets from risk perspective and asks R&D network (see below) to develop responses.

Important initial tasks with which the group could assist government and industry are:

- A UCG Policy should be constructed that adequately reflects the tenets of the Government's concerns and requirements.
- A set of clearly defined Guidelines should be constructed that are unambiguous and allow for variations in regional and local conditions.

A research and development programme, The Queensland UCG R&D Network[4], should be initiated immediately and tied into international expertise. It is not envisaged that a large fund should be

[3] To avoid any perceptions of conflict of interest, members of the ISP propose that they would be excluded from participating in the Advisory Group for a period of two years lest it be suggested this recommendation is an attempt by ISP to position for a future advisory role.

[4] To avoid any perceptions of conflict of interest, members of the ISP propose that they would be excluded from participating in the R&D network for a period of two years lest it be suggested this recommendation is an attempt by the ISP to position for future research.

made available. The main aim initially is to bring together research capability so that government and industry can draw upon a network of expertise. Such a network would form an excellent base upon which industry and government could draw, in due course, for educators as well as researchers. Projects would then be funded on a case-by-case basis with contributions as the parties see fit. It is suggested that government mandate that the UCG companies, as part of their license to operate, contribute to establishment of the group to meet the administrative and networking costs, which should be ~$1m p.a. Companies would also be required to participate in priority setting and communication of outcomes of activities of the network. State government would be encouraged to contribute in-kind and eventually financially to projects as the State budgetary situation improves over time. A number of alternative resourcing models for the network could also be explored, for example, the federal schemes for rural research, e.g., grains research and development corporation, or the Australian Coal Association research Program (ACARP), which is fully industry driven and funded.

Specific Recommendation #7

The government should consider establishing two new entities to support a UCG industry at the level necessary to ensure its best chance to be environmentally, socially and economically viable.

1. Queensland UCG Independent Assessment, Evaluation and Advisory Group.
2. The Queensland UCG R&D Network.

8 Industry scale-up (multi-panel operations)

The ISP would like to highlight the lack of detailed data presented regarding the plans for multi-panel operation and commercial scale-up. The reports on the pilot trials show that no multi-panel operation has been carried out thus far. The panels that have been gasified, to a greater lesser extent, have been for the purpose of data gathering and experimentation. Whilst this is a suitable approach for a pilot trial, it appears to have followed an *ad hoc* design evolution rather than a systematic design evolution. It is therefore not possible for the ISP to assess the design for scale-up.

Significant issues remain to be dealt with including:

- the altered hydrogeology across a multi-panel site;
- the relationship between completed panels (cavities) and active gasifier(s);
- the potential for unacceptable odour production from multiple simultaneous gasifiers and the consequent need for a substantial distance buffer to potentially exposed neighbours;
- multi-panel design that avoids connectivity between final cavities and active, potentially contemporaneous, panels resulting in:
  - unacceptable surface subsidence;
  - groundwater transport of contaminant and wild fire because of loss of control of oxygen conditions; and
- the need for external injection of water to maintain the hydrostatic pressure across the site. It is clear that the observations made above on challenges associated with water injection to maintain hydrostatic pressure (see Section 5.5) are amplified considerably for multi-panel operations. Depending on the final design chosen it may indeed be necessary (and possible) to establish a minimum distance from a UCG *facility boundary* and other activities, e.g., CSG that require different hydrostatic operating conditions.

All of these design considerations will have significant implications towards multi-panel operation and commercial scale-up, site decommissioning and rehabilitation.

For commercial scale multi-panel operation, it is the opinion of the ISP that full consideration should also be given to critical systems (see Section 5.4.1.3) during the design phase. These systems should include temperature relief systems for the well head (i.e., water quenching / steam injection), gas detection for flammable and toxic gases, bund areas for excess process water or process liquids and fire protection systems. The ISP recognises that a further system of physical protection is the establishment of an active zone around the cavity which may contain similar or lower levels of contamination in the ground water as is found inside the cavity due its intimate proximity.

Conclusions

Physical protection systems for a full scale multi-panel operation should include temperature relief systems for the well head, gas detection for flammable and toxic gases, bund areas for excess process water or process liquids and fire protection systems.

Above ground and underground buffer or active zones be established as the final layer of physical protection once the final design for a multi-panel system is known.

The UCG proponents must establish acceptable and agreed decommissioning procedures before proceeding to the commercial phase of operation.

Multi-panel operation requires a full understanding of the site geology and hydrogeology. A systematic design of the multi-panel operation should be undertaken prior to the commencement of any commercial activities.

Specific Recommendation #8

A commercial operation should be designed from the outset on a foundation of well-established principles i.e. a risk-based approach from the outset in all phases of the life-cycle of multi-panel operation.

The Carbon Energy and Linc Energy sites have been operated as pilot sites. Any consideration of commercial activity should be preceded by a comprehensive, multi-panel, risk-based plan.

9 List of Recommendations

9.1 Overarching recommendations

Overarching recommendation 1.

The ISP recommends that the Queensland government permit Carbon Energy and Linc Energy to continue the current pilot trials with the sole, focused aim of examining in a comprehensive manner the assertion that the self-cleaning cavity approach advocated for decommissioning is environmentally safe.

Overarching recommendation 2.

The ISP recommends that a planning and action process be established to demonstrate decommissioning. Successful decommissioning needs to demonstrate the self-cleaning process and/or any necessary active treatment. To achieve this:

1. *A comprehensive risk-based plan for decommissioning must be produced;*
2. *The Plan must take account of the fact that both companies now have connected cavities suitable for demonstration [Linc Energy is still gasifying];*
3. *The Plan must include at a minimum a conceptual model and relevant numerical models, a sampling and verification/validation strategy, and event-based milestones that, where possible, are time bound.*
   Two significant phases are recognised:
   a. *Sampling of the zone surrounding the cavity; and*
   b. *Direct cavity access.*
4. *The government must establish a process by which the plans and their implementation are assessed for adequacy.*

Overarching recommendation 3.

The ISP recommends that until decommissioning is demonstrated, as per Overarching Recommendation #2 no commercial facility should be commenced.

9.2 Specific recommendations

Specific recommendation #1

The government together with the UCG industry and an independent advisory body, should develop guidelines and standards for site selection. The ISP recommends that site selection is a process that should be preceded and informed by appropriate geological surveys, hydrogeological modelling and an assessment of the community and environmental context. Such assessments must serve as Go / No Go gates for decision to develop or not any site for UCG operation, i.e., any limiting factor should signal No Go for the site.

Specific Recommendation #2

The ISP recommends that for each new panel, the UCG industry adopts a 'commissioning' approach rather than 'start-up' or 'ignition' regardless of size or multiplicity, to reduce the risks associated with this phase. Commissioning should involve world's best practice for risk management in process industries including HAZOP, fault tree analysis, event tree analysis, LOPA including all the controls to ensure that the inherent risks of UCG activities are minimised from the outset.

Specific Recommendation #3

If the UCG reaction has been extinguished, then restarting the panel should follow the pre-defined risk protocols. If restart is deemed unacceptable the process should proceed directly to decommissioning and rehabilitation.

Specific Recommendation #4

No further panels should be ignited until the long term environmental safety provided by effective decommissioning is unambiguously demonstrated. Evidence of the effectiveness of decommissioning must be comprehensive.

Specific Recommendation #5

The companies should immediately propose, test and establish acceptable and agreed processes and outcomes for rehabilitation.

Specific Recommendation #6

The ISP recommends that any UCG operation should be licensed on the basis that it is responsible for maintaining and controlling all its operating conditions, taking into account the conditions of the site at the time of approval, including maintenance of groundwater pressure.

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The Carbon Energy and Linc Energy sites have been operated as pilot sites. Any consideration of commercial activity should be preceded by a comprehensive, multi-panel, risk-based plan.

Terms of Reference
Peer Review of Independent Scientific Panel Report into Underground Coal Gasification

Background

1. The Queensland Government appointed an Independent Scientific Panel (ISP) to assist the Queensland Government in the assessment of the technical viability and environmental sustainability of underground coal gasification (UCG).
2. On 30 November 2012, the ISP delivered its final report (the ISP Report) to the Queensland Government.
3. The ISP's three overarching recommendations suggest that the trials should continue for six months, albeit under strict conditions, to effectively demonstrate decommissioning is environmentally safe and sustainable and until decommissioning is successfully demonstrated, no commercial facility should commence.
4. The ISP also provided eight additional specific recommendations, largely relating to the operation of a UCG industry in Queensland.

Peer Review

5. A Peer Review process will be led by Dr Geoff Garrett AO, Queensland Chief Scientist.

Scope

6. The Peer Review will focus on reviewing the ISP Report on UCG to assess the reasonableness of the three overarching recommendations, the eight specific recommendations and the conclusions (including any interim recommendations).
7. This review may result in a consensus perspective which may lead to modifications or additions to the ISP Report.
8. In undertaking these activities, submissions from the trial proponents and the ISP will be considered where relevant to any assessment of the ISP Report.
9. In undertaking the Review the Chief Scientist will engage other experts if and as he deems necessary. He will also be supported by an officer of the Department. The Peer Review process will also involve, as appropriate, technical experts from the UCG trial companies, and member(s) of the ISP, as required.

Key Deliverable

10. A report responding to the matters outlined in section 6 of these Terms of Reference.

Timeframe

11. The key deliverable target is 1 July 2013.

Powder River Basin Resource Council * Sierra Club *
Natural Resources Defense Council * Wyoming Outdoor Council

Via hand-delivery

March 26, 2014

Department of Environmental Quality
Water Quality Division
Attn: Kevin Frederick, Administrator
122 West 25th Street, Herschler Bldg. 4W
Cheyenne, WY 82002

RE: WQD's re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.'s proposed underground coal gasification research and development testing project

Dear Mr. Frederick,

Our organizations retained Stratus Consulting to review Linc Energy's proposed aquifer exemption for the Wyodak coal seam. We are attaching their report. Please review and consider the report as public comments on the proposed aquifer exemption, and please respond fully to the report in your response to comments.

The report finds that the aquifer exemption requested by Linc should not be issued for the following reasons:

- The Fort Union Formation is an important and commonly used regional water supply aquifer in Wyoming;
- The depth, location, yield, and existing groundwater quality of the Wyodak aquifer do not prevent it from being a future drinking water source;
- Hydraulic communication between the overburden, Wyodak, and underburden aquifers exists under current conditions and may become more pronounced as the UCG process proceeds;
- There are a number of technical issues with respect to Linc's calculations in its aquifer exemption application and correspondingly DEQ's statement of basis; and
- Linc and DEQ's proposed groundwater monitoring program is too limited.

The consultants believe those concerns must be addressed before any aquifer exemption could be justified.

For all of these reasons, our organizations want to affirm our strong opposition to this application for an aquifer exemption, and we urge DEQ and EPA to deny the application.

If you have any technical questions related to the report, please feel free to contact the consultants directly: Kaylene Ritter, Connie Travers, and Cameron Wobus, Stratus Consulting, P.O. Box 4059, Boulder, CO 80306, (303) 381-8000. We have attached their biographies to this letter.

Thank you for your time and attention.

Sincerely,

Shannon RA

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KAYLENE RITTER
Position:Managing Scientist
Education: PhD applied chemistry and geochemistry, MS earth sciences, BS earth sciences
Areas of Focus: Natural resource damage assessment, climate change effects and mitigation

Kaylene Ritter is an environmental geochemist with expertise in the fate, transport, and effects of contaminants in groundwaters, surface waters, sediments, soils, and biological resources. She works with state and federal agencies and tribes on natural resource damage assessments (NRDAs), and is involved in regulatory and policy support work related to climate change effects and mitigation. Dr. Ritter has worked on numerous NRDA sites, including ocean and inland oil spill sites, southwestern sites contaminated with metals and radionuclides, and midwestern and eastern urban/industrial sites contaminated with organic and metal pollutants. At these sites, she has provided support in injury assessments, damage assessment, and restoration planning. Her work on climate change effects and mitigation has focused on the evaluation of vulnerabilities associated with the geologic sequestration of carbon dioxide. Dr. Ritter holds a PhD in applied chemistry and geochemistry from the Colorado School of Mines, an MS in earth sciences from the University of Waterloo, and a BS in earth sciences from Laurentian University.

CONNIE TRAVERS
Position:Vice President
Education: MS applied hydrogeology, BS geology
Areas of Focus: Hydrogeology, groundwater contaminant fate and transport, hydrological modeling

Constance Travers is a hydrogeologist with 17 years of experience in hydrogeology, water resources, and environmental chemistry. She has extensive experience in the development, testing, and application of numerical models used in predicting the mobility of water and inorganic and organic contaminants in the subsurface, as well as in surface water. Ms. Travers has developed vadose zone, surface water, and groundwater models ranging in complexity from conceptual hydrologic models to 3-dimensional numerical models of regional flow systems. Her expertise in groundwater flow, contaminant chemistry, and transport and fate processes has been used extensively by litigation teams involved in environmental lawsuits. At sites throughout the United States, Ms. Travers has worked on subsurface fate and transport issues to support site characterization, remedial investigations, and feasibility studies. She has assessed the mobility of free-phase petroleum and dissolved petrochemical constituents at sites in Washington, Pennsylvania, Alaska, Colorado, Texas, and Nevada. At sites in Oregon and Florida, she has evaluated the migration and fate of pesticides in soils and groundwater as part of the assessment and selection of remedial alternatives. Ms. Travers has directed multidisciplinary teams to assess the water quality impacts of mining operations, including assessment of the water quality and ecological risks associated with the lakes that form in dewatered open pits, the effects of tailings impoundments and waste rock storage facilities on receiving waters, and the impact of mine dewatering on groundwater and surface water resources. She has managed hydrologic field investigations including sampling of surface water, sediments, and groundwater; monitoring well installation; cone-penetrometer; and Geoprobe work.

CAM WOBUS

Position:Managing Scientist
Education: PhD earth sciences (geomorphology), MS earth sciences (hydrogeology), AB economics and geology
Areas of Focus: Surface and groundwater hydrology, sediment transport, numerical modeling of hydrologic systems, climate change impacts

Cameron Wobus, managing scientist, is an earth scientist with approximately 15 years of experience in surface and groundwater hydrology, fluvial geomorphology, and numerical modeling. His recent work has focused on climate change impacts to landscapes and ecological resources; for example, he developed a statistical model of flood damages in the United States that was used to estimate changes in monetary damages from flooding under various climate change scenarios. Dr. Wobus modified an existing model of coral reef mortality and bleaching to be used to estimate coral cover trajectories at multiple sites throughout the United States under climate change. He developed models to quantify changes in the magnitude of extreme precipitation events throughout the continental United States to assist water utilities with their preparedness for extreme events. Other projects at Stratus Consulting have included assisting state and federal trustees with quantifying damages from a large oil spill; providing environmental litigation support to the U.S. Department of Justice on Clean Water Act matters; and modeling the hydrology and hydrogeology of proposed mine sites to evaluate the potential ecological effects of hard rock mining. Before joining Stratus Consulting, Dr. Wobus was a research scientist at the University of Colorado, where he was the lead principal investigator on a multi-institution project to quantify the effects of climate change on coastal erosion in northern Alaska. His peer-reviewed articles have appeared in journals such as *Nature, Geophysical Research Letters, Earth and Planetary Science Letters, Geology,* and the *Journal of Geophysical Research.* Dr. Wobus holds a PhD in earth sciences from the Massachusetts Institute of Technology, an MS in hydrogeology from Dartmouth College, and a BA in economics and geology from Bowdoin College.

Memorandum

To: Shannon Anderson and Kevin Lind, Powder River Basin Resource Council

From: Kaylene Ritter, Connie Travers, and Cameron Wobus, Stratus Consulting Inc.

Date: 1/24/2014

Subject: Review of Linc Energy Wyoming's proposed Wyodak Coal aquifer exemption

1. Introduction

Linc Energy Wyoming (Linc) has proposed an underground coal gasification (UCG) research and development project (the demonstration project) for the Wyodak Coal aquifer in the Fort Union Formation in Campbell County, Wyoming. As part of the application process, Linc has requested an aquifer exemption and groundwater reclassification for the Wyodak Coal aquifer in and around their project site. The Powder River Basin Resource Council (PRBRC) has requested that Stratus Consulting conduct a technical review of the aquifer exemption request, based on a review of the following sections of Linc's UCG Research and Development (R&D) Permit Application (Linc, 2013):

- Section 13.14, Appendix D-12 – *Statement of Basis, Wyodak Coal Aquifer Exemption*
- Section 13.7 – Geology
- Section 13.8 – Hydrology.

In addition, we have reviewed aquifer exemption-related public comments and Linc's responses to these comments. We have also cited selected literature, reports, and documents that are relevant to our comments. Our comments in this memorandum are structured as follows:

- Section 2 provides a summary of key findings from our review
- Section 3 provides a brief overview of the proposed UCG demonstration project and aquifer exemption area
- Section 4 provides a summary of the local geology, focusing on the implications of geologic information for UCG operations and hydraulic control
- Section 5 describes the local hydrogeology, including a description of the aquifer units and their hydrologic properties, current aquifer classifications, and groundwater uses
- Section 6 provides a summary of the approach used by Linc to delineate the aquifer exemption area, and our comments on their approach
- Section 7 provides a description the proposed frequency and type of monitoring of the exemption area, and our comments on the proposed monitoring
- Section 8 provides recommendations.

2. Summary of Key Findings

Based on our review of the Statement of Basis, we have the following overarching comments:

- Linc Energy is requesting an aquifer exemption that would allow them to contaminate groundwater in and around the Wyodak Coal aquifer, which is part of the Fort Union Formation. The Fort Union is an important and commonly used regional water supply aquifer in Wyoming. Linc alleges that the depth, location, low yield, and (or) the existing groundwater quality of the Wyodak aquifer preclude future use as a drinking water supply. We disagree.

- Significant heterogeneity is present in the Wyodak and surrounding geologic units. This heterogeneity has implications for calculations of groundwater travel times and the size of the aquifer exemption area. Heterogeneity between these units also has implications for hydraulic communication between aquifers, and for Linc's ability to maintain hydraulic control of UCG operations.

- Hydraulic communication between the Overburden, Wyodak, and Underburden aquifers exists under current conditions and may become more pronounced as the UCG process proceeds because of the effects of the operations on the local hydrogeologic system.

- Water levels in the Overburden, Wyodak, and Underburden aquifers in the project area are currently recovering from coal bed methane operations, with water levels in some wells rising as rapidly as 2 ft/day. For several wells, these water level changes are larger than the drawdown measured during the aquifer tests that Linc's hydraulic calculations rely upon. Linc's hydraulic calculations do not appear to have considered this factor, resulting in inaccurate estimations of key parameters that propagate through all of the aquifer exemption calculations.

- There are a number of technical issues with respect to the calculation of the aquifer exemption, including:

  - The aquifer exemption calculations contain inappropriate assumptions for key parameters, including the distance to excursion wells and the hydraulic gradient used to calculate flow velocities.

  - The aquifer exemption calculations do not sufficiently consider uncertainty. Single values were used in aquifer exemption calculations, ignoring the range of parameter values that would be representative of this natural system.

   - The aquifer exemption request is unclear about which aquifer is being proposed for exemption, and whether this includes the Wyodak aquifer only, or the Wyodak and Overburden aquifers.

- The proposed groundwater monitoring program is too limited [e.g., it does not consider contaminants such as polycyclic aromatic hydrocarbons (PAHs) and benzene, which are likely to be mobilized by the UCG process].

All of the issues identified for this proposed demonstration project would apply and be amplified by any commercial-scale operation.

3. Overview of the Proposed UCG Demonstration Project and Aquifer Exemption Area

Here we provide a brief overview of the UCG process in general, the demonstration project that has been proposed by Linc, and the associated aquifer exemption. Section 6 provides a more detailed description of Linc's approach for delineating the aquifer exemption.

3.1 The UCG Process

UCG is a process by which coal is partially combusted *in situ*, by introducing oxygen or air into subsurface coal seams via injection wells. The introduction of an oxidizing agent creates heat, which initiates a series of chemical reactions that generates a gas primarily comprising hydrogen and carbon monoxide, with smaller amounts of carbon dioxide and methane. This combination of gases, termed "syngas," is extracted via one or a series of production wells, and can be used to generate energy onsite, can be liquefied for later energy production, or can be used as raw materials for a range of petrochemical products. A schematic of the UCG process is shown in Figure 1.

Based on the small number of UCG projects that have been conducted to date, two of the most significant environmental risks appear to be related to groundwater contamination and surface subsidence. The primary contaminants of concern that can be released into groundwater from UCG are organic contaminants such as PAHs, phenols, and benzene, and metals and metalloids that might be present as impurities in the target coal seams or overlying units (e.g., Skousen et al., 2000; Sury et al., 2004; Liu et al., 2006). Subsidence is primarily of concern for UCG projects conducted in shallow coal seams, where combustion of the coal can cause overlying strata to collapse. A more detailed overview of the environmental risks associated with UCG is contained in Section 2 of Stratus Consulting (2010), included as Appendix A to this memorandum.

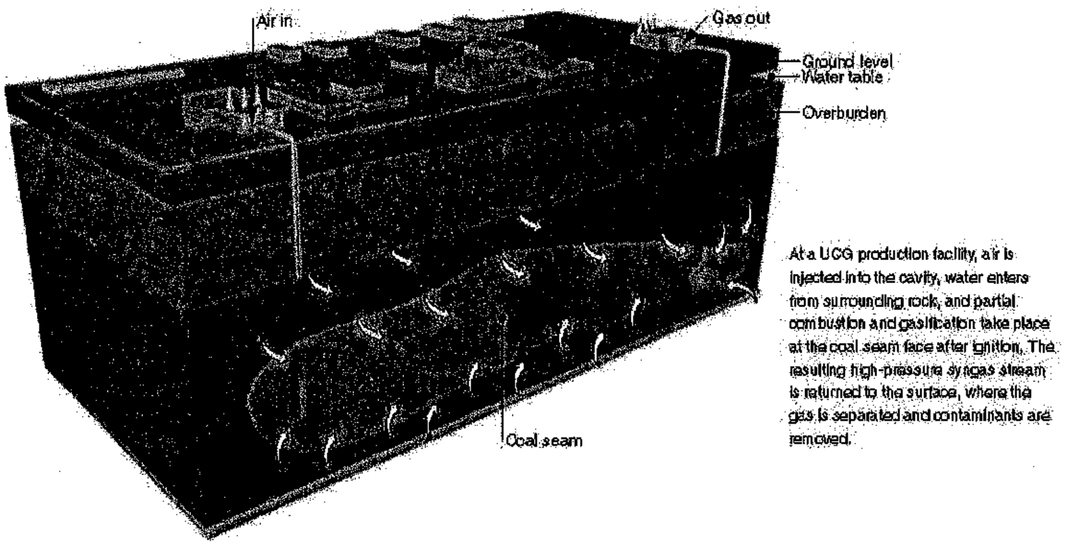

Figure 1. The UCG process.

Source: Walter, 2007.

3.2 Linc's UCG Demonstration Project

Linc is proposing to conduct a UCG demonstration project in the Powder River Basin (PRB). The objectives of Linc's demonstration project are "to prove the technical soundness of Linc's UCG design, operation and restoration procedures, and that UCG can be accomplished in the PRB without adverse environmental impacts" (Linc, 2013, p. 13.14-3). Linc proposes to target the Wyodak Coal aquifer for this demonstration, which is located approximately 1,100 feet below land surface. Approximately 11 to 16.8 tons of coal per day will be consumed to produce approximately one million standard cubic feet per day (MMscfd) of synthesis gas or "syngas" during the demonstration period (Linc, 2013, p. 13.14-3). The demonstration will last 90–120 days (Linc, 2013, p. 13.14-9).

As a part of the demonstration project, Linc has applied for a groundwater reclassification and aquifer exemption for the Wyodak Coal aquifer in the region surrounding their demonstration project. The aquifer exemption would exempt the Wyodak Coal aquifer from protection, in essence allowing Linc to contaminate groundwater in a defined region surrounding their project.

The aquifer exemption would cover a surface area of approximately 80 acres surrounding the demonstration project.

4. Geology of the Project Area and Relevance to UCG Operations

The proposed project area is contained within a 640-acre (1-square mile) section of the PRB, a north-northwest trending asymmetric syncline in northeastern Wyoming. The PRB is bounded by the Bighorn Mountains to the west, the Black Hills to the east, and the Hartville Uplift and Laramie Mountains to the south. The PRB contains up to 18,000 feet of sedimentary rocks, which were deposited in a foreland basin adjacent to the surrounding mountain ranges during the Cretaceous-Tertiary Laramide orogeny (~ 70–35 million years ago). The Wyodak coal seam is one of a number of coals within the Tongue River Member of the Paleocene Fort Union Formation. The Wyodak is a sub-bituminous C to sub-bituminous B rank coal, located approximately 1,100 feet below the land surface at the proposed demonstration site. According to descriptions in Linc (2013), the Wyodak is bounded both above and below by shale and claystones of varying thicknesses.

Overall, the Fort Union Formation is a thick sequence of non-marine sandstone, siltstone, mudstone, shale, and coal (Linc, 2013, p. 13.7-8). The Tongue River Member comprises a sequence of river channel, overbank, floodplain, and swamp deposits, and is 1,000–2,100 feet thick within the PRB. As described in Linc (2013), this type of depositional environment "typically results in a high degree of heterogeneity both laterally and vertically within the deposited strata." (Linc, 2013, p. 13.7-16). Furthermore, "coal deposits vary unpredictably in three-dimensional geometry and thickness as they thicken, thin, merge, split, abruptly terminate, or transitionally wedge out laterally" (Linc, 2013, p. 13.7-10). Figure 2 shows this heterogeneity schematically.

Available borehole logs provide additional information on the degree of heterogeneity within the Tongue River Member in the project area. The Wyodak is described as "24 to 30 feet thick and laterally continuous within the Project Area." However, Linc also notes that "The exception is within the northeast portion [of] the Project Area where it [is] about 12 feet thick" (Linc, 2013, p. 13.14-4). Based on this existing characterization, the thickness of the Wyodak therefore varies by more than 100% over length scales of less than 1 mile.

Much of Linc's interpretation of the stratigraphy also appears to be based on geologic modeling (Linc, 2013, p. 13.7-3). This modeling presumably uses existing data from boreholes to extrapolate between available data points and estimate the thicknesses of geologic units throughout the project area. However, we were unable to find any documentation on the model that was employed, what parameters were used, or the degree of uncertainty in model outputs.

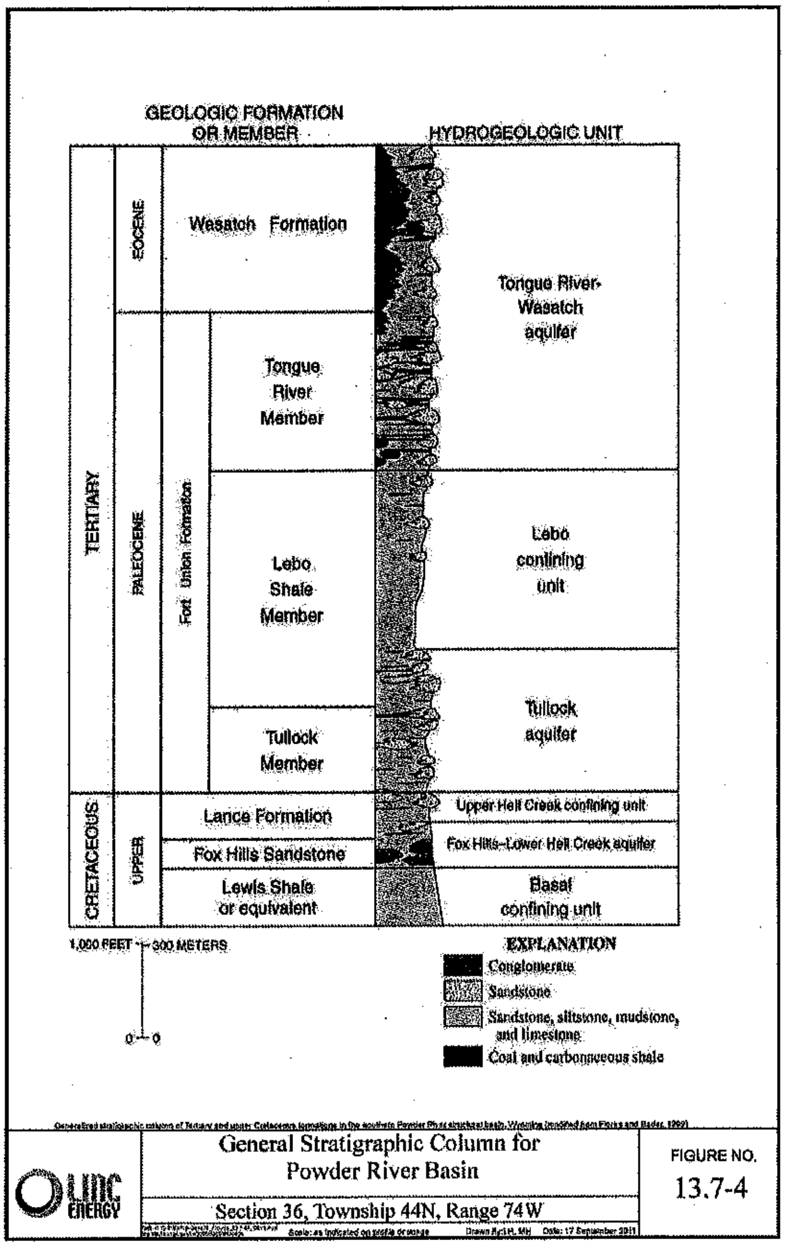

Figure 2. Stratigraphic column of the PRB. Note the high degree of vertical and horizontal heterogeneity shown schematically within the Tongue River Member.

Source: Linc, 2013, Figure 13.7-4.

Thus it is not completely clear from available information that Linc has a detailed enough understanding of the site geology to ensure that hydraulic control can be maintained during UCG development at demonstration project, let alone a commercial-scale operation.

In addition to the heterogeneity within the Wyodak, the depositional environment of the Ft. Union Formation suggests that the low-permeability units separating the Wyodak from overlying and underlying aquifers may also be discontinuous and/or variable in thickness. Although potentiometric surface elevations within the Wyodak and overlying units indicate that the Wyodak is generally hydraulically isolated from the overlying aquifer in the project area, lateral changes in the thickness and/or continuity of the overlying aquitard could lead to leakage between these units over the footprint of a full-scale commercial development. This is further corroborated by the results of the pumping test conducted by Linc, as well as other studies conducted in the area that have shown communication between the Wyodak and the Overburden and Underburden aquifers (see Section 5.3 below). The Queensland Independent Scientific Panel (ISP) report on UCG pilot trials also suggests that the UCG process itself can compromise the integrity of confining layers above the UCG cavities (Moran et al., 2013). Hydraulic separation between the UCG target formation, the Wyodak, and the surrounding aquifers is therefore not assured for Linc's demonstration project, or for commercial-scale operation.

5. Local Hydrogeology and Groundwater Use

5.1 General Hydrogeology

The hydrostratigraphy of the PRB results in a series of sand and coal aquifers separated by lower permeability claystone and shale units. From the ground surface, the following aquifers are present in the basin (Linc, 2013, p. 13.18-13):

- Surficial Water Table aquifer
- Felix Coal aquifer
- Lower Wasatch aquifer
- Edgerton aquifer
- Upper Fort Union aquifer
- Big George Coal aquifer
- Big George Underburden Sand aquifer
- Overburden aquifer
- Wyodak Coal aquifer
- Underburden aquifer.

The Edgerton and the six aquifers underlying it are part of the Fort Union Formation (Linc, 2013; Figure 13.7-3), which is an important regional aquifer used for municipal water supply. The importance of this aquifer is described in the Gillette Area Water Master Plan:

> The Fort Union Formation is one of the most prolific Tertiary-age fresh water aquifers in the arid western half of North America. Certainly within the state of Wyoming, and the Powder River Basin in particular, people and industry are highly dependent on this seemingly inexhaustible and exceptional quality ground water. This is especially true when the almost total lack of surface water supplies in this area is considered (WSEO, 1995, p. 3-1).

The Water Master Plan notes that there are other geologic formations in the area, such as the underlying Fox Hills and Lance formations, and overlying Wasatch Formation that produce water, but these aquifers "are not proven to provide the quality of water that the Fort Union Aquifer provides" (WSEO, 1995, p. 3-6). The City of Gillette, located 35 miles to the north of the proposed demonstration project area, relies on groundwater pumped from the Fort Union Formation for municipal supply. Well logs for Gillette supply wells indicate that they are generally constructed by perforating the wells in multiple, higher-permeability zones within the Fort Union Formation, and thus, multiple aquifers contribute to the water supply. The Town of Wright, located 10 miles to the east of the proposed UCG demonstration project, relies on four wells completed in the Fort Union Formation for municipal supply (WWDO, 2013).

5.2 Wyodak Coal Aquifer

The Wyodak Coal aquifer "has been designated an aquifer in the sense that it is an underground source of drinking water as defined by UIC regulations" (Linc, 2013, p. 13.4-6). Coal beds in the PRB are often the most permeable aquifers and are preferred for groundwater development (Bredehoeft, Undated). As described above, the Wyodak unit is approximately 30-feet thick, extending from 3,910 to 3,880 feet NVGD, although it thins to 12-feet thick in the northeast portion of the permit area.

The Wyodak Coal aquifer is confined, and overlain and underlain by claystone and shale units. The confining unit above the Wyodak is approximately 15–30 feet thick and the unit beneath the Wyodak is about 20-feet thick (Linc, 2013, p. 13.8-14). These lower-permeability units separate the Wyodak from the Overburden and Underburden aquifers. The potentiometric surface of the Wyodak has been lowered from coal bed methane (CBM) development, which began in 1997, and it currently ranges from about 4,320 to 4,330 feet NVGD within the permit area. CBM production from the Wyodak at the site has been discontinued and groundwater levels in the Wyodak are recovering. As reported by Linc (2013, p. 13.8-20):

> The Overburden well hydrographs trended slightly downward throughout 2011; those with the longest record showing a decline of one to five feet. The Wyodak well with the best record, 13MW19-WD, showed a steady water level rise from February 2011 through January 2012, a total of 72 feet, averaging 0.21 ft/day. This trend was confirmed by four Wyodak test observation wells, which experienced water level increases of from 45 to 55 feet from June through December 2011. The Underburden monitoring wells all experienced declines from January through December 2011, exclusive of data affected by pumping or well construction activities. Declines ranged from six to 34 feet and averaged about 16 feet over this period. The hydrographs from the three deep aquifers showed rising Wyodak levels with corresponding declines in the Overburden and Underburden, demonstrates the ongoing trend of hydraulic head recovery in the Wyodak following cessation of CBM-related pumping.

Potentiometric levels within the Wyodak in the vicinity of the gasifier cavities are about 320 feet lower than the underlying Underburden aquifer and about 85 feet lower than the overlying Overburden aquifer. According to data presented in Linc's license application, groundwater levels in the Wyodak are still 300 feet below pre-CBM development levels. The maintenance of steep, vertical hydraulic gradients between the units indicates that shale and claystones that separate the Wyodak from the Overburden and Underburden aquifers have relatively low permeability and generally act as confining layers.

5.2.1 Wyodak Hydraulic Properties

The primary (matrix) porosity of the Wyodak Coal aquifer is relatively low, but permeability is present as a result of fractures in the coal, which occur along bedding planes and in sets known as cleats. Groundwater flow is primarily through these fractures within the coal, and cleat geometry may result in anisotropy and preferential flow directions within the coal layer (Linc, 2013, p. 13.14-7).

At the proposed Gasifier 6 site, Linc conducted two pumping tests to evaluate the properties of the Wyodak aquifer. The first test failed because of leakage into an improperly sealed well, so we did not evaluate these results. Based on the second aquifer test, Linc estimated Wyodak transmissivity values ranging from 0.57 to 1.8 ft^2/day. Assuming the thickness of the Wyodak is 30 feet, these transmissivity values indicate that the horizontal hydraulic conductivity ranges from 0.02 to 0.06 ft/day.[1] A single hydraulic conductivity value of 0.06 ft/day was used in the aquifer exemption calculations.

1. Transmissivity (T) is the product of the hydraulic conductivity (K) and aquifer thickness (b). Thus, the hydraulic conductivity can be estimated by dividing the transmissivity by the aquifer thickness (K = T/b).

We have two concerns about the aquifer testing and how these data were used to determine the aquifer exemption area:

1. It does not appear that Linc's analysis of the aquifer test considered the rising water levels in the Wyodak as these wells recover from CBM depletion. No mention is made of the rising water levels in the sections of the document that describe the pumping tests, although increasing water levels are evident in many observation wells in early monitoring times. For example, water levels in observation well OW-30 were increasing at a rate of approximately 2 ft/day from January 27, 2012 through January 29, 2012, and then they began to decline, probably in response to pumping at TR44 that was initiated on January 27, 2012 (see Linc, 2013, Addendum 13.8-D1). Because analysis of the aquifer testing is based on water level changes in observation wells, ignoring the regional groundwater level rise during the pumping test could cause Linc to inaccurately estimate the transmissivity and hydraulic conductivity of the aquifer. This propagates into the aquifer exemption calculations because the estimated hydraulic conductivity is used to estimate both groundwater flow rates and the distance contaminants can be transported by the groundwater over a given time period.

2. Methods used by Linc to analyze the aquifer tests (Theis and Papadopulos-Cooper) are appropriate for the analysis of groundwater flow in a porous medium. However, as described in the Linc application, flow in the Wyodak is primarily in fractures, so these hydraulic analysis methods may be less appropriate for estimating aquifer properties in the Wyodak. In the application, Linc should have addressed the issue of whether the fractured Wyodak can be assumed to behave as a porous medium, and what the implications are for flow and contaminant transport in preferential flow paths created by the fractures.

Literature studies of the Wyodak aquifer hydraulic properties indicate that the hydraulic conductivity values obtained from the site pumping test are lower than mean values obtained from other aquifer tests. A U.S. Geological Survey report (Bartos and Ogle, 2002) summarized three previous studies that evaluated the hydraulic conductivity of the coal bed aquifers in the PRB using results from hundreds of aquifer tests. All three studies found that the data were logarithmically distributed, with geometric means of 0.5 ft/day (Peacock, 1997); 0.8 ft/day (Martin et al., 1988), and 0.9 ft/day (Rehm et al., 1980). Furthermore, Linc cites regional groundwater studies that indicate that the Anderson Coal aquifer (the coal aquifer is often referred to as the Wyodak-Anderson coal zone) has a hydraulic conductivity of 3 ft/day (Linc, Table 13.8-5). This information suggests that the hydraulic conductivity of the Wyodak aquifer may be an order of magnitude higher than indicated by Linc's analysis of a single pumping test in their proposed demonstration project area. An order of magnitude higher hydraulic conductivity would result in an order of magnitude faster travel time, which means that contaminants could potentially travel much farther than estimated by Linc in their transport analysis for the exemption area.

5.3 Hydraulic Communication between the Wyodak and the Overburden and Underburden Aquifers

As described in Section 4, the geologic setting of Linc's proposed demonstration project is one in which lateral heterogeneity is likely to create zones of hydraulic communication across aquifers. The literature also suggests that there may be hydraulic communication between overlying units and the Wyodak Coal aquifer; however, this possibility is not adequately explored in the aquifer exemption application. Linc states,

> "There is potential for leakage through the aquitard where groundwater levels in the Fort Union are lower than the Wasatch. A study of paired wells determined a small amount of leakage from a 40 foot thick claystone separating a sandstone aquifer above from a pumped coal below (AHA and GEC, 2002)" (Linc, 2013, p. 13.8-11).

In addition, Linc states that the Wyodak Coal aquifer is surrounded by "impervious over and underburden" (Link, 2013, p. 13.14-B3). However, groundwater modeling conducted for Wyoming and reviewed by Dr. John Bredehoeft (Bredehoeft, Undated) indicates that there is hydraulic communication between the coal bed aquifers in the Fort Union Formation, such as the Wyodak and the overlying Wasatch aquifer. Modeling shows that groundwater pumping in coal aquifers results in water level declines in the coals as well as within the Wasatch, but that declines in the Wasatch water level may lag those in the coal bed aquifers (Bredehoeft, Undated). At the proposed UCG demonstration site, leakage analysis conducted by Linc (2013, Table 13.8-7) for observation wells during their Wyodak pumping test indicated some leakage from surrounding units (overlying or underlying) during the test. In addition, groundwater levels in the Overburden and Underburden are still decreasing as the result of CBM production in the Wyodak (Linc, 2013, p. 13.8-20), indicating that there is some hydraulic connection between the Wyodak and these units.

Furthermore, hydraulic communication between the Wyodak and the Overburden may be enhanced by UCG production, due to fractures in the overlying units and collapse of these units into cavities formed by the UCG process. The license application does not address the potential for increased hydraulic communication between the Wyodak and overlying aquifers, and potential creation of pathways, following the completion of the UCG process. As noted above, the Queensland ISP report on UCG pilot tests in Australia found that this is a risk of UCG, as it can create an escape pathway for contaminated water (Moran et al., 2013, p. 38).

5.4 Groundwater Classification Based on Current and Future Use

Conditions for EPA to exempt an aquifer from protection are if "it does not currently serve as a source of drinking water" and "it cannot now and will not in the future serve as a source of drinking water because it is mineral, hydrocarbon, or geothermal energy producing, or it can be demonstrated by a permit applicant as a part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible" [40 C.F.R. 146.04].

Linc's permit application states that "No potable-use wells are located within a three-mile radius of the Project Area. There are 18 wells outside the Project Area but within three (3) miles (plus one listed as cancelled). These wells are listed as CBM wells, CBM/Stock wells, monitor wells or 'miscellaneous.' Except for some of the CBM and CBM/Stock wells, none produce from the Wyodak aquifer" (Linc, 2013, p. 13.14-5).

Linc (2013, p. 13.14-B3) also argues that the Wyodak Coal aquifer is not now and will not likely be a source of drinking water supply because of its depth, location, and low yield (1 gallon per minute), which "makes recovery of water for drinking water purposes economically impractical."

We have several comments on this argument:

- It is unclear how Linc has estimated the yield of the Wyodak Coal aquifer. The technical basis for this yield is not provided, nor does Linc provide the spatial area of the Wyodak over which they assume this yield applies.
- Because of heterogeneity in the coal aquifer, there will be variability in the yield of wells completed in the Wyodak, and it cannot be assumed that all wells will have a yield below 1 gallon per minute. Furthermore, relatively low-yield wells (1 gallon per minute) can still be used for domestic purposes.
- The available data suggest that the wells are being used for stock purposes, so clearly the depth is not precluding pumping from the aquifer.
- A well completed for water supply purposes could span and tap several Fort Union Formation aquifers, including the Wyodak, which is how the municipal wells in Gillette are configured. In this situation, contamination in the Wyodak could compromise the water quality of the entire supply well.
- As acknowledged in the Statement of Basis, "the Wyodak has been designated an aquifer in the sense that it is an underground source of drinking water as defined by UIC regulations" (Linc, 2013, p. 13.14-6).

These factors indicate that although the Wyodak Coal aquifer in the vicinity of the project area is not currently being used as a drinking water source, it could be used for this purpose in the future.

5.5 Groundwater Quality

As a justification for exempting the Wyodak from aquifer protection, Linc states that "...comparing groundwater chemistry of Wyodak groundwater at the Project Area to the criteria presented in Wyoming Water Quality Rules and Regulations, Chapter 8, Table 1-Underground Water Class; groundwater in the Wyodak aquifer would be considered Class III (stock). WDEQ (Wyoming Department of Environmental Quality) can classify the water as Class I based on the technical practicability and economic reasonableness of treating ambient water quality to meet use suitability standards. In this case, Wyodak groundwater is found closely associated with commercial deposits of minerals and is Class V (Mineral Commercial)" (Linc, 2013, p. 13.14-6).

Linc also states that "...ambient concentrations of iron (Fe), manganese (Mn) and Total Dissolved Solids (TDS) in the Wyodak aquifer samples exceeded the maximum concentrations for Class I groundwater. The Sodium Adsorption Ratio (SAR) in the samples exceeded the maximum concentration for Class II groundwater as does, in some samples, Residual Sodium Carbonate and iron" (Linc, 2013, p. 13.14-6).

These statements raise two issues. First, WDEQ has the sole authority to classify groundwater, and it is not appropriate for Linc to independently determine the classification of this water. Although iron, manganese, and TDS levels in the three wells summarized slightly exceed U.S. Environmental Protection Agency (EPA) secondary maximum contaminant levels (MCLs), exceedence of secondary MCLs, which are based on aesthetic properties of the groundwater, does not preclude groundwater from being used as a drinking water supply (Linc, 2013, Table 13.8-10). As noted by Linc, WDEQ can classify the water as Class I based on the technical practicability and economic reasonableness of treating ambient water quality to meet use suitability standards. Groundwater with somewhat elevated iron and manganese could be treated to remove these constituents, if necessary. The ambient water quality in the Wyodak does not preclude WDEQ classifying these waters as Class I or II.

6. Linc's Approach for Defining the Aquifer Exemption Area

Linc (2103, p. 13.14-2) proposes to set the horizontal boundary for the aquifer exemption area based on:

- The location of excursion wells that will be installed surrounding the gasifier cavity to monitor for groundwater contamination during and after the pilot test
- An additional "reasonable" distance beyond the excursion well perimeter that was calculated using a "science-based" approach.

Our comments on Linc's delineation of the aquifer exemption fall into three broad categories:

1. The aquifer(s) to be included in the exemption
2. The rationale for the placement of the excursion wells (the location of which largely sets the exemption area)
3. The types of calculations and values for input parameters used in the "science-based" approach to establish the distance beyond the excursion wells area to be included in the exemption.

6.1 Aquifer(s) included in the Exemption

The Statement of Basis contains contradictory statements about which aquifers Linc intends to exclude from regulation. According to Linc (2013), the Statement of Basis "is intended to support classification of the Wyodak Coal aquifer in the vicinity of the R&D facility as Class V (Mineral Commercial) and for provision of an aquifer exemption for that portion of the Wyodak." However, in the "Definitions and Acronyms" section, the aquifer exemption area is defined as "the Wyodak Coal and Overburden Aquifer within a 100 foot radius of the perimeter of the Gasifier 6 Trend and Excursion Wells" (Linc, 2013, p. xv). It is not clear whether the exemption area is intended to include only the Wyodak aquifer, or both the Wyodak and Overburden aquifers. This needs to be clarified in the Statement of Basis.

Based on our review, the Overburden and possibly the Underburden aquifers should be included in the exemption. These aquifers should be included for several reasons, including:

- The Wyodak is separated from the Overburden and Underburden aquifers by low-conductivity confining units. However, as noted above, there is evidence for at least some communication between the aquifers across the confining units. This means that there may be pathways between the Wyodak and overlying and underlying aquifers along which contaminants could migrate.

- The UCG process itself may compromise the integrity of the confining layer that directly overlies the Wyodak, potentially creating new pathways to the Overburden aquifer. As noted above, this was found to be the case in the Queensland, Australia UCG pilot trials (Moran et al., 2013).

We further note that the overlying and underlying aquifers likely have different hydrogeologic properties than the Wyodak, including different hydraulic conductivities and hydraulic gradients. For example, aquifer test results from the sandy Overburden aquifer indicate that the aquifer transmissivity is highly variable, but that sections of the Overburden aquifer may be more transmissive than the Wyodak (Linc, 2013, Table 13.8-6). This could result in faster travel times for contaminants in this unit than in the Wyodak and, thus the exemption area in this unit may need to be larger than that in the Wyodak.

6.2 Rationale for Placement of Excursion Wells

According to the Statement of Basis, the horizontal boundary for the Wyodak aquifer exemption area was determined based on "the location of the Wyodak excursion wells and a science-based calculation to establish a reasonable distance beyond the excursion well perimeter" (Linc, 2013, p. 13.14-2). The science-based approach is based on the sum of (1) the distance a contaminant plume, or "excursion" could travel between two excursion wells prior to being detected at one of the wells; (2) the additional distance the excursion could travel during the time it would take to enact recovery operations; and (3) a factor that accounts for heterogeneities in the subsurface. The position of the excursion wells largely defines the exemption area, and the additional distance calculated using the science-based approach makes a comparatively small addition to the exemption area. The placement of the excursion wells is therefore particularly important to setting the exemption area.

6.2.1 Excursion well distance

Linc proposes to place the excursion wells in an oval-shaped configuration at a distance of approximately 600 feet from the gasifier (Figure 3). According to Linc, this configuration is based on (1) experience at other sites, and (2) fate and transport analyses conducted by Linc.

- *Experience at other sites*: Linc states that based on their own UCG experience at other sites, and the results of the Rocky Mountain 1 UCG test (conducted in the late 1980s, near Hannah, Wyoming), a zone of elevated product gas concentration and pressure commonly extends into the coal surrounding a gasifier cavity. They further state that based on the Rocky Mountain 1 test, WDEQ-LQD recognized that a flare zone in proximity to the gasifier cavity is associated with UCG operations, and recommended that monitoring wells be placed at least 600 feet from any gasifier cavity. While considering experience and knowledge gained from other sites is good practice, monitoring plans and well configurations should be based on site-specific conditions, including the local hydrogeologic properties and site-specific operating conditions. It is difficult to assess whether the 600-foot distance will be sufficient for this site, based solely on experience at different sites that likely had different hydrogeologic and operating conditions.

Contaminant fate and transport analysis: Linc states that they conducted contaminant fate and transport analysis in the Wyodak, Overlying, and Underlying aquifers of chloride and benzene, to assist in determining the size of the exemption area (Linc, 2013, p. 13.14-16). For chloride, they report that a concentration of 25 mg/L chloride (emanating from a continuous 500 mg/L source) is estimated to travel 200 feet from its source in the Wyodak aquifer in 5.8 to 10.8 years; in 31.8 to 187 years in the Overburden aquifer, and 9.4 to 26.2 years in the Underburden aquifer. These results would suggest that the aquifer exemption area will adequately encompass any area that would be contaminated if an excursion were to occur. However, Linc does not provide any information on their calculations, input parameters, nor the values for input parameters. This makes it difficult to assess the reported travel times for contaminants. If Linc used the same values for hydraulic parameters such as hydraulic gradient and hydraulic conductivity as they did for their calculation of the exemption area beyond the excursion wells, then the comments we make below on those values (see Section 6.3) would also hold true here.

6.2.2 Overburden and Underburden excursion wells

The trend and excursion wells are screened at different depth intervals to enable monitoring of the groundwater in the Wyodak, Overburden, and Underburden aquifers (and in the case of the trend wells, to allow the injection of water into the Overburden and Underburden aquifers to maintain slight inward gradients toward the Wyodak). All of the wells that form the excursion well perimeter are screened in the Wyodak. The only excursion wells that are screened in the Overburden and Underburden aquifers are those located to the northwest of the oval.

It is unclear why the Overburden and Underburden aquifer excursion wells are only placed in one area of the site. During operations, Linc plans to inject water into the Overburden aquifer to maintain the pressure head such that it is just slightly greater than that in the Wyodak (Linc, 2013, p. 15–9). Given that the regional potentiometric surface is much lower than that currently in the Wyodak (85 feet lower; see Section 5.2), the injection of water could result in a zone of higher pressure heads in the demonstration area, surrounded by lower regional heads in the

Overburden away from the project site. Contaminants entering the Overburden aquifer (e.g., as the result of an operational gas flare) could thus migrate laterally away from the demonstration project. Without wells screened in this aquifer, an excursion would not be detected.

As noted above (Section 6.1), the Overburden aquifer (and possibly Underburden aquifer as well) should be included in the aquifer exemption, and excursion wells should also be screened in these formations. Furthermore, the location and spatial configuration of such Overburden and Underburden excursion wells should be dictated by their hydrogeologic properties, and thus may need to be different than the configuration in the Wyodak (see comments above in Section 6.1).

6.3 Calculation of Area beyond the Excursion Wells to be Included in the Exemption Areas

The "science-based" method of calculating the aquifer area beyond the excursion wells was adopted from aquifer exemption calculations developed for uranium In-situ Recovery (ISR) operations, including the Lost Creek Uranium ISR operation in Wyoming, and the Dewey-Burdock Uranium ISR operation in South Dakota (Linc, 2013, p. 13.13-A3). We have a general comment on the method applied by Linc, and specific comments on each of the three components of the calculation, which are discussed below.

6.3.1 Using ISR methodology at a UCG site

The method applied by Linc was originally developed to calculate aquifer exemption areas for uranium ISR operations. There are some parallels between ISR and UCG operations; however, there are also differences. For example, at ISR sites there is typically a concentric ring of injection wells used to inject chemicals into the subsurface that react with the uranium ore, and a central production well used to extract the uranium. In contrast, the proposed UCG demonstration project involves a more linear configuration, with a horizontally drilled injection well that sequentially burns cavities, aligned with a production well to capture the produced gases (see Figure 3), and surrounded by trend wells in the overlying and underlying aquifers to be used to control pressure. Therefore, it is not clear if the operating conditions or the pressure regimes in ISR and UCG systems are comparable. Linc does not provide their reasoning to justify the use of an ISR methodology to calculate the aquifer exemption area for this UCG project.

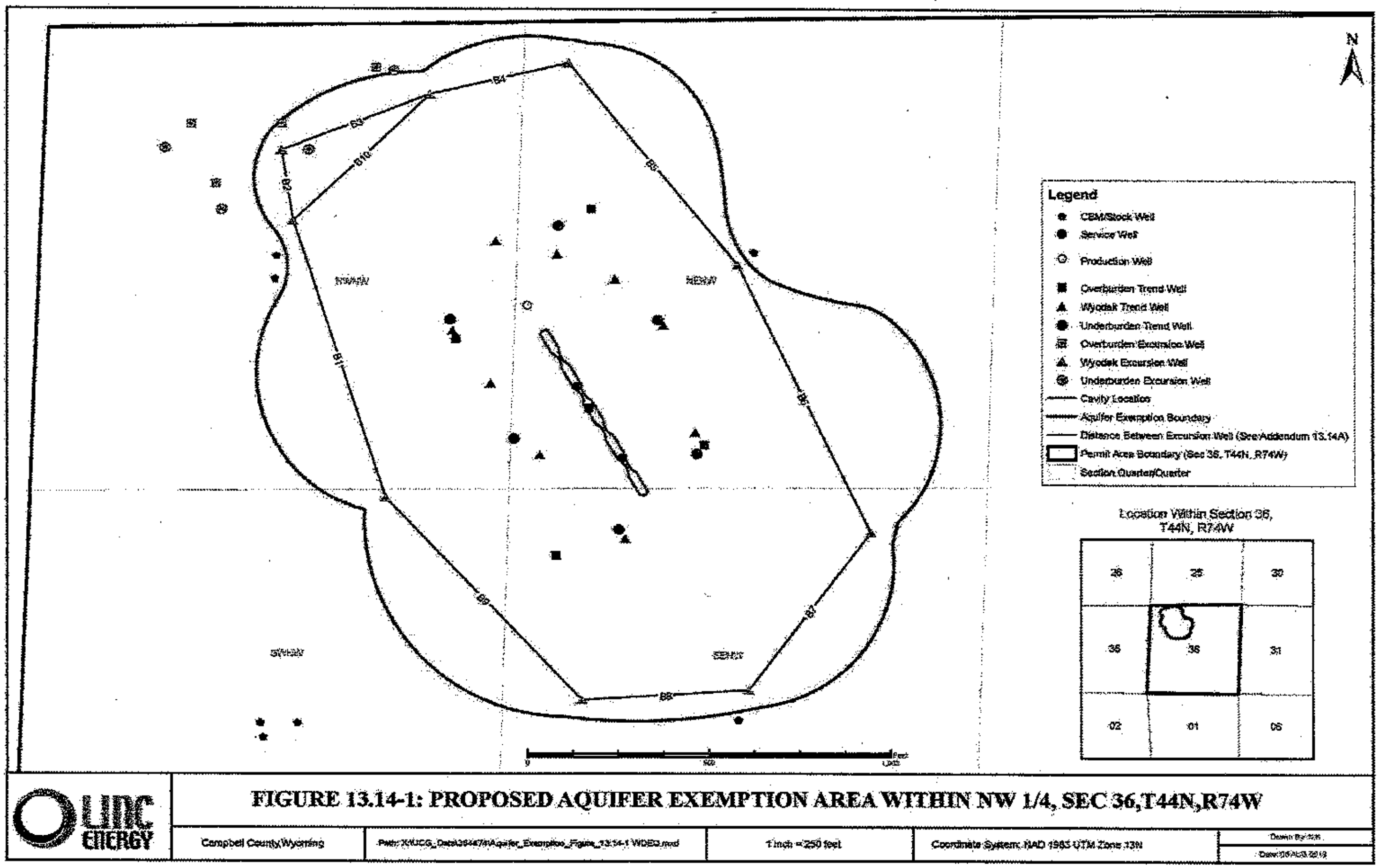

Figure 3. Linc's proposed aquifer exemption area, and trend and excursion wells.

Source: Linc, 2013, Figure 13.14-1.

6.3.2 Calculation of the distance a potential excursion could extend prior to detection at

one of the two wells was calculated assuming (1) the aquifer is homogenous and isotropic (i.e., has uniform aquifer properties in the lateral and vertical directions), (2) the flow is radial, and (3) the discharge rate and the hydraulic gradient remain constant from the time the excursion reaches the excursion well outline to the time it is actually detected at an excursion. The first two of these assumptions are related, and we have the following comments with respect to their applicability for Linc's proposal.

Based on information contained in the Statement of Basis, the Wyodak does not appear to be homogeneous or isotropic. Groundwater flow in the Wyodak is primarily through fractures within the coal, which can occur along bedding planes, as a result of structural deformation, and along cleats. Linc states that "The nature of cleat geometry, with face cleats continuous and butt cleats terminating at face cleats, often results in an anisotropic aquifer system" (Linc, 2013, p. 13.14-7). Therefore, the assumption of a homogeneous and isotropic aquifer may not be appropriate at this site.

As a result of this anisotropy, flow is unlikely to be radial in this setting. Instead, contaminants may preferentially flow in one direction, and/or follow narrow, fracture-controlled preferential pathways that could pass between excursion wells. Such pathways could allow contaminants to travel much faster and reach much greater distances before detection than would be otherwise predicted assuming homogeneous, isotropic, radial flow. Therefore, Linc's calculations could significantly underestimate the distance a contaminant could travel beyond the excursion wells, prior to being detected at a well.

6.3.3 Calculation of the distance an excursion could travel from the time of detection until recovery operations begin

Linc also calculates how far a contaminant, once detected at an excursion well, could travel in the time required to initiate recovery operations. This calculation assumes it requires 30 days to implement a corrective action after detection of an excursion, and another 30 days to complete the remediation (total of 60 days). The distance an excursion could travel in this time is calculated by estimating the velocity of the excursion in the groundwater (feet per day), and then multiplying by the total number of days. The equation Linc uses to calculate the velocity of the excursion, the Darcy equation, is based on flow in a porous medium, and requires estimation of the hydraulic gradient, the hydraulic conductivity, and the porosity of the formation. We have four comments about the use of this equation and the parameter values chosen:

1. *Assumption of porous medium flow*: As noted above, the assumption of flow in a porous medium may not be a valid assumption for the Wyodak Coal aquifer, given that it is fractured, cleated coal. In fractured rock aquifers, hydraulic conductivity can range over several orders of magnitude, and groundwater velocities within the fracture network can be quite rapid (Sara, 2010). Fracture-dominated flow could be substantially faster than what would be predicted with the Darcy equation, and an excursion could therefore travel substantially farther than predicted by the Darcy equation.

2. *Value used for hydraulic gradient*: The hydraulic gradient used in the velocity calculation (0.02) was based on the gradient observed during a pumping test (described above in Section 5). It is not clear why a gradient that was measured during a pumping test was used in a calculation to predict travel distances during the UCG demonstration project. A more appropriate approach would be to predict gradients that would exist during the UCG test and, during cavity flushing, use those gradients in the calculation to predict the distance an excursion might travel during the test. If Linc is using the gradient observed during the pump test as a proxy for gradients expected during UCG operations, they should be explicit about this assumption.

3. *Value used for hydraulic conductivity*: In the Linc calculation, a single hydraulic conductivity value of 0.06 ft/day is used. As described in Section 4, this value is approximately an order of magnitude lower than literature-reported values for this unit, and may be inaccurately estimated due to issues with how Linc interpreted their pump test data. If the hydraulic conductivity used in Linc's calculations is too small, this would result in an underestimate of the distance an excursion could travel in the time required to initiate recovery operations. It is not unusual for hydraulic conductivity values to range by more than an order of magnitude in any given formation. As such, Linc should incorporate a range of hydraulic conductivity values in their calculations to address this natural variability.

4. *Approach to addressing uncertainty:* The only method used by Linc to address uncertainty is to increase the excursion distance by 10% to account for "variability and uncertainty" in subsurface conditions (Linc, 2013, p. 13.14-A5). This factor is described by Linc as an attempt to include the process of longitudinal dispersion of a contaminant plume. However, increasing the travel distance by 10% does not account for the range of heterogeneity in a fractured system, where hydraulic conductivities and travel times could range by several orders of magnitude.

7. Constituents to be Monitored

In addition to describing the configuration of the excursion well network, the aquifer exemption application includes a description of the constituents to be monitored and the frequency of monitoring at each excursion well. The plan includes monitoring of specific conductivity, temperature, and potentiometric level at frequent intervals and an "excursion" is defined as a change in hydraulic gradient; a change in specific conductivity of more than 80 μmhos/cm, or a change in temperature of more than 1°C over a 24-hour period. Monitoring of additional constituents is proposed only at the start and finish of operations, and if excursions are indicated in these other parameters.

Based on this list of constituents to be monitored, it is possible that groundwater contamination could migrate beyond the excursion well network without being detected. For example, although some of the contaminants of concern that could be generated from UCG would be expected to generate a specific conductivity excursion (e.g., metals, sulfate), many of the primary contaminants of concern generated from UCG at other sites might not create a substantial conductivity signal. At Hoe Creek, for example, the primary contaminants of concern for groundwater were organic compounds such as PAHs, coal tars, benzene, toluene, ethylbenzene, and xylene (Burton et al., Undated). Many of these constituents might not generate a substantial specific conductivity excursion, and could therefore pass the excursion well network undetected, based on the current design. For example, the EPA drinking water MCL for benzene is 0.005 mg/L, yet concentrations significantly exceeding this concentration would not substantially alter the specific conductivity.

In addition, although Linc indicates that their groundwater monitoring plan was developed "based on the experiences of the Rocky Mountain 1 UCG test" (Linc, 2013, p. 13.14–17), available information from the Rocky Mountain site indicates that their monitoring plan was significantly different. The list of constituents monitored at the Rocky Mountain site was more comprehensive. For example, the summary report from the Rocky Mountain UCG test notes that "[s]amples from the inner ring of monitoring wells were analyzed for ammonia, boron, cyanide, phenols, TDS, and TOC (the parameters historically associated with UCG groundwater contamination)" (Dennis, 2006, p. 20). We recommend that the list of monitored constituents be similarly expanded for the Gasifier 6 site.

8. Recommendations

The UCG process has the potential to generate fuel from the Wyodak coal, one of many otherwise unrecoverable coal seams in the PRB. Given the number of other similar coal seams in the PRB, Linc's demonstration project would presumably lay the groundwork for expansion to commercial operations in the Wyodak, and potentially into other coal seams in the region.

Because the UCG process occurs deep enough that it cannot be directly observed, a thoughtful groundwater monitoring and control plan is essential to protect Wyoming's limited groundwater resources from potential contamination. As currently written, Linc's request for an aquifer exemption in the Wyodak aquifer has a number of shortcomings. In addition, the proposed monitoring plan for the UCG demonstration project could be improved by the following changes:

- The location of the excursion wells should be based on a scientific assessment of how far an excursion could be expected to travel under UCG operating conditions, not simply based on past experience from other sites with dissimilar conditions.
- Hydraulic calculations used to determine potential contaminant travel distances and to set the exemption area should explicitly incorporate transient conditions in the groundwater system, both from the current groundwater recovery of water levels from CBM operations and from projected UCG operations.
- Monitoring should be more extensive in the Overburden aquifer, and the aquifer exemption area should explicitly include the Overburden aquifer, since there are a number of ways that communication could occur between aquifers during UCG operations.
- The list of constituents to be monitored should include those most commonly associated with UCG operations to improve the chances of detecting an excursion.

Given the type of geologic heterogeneity present at this site, it is not clear that sufficient characterization could ever be done to ensure that no contamination from UCG operations escapes the exemption area. This would become especially difficult at the commercial scale. However, consideration of the above points could improve the chances of detecting and controlling potential excursions from this process.

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Potential Environmental Impacts of the Proposed CIRI Underground Coal Gasification Project, Western Cook Inlet, Alaska

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SC11967

A. Potential Environmental Impacts of the Proposed CIRI Underground Coal Gasification Project, Western Cook Inlet, Alaska

Stratus Consulting Inc., 2010

1. Introduction

Cook Inlet Region, Inc. (CIRI) has proposed a combined underground coal gasification (UCG), onsite power generation, and carbon capture and sequestration (CCS) project on CIRI-owned lands on the west side of Cook Inlet, Alaska (the site). Because the project is in an early phase of development, information describing the specifics of the CIRI project is limited at this time. In particular, the site geology has not yet been well characterized; the particular coal seams targeted for gasification have not been described; and the locations of carbon sequestration repositories have not been identified. Despite the lack of specificity surrounding this particular project, there are general environmental risks associated with UCG and CCS, many of which may apply to this site.

Stratus Consulting was retained by the Center for Science in Public Participation to summarize the potential environmental risks associated with UCG and CCS in general, and the CIRI proposed project in particular. This document provides a summary of these general and site-specific issues to the extent possible given currently available site information. Many of the risks and potential adverse impacts discussed herein are common across UCG and CCS. While both technologies are relatively young, there is a greater body of literature on CCS than UCG. We have summarized the risks for each technology here separately, based on the available literature on each technology. Some of the more detailed information currently available in the literature on CCS risks and summarized here, associated for example with wells, faults and fractures, is also likely applicable to UCG operations.

This report is organized as follows:

- The remainder of Section 1 provides an introduction and brief overview of the proposed project, as well as a general summary of the proposed technologies
- Section 2 provides a summary of the potential environmental risks associated with UCG, along with a review of lessons learned from pilot projects around the world
- Section 3 summarizes the potential environmental risks associated with CCS, with examples from pilot projects around the United States and the world
- Section 4 summarizes the limited information available on CIRI's proposed project, as well as an overview of relevant general geologic information about the project area

- Section 5 provides an overview of general environmental monitoring strategies for UCG and CCS implementation
- Section 6 provides a summary of recommendations, including a synthesis of site assessment and environmental monitoring requirements that should be implemented if the project proceeds beyond its current feasibility phase.

1.1 Overview of the Proposed Project

CIRI's proposed project is located within the Susitna lowlands region of Alaska, approximately 60 kilometers west of Anchorage and north of Tyonek (Figure 1). Although details of the project remain limited at this time, the CIRI proposal generally contains three major components:

1. UCG of subsurface coal seams. UCG involves oxidizing coal in place by injecting air or oxygen into the subsurface, which generates a combustible gas product that can extracted and used for power generation.
2. Onsite construction of a 100-MW combined-cycle power plant that will be fueled with the gas product generated by UCG.
3. Capture of a portion of the carbon dioxide (CO_2) generated by the entire process, and sequestration of this CO_2 underground where it will not contribute to global carbon emissions. CIRI has proposed that this carbon would be sequestered via a process referred to as enhanced oil recovery (EOR), in which CO_2 is pumped into declining oil reservoirs to enhance the flow of oil to existing petroleum production wells.[1]

Both UCG and CCS are emerging technologies, and commercial scale implementation of each has occurred at only a small number of sites around the world. The combination of the two technologies at a single commercial-scale site would be the first project of its kind in the world. While the combined approach holds promise as a "green" fossil fuel project, the possibility for success as a commercial venture and the type and extent of environmental impacts are largely unknown.

1. Though their original plan outlined carbon storage via EOR, subsequent communications with CIRI have indicated that they are likely to consider other options for the CCS component of the project, such as injection into deep saline formations (DSFs).

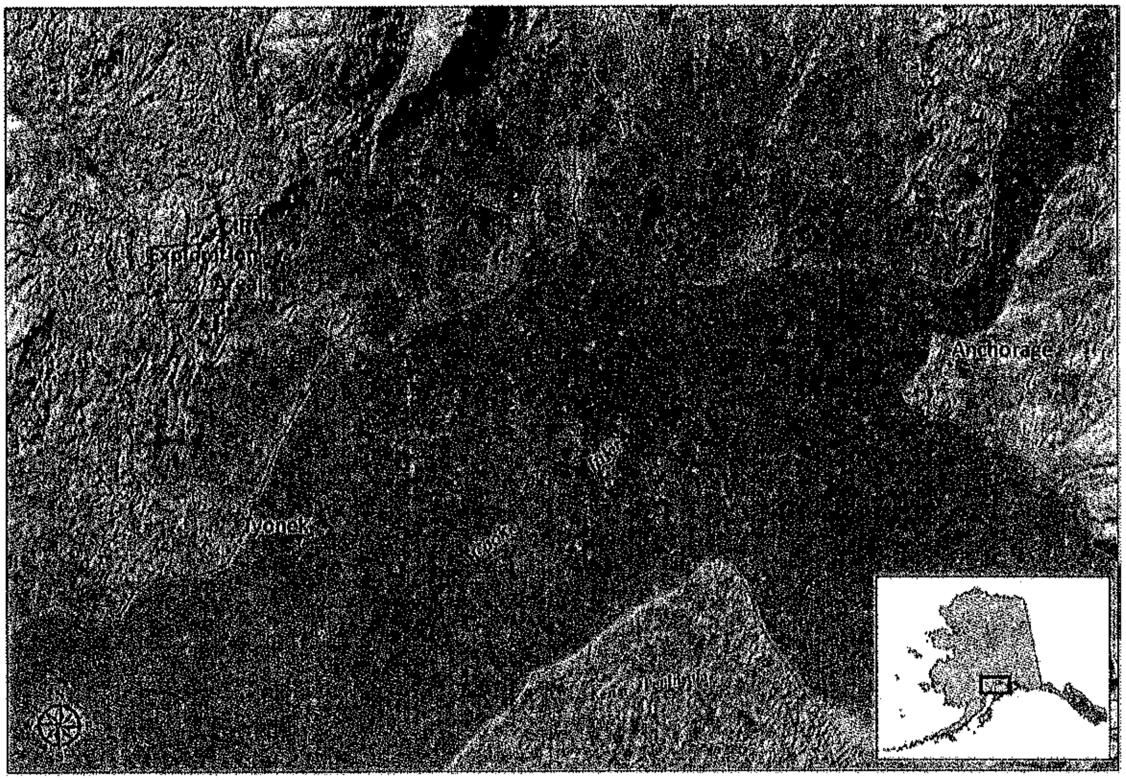

Figure 1. CIRI exploration location map.

2. Environmental Risks of UCG

2.1 The UCG Process and Overview of Environmental Risks

The UCG process involves oxidizing subsurface coal seams, which generates a combination of hydrogen and other gases, referred to as syngas (short for "synthesis gas"). Air or oxygen is pumped into a subsurface coal seam through an injection well. The introduction of an oxidizing gas produces heat, which partially combusts the coal *in-situ* and creates the syngas product (Clean Air Task Force, 2009; Friedmann, 2009). The syngas generated by the UCG process is primarily composed of hydrogen, carbon monoxide, and smaller amounts of CO_2 and methane (e.g., Stephens et al., 1985; Clean Air Task Force, 2009; Friedmann, 2009). The syngas is extracted from the UCG burn cavity by a production well, which brings the gas product to the surface to be burned. CO_2 can be separated from the syngas stream prior to combustion and collected for CCS. A schematic of the UCG process is shown in Figure 2.

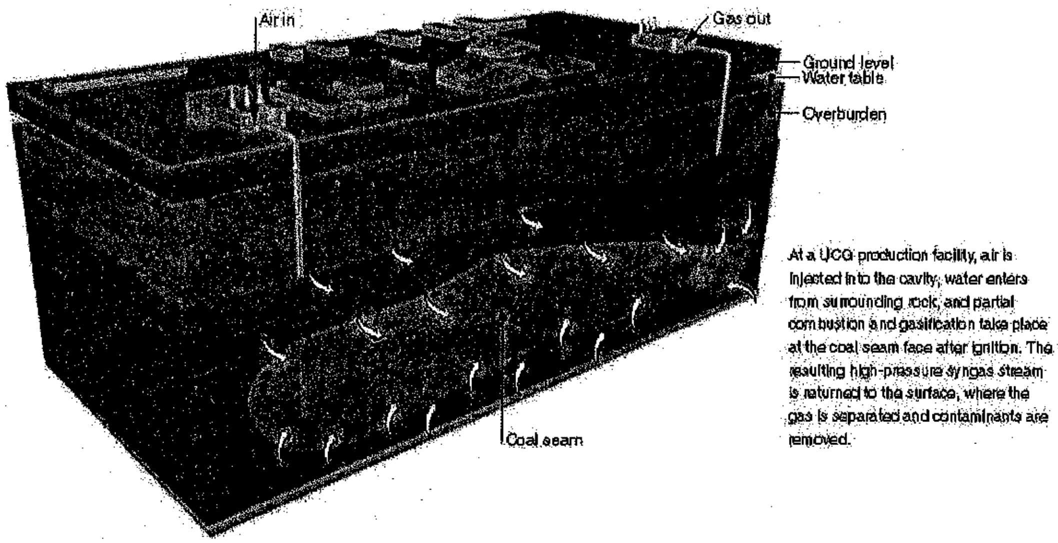

Figure 2. UCG process.

Source: Walter, 2007, p. 15.

When compared to conventional coal mining, UCG has a number of potential environmental benefits. In particular, surface disturbance is minimized relative to the disturbance caused by conventional mining, and the *in situ* gasification of coal allows many of coal's potentially hazardous combustion products and leachable contaminants to remain in the ground. Despite these potential benefits, however, the process still creates environmental risks. Based on a limited number of pilot projects in the United States and a small number of full-scale operations worldwide, two main environmental risks have thus far been associated with the UCG process. First is the risk of groundwater contamination. Organic contaminants such as polycyclic aromatic hydrocarbons (PAHs) may be generated during combustion of coal, and trace metals in the coal may be released through geochemical reactions induced by the UCG process. Contaminants may also be released from adjacent geologic units. These organic and metal contaminants could migrate and contaminate groundwater aquifers. Second, because the *in situ* burning of coal creates cavities in the subsurface, there is a risk of ground subsidence, whereby the overlying rock layers partially collapse into the newly created void space. Subsidence creates a hazard for any surface infrastructure that might be present above the UCG zone, and may create detrimental changes in surface or groundwater hydrology above the cavity.

In addition, there are other potential adverse impacts to human health and the environment associated with UCG. For example, uncontrolled migration and leakage of syngas to the surface could result in adverse impacts to local ecosystems and human settlements. Contaminants released from the coal and adjacent geologic units during the UCG process could also be released at the surface, contaminating surface water and/or air. Finally, because all of the combustion occurs in the subsurface where it is difficult to monitor, there is the potential for the oxidation reaction to migrate beyond the target zone or become uncontrolled.

Evaluating each of these risks requires an understanding of the subsurface geology, including the structural integrity, geochemical, and hydrologic properties of the targeted coal seam and rock units surrounding the targeted coal seam. Evaluating risk also requires characterization of potential subsurface and surface receptors, such as groundwater and surface water resources, sensitive ecosystems or species, and human health and infrastructure.

2.2 Groundwater Contamination

One of the most important potential adverse environmental effects related to UCG is groundwater contamination. Here we describe the potential sources of contamination, the geologic factors that will influence the migration of any contaminants generated, and how these risks can be mitigated.

2.2.1 Potential sources and types of contaminants

There are different sources and types of contaminants that may be associated with UCG operations. Uncontrolled migration and leakage of the syngas itself could result in contamination of overlying aquifers. In addition, by-products may be inadvertently generated from the coal during the UCG process. These products may include organic contaminants such as PAHs, phenols, and benzene, as well as inorganics including sulphate, boron, and metals and metalloids such as mercury, arsenic, and selenium, which may be present as metal sulfide impurities in the coal (e.g., Sury et al., 2004; Skousen et al., 2000). Mercury, arsenic, and selenium are volatile metals/metalloids, and they can also be released as gases during the coal gasification process (Liu et al., 2006). Their release could adversely affect water quality and air quality in the underground and on the surface depending on the temperature of the reaction, the type of geochemical reactions occurring during the gasification process, and the presence of pathways from the coal to the surface.

The geologic units surrounding the seam may also be sources of contaminants. Rock units immediately adjacent to the targeted coal seam will also likely be influenced by UCG operations, and thus, oxidation and other geochemical processes in the surrounding rock could also result in the release of contaminants. The types of contaminants potentially released as a result will depend upon the mineralogy and trace impurities of the surrounding rock.

2.2.2 Factors that may influence the potential for groundwater contamination

Fully characterizing the groundwater systems surrounding the targeted coal seam is crucial for evaluating the potential for groundwater contamination from UCG activities. Key hydrogeologic factors that will determine whether or not groundwater becomes contaminated include the hydraulic conductivity (permeability), thickness, and lateral continuity of surrounding rock units that separate the coal seam from any nearby aquifers, and the presence of fractures or faults that may create conduits for fluid migration out of the reactor zone.

Sury et al. (2004) present a flow chart for evaluating the hydrogeologic setting of a proposed UCG project (Figure 3). Note that in addition to pre-existing hydrogeologic conditions such as the permeability and lateral continuity of confining layers, there are a number of factors related to the UCG process itself that can influence the migration of contaminants from the reactor zone. In particular, since the partial combustion of coal creates a cavity in the subsurface (see Section 2.3), the process can create fractures, partings between geologic strata, or induced faults that can create new conduits for fluid flow. Physical properties of the rock, as well as pressure changes induced by UCG operations, will influence the potential for induced fracturing. The potential for these induced fluid migration pathways to allow contaminant migration out of the UCG zone must be evaluated based on available geologic information.

Note that fault and fracture zones are complex, and their behavior under the conditions imposed by UCG operations may be difficult to predict. Faults and fractures may be transmissive or sealed. Transmissive faults and fractures are capable of transmitting gases and/or fluids, and thus may act as direct contaminant pathways to groundwater aquifers from the UCG zone. Sealed faults and fractures may be re-opened as a result of UCG operations, and thus may also act as contaminant pathways. Fractures may also be re-opened by the pressure created as a result of the injected air/oxygen and the formed syngas, or by the dissolution of minerals along fracture zones due to the geochemical conditions created by the UCG operations.

UCG injection and capture wells, if not properly completed, may also act as conduits for contaminants (Sury et al., 2004). In order to maintain well integrity, well materials must be resistant to the potentially corrosive conditions created in the subsurface during operations. If present, existing wells and boreholes associated with previous exploration, and oil and gas operations, may also act as contaminant pathways to groundwater aquifers if they are not properly plugged and sealed, or if the well materials have degraded over time.

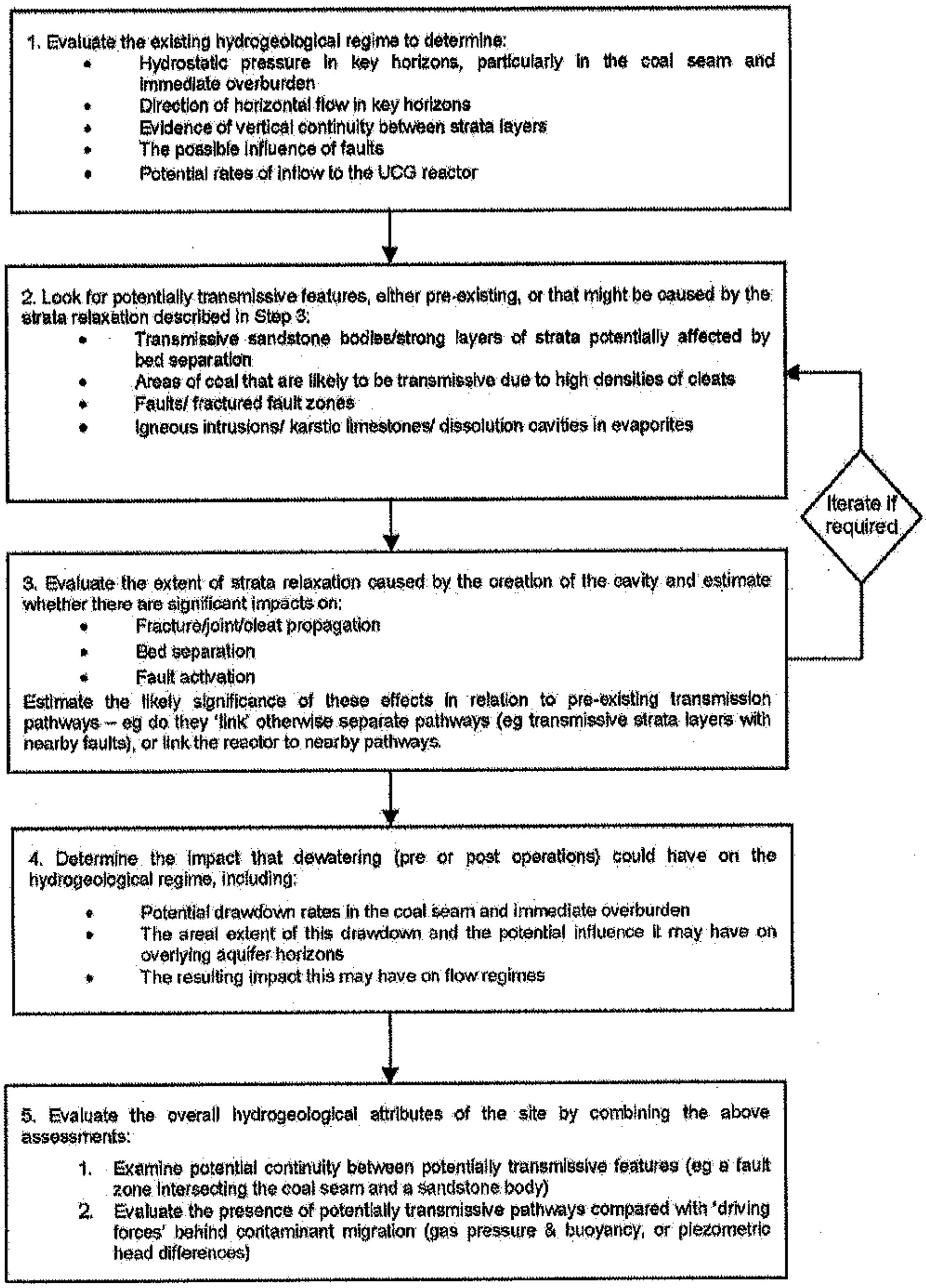

Figure 3. Concept for the general hydrogeological evaluation process.

Source: Sury et al., 2004, Figure 4.1.

Finally, conditions created by the burn itself may influence the potential for the spread of contaminated groundwater. Groundwater models have been developed which suggest that heating in the reactor zone can create convection cells in overlying units, which can generate rising plumes of potentially contaminated groundwater (Walter, 2007). Combined with the potential for fractures created by the collapse of the UCG burn cavity, these induced groundwater circulations can help to spread contaminants from the burn zone into overlying aquifers.

2.2.3 Mitigating groundwater contamination risks

Recommendations for groundwater protection have included ensuring that drinking water aquifers are at a distance of more than 25 times the seam height from the reactor (e.g., Shafirovich et al., 2008). In practice, detailed characterization of the hydraulic properties of the geologic units surrounding the reactor zone and an understanding of the hydrogeology of potential drinking water aquifers in the region, are likely to be more appropriate technical considerations.

In addition to geological controls, engineering controls are also important in limiting migration of contaminated groundwater from the reactor zone. In particular, ensuring that the UCG reactor zone pressure is lower than the ambient (hydrostatic) pressure should create inward hydraulic gradients, so that groundwater is flushed into the reactor rather than out of it. Experience suggests that maintaining a reactor pressure lower than hydrostatic pressure may be one effective means of avoiding groundwater contamination issues (e.g., Walter, 2007). For example, the Chinchilla project in Australia, where reactor pressure has been controlled to be lower than ambient pressure, appears to have had no escape of contaminated groundwater to its surroundings. In contrast, UCG pilot projects in shallow seams and without careful reactor pressure control such as at Hoe Creek, Wyoming, were plagued with significant groundwater contamination issues (e.g., Burton et al., 2007).

One potential problem with maintaining low reactor pressures is that higher pressures and temperatures create a higher methane content in the gas and therefore a more energy-rich product (e.g., Shafirovich et al., 2008). Thus, there may be conflicts between controlling gradients to minimize risk of groundwater contamination versus producing a more energy-rich product.

In summary, groundwater contamination is likely to be one of the most significant environmental concerns related to the UCG process. A combination of careful site selection and proper engineering controls is essential to limiting groundwater contamination from UCG sites.

2.3 Subsidence

Combustion of underground coal seams and removal of the resulting syngas creates void space in the subsurface. These voids can result in subsidence of the land surface above the UCG reactor zone. The problem of surface subsidence related to UCG projects is analogous to subsidence related to subsurface coal mining operations; as a result, there is a well-developed literature on the physical parameters controlling the magnitude of subsidence that might be created by UCG projects (e.g., Gregg, 1977; Shu and Bhattacharyya, 1993; Burton et al., 2007).

In practice, there may be no way to prevent collapse of the burn cavity itself during UCG operations. However, physical properties of the overlying rock column can mitigate the effects of cavity collapse at the land surface. The factors controlling the amount of subsidence generated by the collapse of subsurface cavities include the depth and width of the subsurface cavity; the geotechnical properties of the overlying rocks (overburden); and the degree of fracturing of the overburden. An analytical model by Shu and Bhattacharyya (1993) suggests that the primary control on surface subsidence is the ratio of cavity width to depth. Thus wide and/or shallow cavities are the most likely to induce significant subsidence at the surface. Other modeling frameworks have been developed to evaluate the potential for induced subsidence from evacuation of subsurface cavities (e.g., Creedy and Garner, 2004); some commercially available software packages can also be adapted to evaluate subsidence risks for particular settings (e.g., Burton et al., 2007).

In addition to the width and depth of the cavity, the physical properties of the overburden and the coal seam will also be important in controlling the degree of subsidence at the surface. A modeling study by Dr. T.X. Ren (Appendix E of Creedy and Garner, 2004) indicates that while the mechanical properties of the overburden are important in controlling collapse and subsidence, the thermal and mechanical properties of the coal seam itself also play an important role in controlling cavity growth. Laboratory analysis of the geotechnical and thermal properties of the overburden and the coal are required to characterize the risk of surface subsidence.

To minimize the risk of subsidence, Burton et al. (2007) suggest that coal seams targeted for UCG should be deeper than 200 meters (m). This recommendation appears to be based on a combination of experience from pilot studies and modeling constraints. For example, subsidence occurred at the Hoe Creek pilot study, where the target coal seam was approximately 10-m thick and only 40–50-m deep; deeper UCG projects in the United States and elsewhere have had fewer problems with surface subsidence (Burton et al., 2007). Modeling studies also indicate that deeper coal seams will result in lower surface subsidence: as the depth of the cavity increases, the overlying rock column is more likely to accommodate some of the resulting strain, resulting in a broad warping of the ground surface that will be more subdued for deeper UCG cavities (e.g., Shu and Bhattacharyya, 1993).

If the UCG zone underlies any significant infrastructure such as roads, buildings, or power generating facilities, subsidence will clearly present an engineering concern. Subsidence can also have detrimental ecological effects, such as creating depressions that may collect water, capturing flow from rivers and streams, or altering groundwater recharge, discharge, and flow patterns in the subsurface. The impacts of subsidence will depend on site-specific attributes, which must be evaluated prior to initiation of a UCG project.

2.4 Other Environmental Risks

Although groundwater contamination and subsidence are most often cited as the primary environmental risks associated with UCG, there are additional environmental concerns that should be addressed when designing a UCG project. Of these, gas leakage to the surface and the potential for uncontrolled reaction rates appear to be the most significant concerns.

Gas leaks to the surface may occur through pre-existing faults or fractures, or they could occur as a result of induced fractures created by subsidence (Gregg, 1977). The potential environmental risks associated with a gas release will depend on the nature of the gas and the ecological resources present at the surface, but could include asphyxiation, vegetative die-off, or acidification of surface waters. Volatilization of metals and metalloids such as arsenic, mercury, or selenium, if they occur, could also create toxic conditions if these volatile compounds migrate to the surface.

Another potential environmental concern related to UCG is the relative lack of control on reaction rates in the subsurface. As noted by Friedmann et al. (2009), the only engineering control on reaction rate is the rate of gas injection. Parameters such as the rate of cavity growth or water influx to the burn zone cannot be controlled with existing technology. Furthermore, to the extent that UCG induced fracturing could provide pathways for increased air intrusion to the reactor zone, it is possible that even the rate of gas injection could become difficult to control. As a result, there is the potential for the generation of uncontrolled burns in the subsurface.

2.5 Site Characterization and Monitoring Needs for UCG Projects

Although many authors have proposed "rules of thumb" for the proper siting of UCG projects (e.g., more than 200-m deep, more than 25 times the seam thickness from the nearest drinking water aquifer), there is no substitute for site-specific geological information. At a minimum, proper siting of a UCG project to minimize risk of contaminant releases or subsidence requires the following information:

- Characterization of the geologic units above and below the target coal seam, including a consideration of the lateral continuity, heterogeneity, porosity, permeability, and continuity of confining layers and overburden
- Characterization of the physical nature of the coal seam, including depth, width, thickness, and permeability, with particular attention paid to the potential size and spatial extent of the burnout area from UCG
- Geochemical and mineralogic characterization of the coal seam and host rock to evaluate potential contaminants of concern, such as sulfides, metals, metalloids, or other trace impurities
- A pilot burn test of samples from the target coal seams that would identify the gases produced by UCG
- Identification and characterization of groundwater aquifers in the subsurface, including their chemistry (e.g., major, minor, and trace), groundwater flow directions, and horizontal and vertical hydraulic conductivity
- Laboratory analysis of the thermal and mechanical properties of the target coal seams and overlying stratigraphy, to enable an evaluation of the potential risk of subsidence resulting from UCG burnout
- Evaluation of existing and potential faulting in the area, with particular attention paid to whether faults/fractures are sealed or transmissive
- Evaluation of existing wells and boreholes, their location, depth, and the integrity of well construction and sealing/plugging materials, and stability under UCG-imposed conditions.

In order to properly characterize the subsurface stratigraphy, exploratory boreholes and downhole geophysical measurements should be tied to seismic lines to enable a complete characterization of the lateral continuity of coal seams and surrounding aquifers and aquitards. Burton et al. (2007) also stress the importance of understanding the depositional context of coal beds targeted for UCG, because this basic geologic framework can be used to evaluate the lateral extent of coal seams and their connection to surrounding permeable units. For example, coal seams deposited in tidal environments may be more laterally continuous than coals deposited along floodplains, and the overlying stratigraphy may also be more predictable based on basic principles of sequence stratigraphy. Empirical data from seismic lines and boreholes should therefore be coupled with an understanding of the depositional environment of the target coal seams, so that their lateral continuity and relationship to overlying materials can be inferred based on geological constraints.

If site characterization data demonstrate that the environmental risks of the project can be managed and the project proceeds, the following monitoring requirements should be considered:

- The pressure in the burn cavity should be monitored and managed to ensure that hydraulic gradients are directed inward, to minimize groundwater flow out of the cavity
- Groundwater in surrounding aquifers should be sampled and monitored regularly, to detect any contaminant migration from the burn cavity
- Tiltmeters, radar interferometry, and/or high-resolution differential global positioning system (GPS) should be used to monitor for subsidence at the surface
- Gas detection monitoring should be implemented to detect any surface leakage of syngas that may occur.

3. Environmental Risks of CCS

Conceptually, UCG may be well-suited to CCS, since (1) coal seams are commonly located in the types of sedimentary environments where formations suitable for CCS are found; and (2) CO_2 can be relatively easily and economically separated from the pre-combustion gas stream, compared to post-combustion separation (Friedmann et al., 2009). The combination of UCG and CCS technology may therefore become common. Like UCG, however, CCS also has a number of technological challenges and environmental risks that need to be carefully addressed.

The primary risks of CCS relate to unanticipated or uncontrolled releases of CO_2 from the sequestration zone. The environmental risks associated with such releases range from acidification of groundwater aquifers to asphyxiation of biota, including humans, at the land surface. In addition, since CCS is designed to mitigate climate change risk, loss of CO_2 from the sequestration zone also negates the intended environmental benefits of the process.

3.1 Geologic Sequestration Systems

According to U.S. EPA (2008), geologic sequestration (GS) systems for CCS consist of an injection zone and an overlying confining system. The injection zone is a geologic formation or group of formations that are targeted for CO_2 injection. Formations with relatively high porosity and high permeability, such as sandstones, allow for greater storage of CO_2 and are preferred injection zone materials. To maximize storage capacity, the CO_2 is compressed and injected as a supercritical fluid. These artificially high pressures create a tendency for the injected CO_2 to diffuse out of the injection zone. In addition, the injected CO_2 will have a tendency to rise due to the relative buoyancy of supercritical CO_2 compared to the native fluids (e.g., brine or saline water) present within the injection zone. The role of the confining system, also sometimes referred to as a caprock, is to prevent the upward migration of the injected CO_2. Thus, low-permeability geologic formations such as siltstones or mudstones that are thick and laterally continuous are preferred formations for confining systems (IPCC, 2005; U.S. EPA, 2008).

In this section, we describe the mechanisms at play to keep CO_2 sequestered in the subsurface, the types of geologic settings being considered for CCS, a brief summary of current CCS operations, regulatory considerations, and potential risks and adverse impacts associated with CCS.

3.1.1 GS CO_2 trapping mechanisms

The CO_2 is retained in the injection zone through a combination of different trapping mechanisms. The confining system, a physical stratigraphic trap that inhibits the upward migration of CO_2, provides one of the most important trapping mechanisms.

Within the injection zone, additional trapping mechanisms can occur to sequester the CO_2. These include residual CO_2 trapping, dissolution trapping, preferential adsorption trapping, and mineral trapping. Residual CO_2 trapping occurs when the CO_2 is retained by capillary forces in some of the pores of the injection zone geologic formation(s). Solubility trapping can occur as a result of the dissolution of CO_2 into the fluid inhabiting the pore space of the geologic formations (e.g., saline water). The fluids become denser as a result of CO_2 dissolution, and will tend to sink, thus further entraining the CO_2 in the subsurface. CO_2 trapping through preferential adsorption occurs when CO_2 adsorbs to certain geologic materials such as coal and shale that have a high affinity for CO_2. Mineral trapping occurs when the CO_2 reacts with the injection zone rock and/or fluids to form solid minerals. Although mineralization is the most permanent trapping mechanism in GS systems, it occurs relatively slowly compared to the other mechanisms [see IPCC (2005) and U.S. EPA (2008) and references therein for more detailed descriptions of these trapping mechanisms].

3.1.2 Geologic settings under consideration for GS

There are a number of different types of geologic settings under consideration for sequestration. These include deep saline formations (DSFs), oil and gas reservoirs (both depleted formations, and formations targeted for enhanced oil and gas recovery), and coal seams.

DSFs are sedimentary geologic units in which the pore space between the formation rock is filled with saline (salty) water. These formations are found in subsurface sedimentary basins and are deep enough (800–1,000 m) to achieve pressures that will keep the CO_2 in its compressed, supercritical phase. There are many very large sedimentary basins across the United States, and DSFs are believed to have the greatest capacity for sequestration, compared to the other settings under consideration (Dooley et al., 2006; NETL, 2007). The National Energy Technology Laboratory (NETL) has estimated that DSFs may have the capacity to store between 1,000 and 3,700 billion tons of CO_2 (NETL, 2007). However, they are typically less well characterized than other settings, such as oil and gas fields, and thus storage capacities are somewhat uncertain, and may be overly optimistic.

Oil and gas fields have stored oil and natural gas for hundreds of thousands to millions of years prior to resource extraction, and are thus believed to be good potential candidates to store CO_2 for long periods of time (Benson et al., 2002; IPCC, 2005). CO_2 is currently injected into some reservoirs to enhance the extraction of oil, in a process called EOR. Similarly, CO_2 is also used in some reservoirs to enhance the extraction of natural gas. Both depleted oil and gas fields, and EOR sites, could potentially be transitioned to GS. These reservoirs are typically very well characterized, which is advantageous for their use to store CO_2. However, as a result of extraction activities, these formations are typically penetrated by many wells and boreholes, which is disadvantageous to GS, because the penetrations could be conduits for CO_2 leakage (Celia et al., 2004; Heller, 2005). According to NETL, the estimated CO_2 storage capacity associated with EOR sites is 90 billion tons (NETL, 2007). This is much smaller than the estimated capacity of DSFs. However, these settings may be attractive candidates for immediate implementation of CCS, because much of the needed infrastructure and CO_2 injection technology is already in place.

Coal seams have also been suggested for GS. Because of coal's high affinity for CO_2, CO_2 may be stored in coal beds through adsorption to the coal surface. CO_2 may also enhance the extraction of methane from coal beds (enhanced coalbed methane), because coal's high affinity for CO_2 may displace methane present in the coal beds, which could then be captured for extraction. However, the small-scale fractures (cleats) that allow fluid flow through coal seams can become plugged as a result of CO_2 adsorption, and thus restrict further CO_2 storage (Haszeldine, 2006). Thus, the sequestration of CO_2 in coal beds may be challenging.

Other geologic settings, such as volcanically deposited basalts, oil or gas-rich shale, geologic repositories such as salt caverns, and abandoned mines may also be considered for GS, but are not currently major focuses (see IPCC, 2005, for further discussion of these other settings).

3.1.3 Natural and industrial analogs and existing CCS operations

Natural and industrial systems that have stored CO_2 and other fluids (e.g., gases such as natural gas) may provide analogs for GS, demonstrating the potential ability to store CO_2 and other fluids in the subsurface. CO_2 accumulates underground naturally in a variety of geologic settings, and there are numerous natural analogs that demonstrate the long-term trapping of CO_2 in the subsurface. For example, 200 million metric tons of naturally occurring CO_2 have remained trapped in the Pisgah Anticline in central Mississippi, northeast of the Jackson Dome, for more than 65 million years with no evidence of leakage (IPCC, 2005). Industrial analogs include the practice of injecting and temporarily storing natural gas in underground reservoirs. The oil and gas industry has engaged in this practice for nearly 100 years (IPCC, 2005). Experience from these natural gas storage operations is mixed. While these operations demonstrate that fluids and gases can be stored in the subsurface, there have been several instances of documented leakage of natural gas to the surface, either due to induced fracturing caused by application of excessive pressures to the formations, pre-existing leakage pathways through the confining system, or leakage at improperly sealed or plugged wells (Perry, 2005). Furthermore, these sites are generally used for temporary storage and hence do not provide insight into the long-term feasibility of underground storage of fluids and gases. These sites do provide some evidence that with careful management, confining systems can be exposed to repeated stress cycling (i.e., depressurizing and pressurizing) without adverse effects on seal integrity, which may support the use of depleted oil and gas reservoirs for CO_2 storage.

As mentioned above, the oil and gas industry also has experience in the injection of CO_2 through enhanced product recovery projects. EOR has been practiced for over 35 years, and these projects contribute substantial knowledge about the design of CO_2 injection wells and technologies for handling, injecting, and monitoring injected supercritical CO_2 (Benson et al., 2002; Heinrich et al., 2003; IPIECA, 2007). However, such projects are designed to maximize oil production, and thus provide rather limited insight into the long-term storage of CO_2 in the subsurface.

While few in number, currently operating pilot and commercial CCS projects have thus far demonstrated that CCS can be successfully implemented. Currently operating commercial projects include the Sleipner project in the North Sea (Norway), the Weyburn EOR project (Canada), and the In Salah Gas Formation project (Algeria). Additional commercial GS projects that are in the planning stages and are anticipated to be underway in the near future include the Gorgon Joint Venture (Barrow Island, Australia) and other potential sites in Europe and the United States. There are also a number of smaller-scale research field experiments that have recently been conducted or are underway at sites in the United States and internationally. Examples include the CO_2 SINK Ketzin site in Germany, the U.S. Frio Brine Experiment (Texas), and the currently underway regional projects supported by the U.S. Department of Energy's (DOE's) Regional Carbon Sequestration Partnerships Program [see U.S. DOE (2010) for a summary of this program]. For a more comprehensive list of current and planned GS projects in the United States and around the world, see NETL's CO_2 Storage website (http://www.netl.doe.gov/technologies/carbon_seq/core_rd/world_projects.html) and the Scottish Centre for Carbon Storage website (http://www.geos.ed.ac.uk/ccsmap).

Operating commercial and experimental projects have demonstrated thus far that CO_2 can be injected and sequestered in geologic formations. However, these sites have been operating for only a relatively short period of time (Sleipner is the longest running operation, and began in 1996), and hence do not yet demonstrate the long-term storage of CO_2 in the subsurface over required storage time periods of hundreds to thousands of years. Full commercial-scale deployment of GS will also involve injecting much larger volumes of CO_2 than currently operating projects. Because of their smaller scale, current projects likely do not demonstrate the full range of scenarios that may be encountered in commercial-scale deployment. For example, commercial-scale GS projects will encompass areas that may be miles in diameter (as opposed to for example the small fraction of a mile encompassed by most DOE pilot projects), and thus may be more likely to:

- Encounter geologic heterogeneities that may serve as CO_2 leakage pathways, including faults and fractures, or potential anthropogenic pathways such as unplugged wells and boreholes
- Face challenges regulating pressure, and thus experience adverse pressure effects that can cause fracturing or other adverse impacts, such as the displacement of brine into overlying aquifers, or regional effects on groundwater flow
- Encounter basin-wide effects, and influences of neighboring projects.

However, pilot projects can nevertheless provide useful information, particularly if multiple projects are implemented and evaluated across a variety of geologic settings.

3.1.4 Regulatory framework for CCS

Federal and State regulations address the injection of fluids into the subsurface for the protection of underground sources of drinking water (USDWs), under the Safe Drinking Water Act (SDWA). Specifically, the U.S. Environmental Protection Agency (U.S. EPA) Underground Injection Control (UIC) program regulates the injection of fluids into the subsurface (including liquids, gases, and semisolids), and the regulations are designed to ensure that injected fluids do not endanger USDWs.

According to the U.S. EPA (2010), GS of CO_2 through well injection meets the definition of "underground injection" in Section 1421(d)(1) of the SDWA, and the U.S. EPA has authority for underground injection under the SDWA UIC program. The U.S. EPA, states, territories, and tribes that have primacy for UIC programs ("Primacy States") act as co-regulators to protect USDWs from any potential endangerment from underground injection of CO_2.

In July 2008, the U.S. EPA published a Proposed Rule for Federal Requirements for CO_2 GS wells under the UIC program. The Proposed Rule describes a new class of wells for the regulation of CO_2 injection, and addresses issues related to siting, well construction, monitoring, and site closure. See U.S. EPA's website (http://www.epa.gov/safewater/uic/wells_sequestration.html) for the history and current status of the Proposed Rule.

3.2 Potential Risks and Adverse Impacts Associated with CCS

The main environmental risks associated with CCS are related to the potential for leakage from the GS formation, and the potential for adverse impacts in the subsurface associated with the applied injection pressures. Key attributes of GS systems that have been identified as particularly important when evaluating the potential risk of leakage of CO_2 from the injection zone include wells, faults, and fracture zones. The applied injection pressures may also induce fracturing or reactivate faults, and may have other adverse impacts to the subsurface, such as displacing large volumes of brine, or potentially causing changes in groundwater flow directions.

Wells (and other artificial penetrations such as boreholes) have been identified as one of the most probable conduits for the escape of CO_2 from GS systems (Gasda et al., 2004; Benson, 2005; IPCC, 2005; Carey et al., 2007). If not properly sealed and plugged, wells and boreholes that were previously installed during exploration and resource extraction can be a direct conduit for CO_2 to escape from depth to the surface. Such wells may also act as pathways for brines to contaminate overlying freshwater aquifers. Even properly completed wells may pose a risk of leakage, as the acid generated when CO_2 contacts water may degrade well construction materials over time (Scherer et al., 2005). Identifying and evaluating abandoned wells may be particularly challenging in some geologic settings, such as depleted oil and gas fields. Furthermore, the GS injection and monitoring wells themselves need to be properly constructed and operated in order to avoid leakage of CO_2, and other fluids such as brine. Experience from other analogous injection projects (such as those used in oil and gas operations) has shown that leakage from the injection well itself, as a result of improper completion or deterioration of the casings, packing, or cement well materials, is one of the most significant well failure modes (Benson et al., 2002; IPCC, 2005).

The potential for existing faults and fractures to act as fluid pathways in GS systems is a function of numerous factors, comparable to those described above for UCG. These include the level of applied pressure, whether they are sealed or transmissive; their stratigraphic position with respect to the confining system, their orientation, and their geometry with respect to the applied pressures. Tectonically active settings, such as the proposed CIRI site and southern Alaska in general, may be more likely to have transmissive faults and/or fracture zones, and may be unsuitable for GS. Faults and fractures may also be induced if the GS system is overpressurized during injection of CO_2. The risk of injection pressure exceeding fracture pressure can be reduced through understanding the relevant geologic attributes, careful site characterization, careful operation of GS systems, and monitoring (IPCC, 2005). The potential for existing and induced fractures and faults to result in adverse impacts will depend on numerous additional factors, including whether the faults are connected to an overlying receptor, whether they may be connected to other fluid-conducting pathways (such as wells), and whether or not they may be resealed by geochemical processes associated with GS (U.S. EPA, 2008).

Additional factors that will influence the risk of CO_2 leakage include the lateral extent, thickness, and permeability of the confining system. Furthermore, the physical capacity, injectivity and geochemical and geomechanical properties of the injection zone may also influence the likelihood of leakage.

There are numerous potential adverse impacts resulting from the leakage of CO_2 (as well as other fluids, such as brine) and changes in subsurface pressure caused by CO_2 injection. According to U.S. EPA (2008), categories of receptors that could potentially be adversely impacted by CCS include human health and welfare, the atmosphere, ecosystems, groundwater and surface water, and the geosphere. The vulnerability of a GS system to these adverse impacts is a function of both the presence of the key receptors in the impact categories, and the levels of exposure. A number of factors affect exposure, including but not limited to the concentration and volume of the release, the rate of release (i.e., slow vs. sudden), the proximity of the release to the receptor, and wind or wave dispersion. Impacts are also affected by whether the release is acute but limited (in time or spatial extent) or chronic. The potential impact categories are briefly summarized below; for a more detailed discussion, see U.S. EPA (2008):

- *Human health and welfare*: Adverse health effects caused by CO_2 can range from minor, reversible effects to mortality, depending on the concentration of CO_2 and the length of the exposure (Benson et al., 2002; CEC, 2007). Release of CO_2 may also adversely impact recreational and economic resources by restricting access or use or by changing the quantity and quality of the resource. Resources that could potentially be impacted by CO_2 leakage include mineral extraction, forestry, fisheries, or other harvested natural resources, which could in turn result in adverse economic impacts to humans

- *Atmospheric impacts*: In some cases, small releases of CO_2 from GS may not adversely impact local environmental receptors (e.g., ecological receptors, groundwater and surface water, humans). However, such releases do reduce the climate benefits of capturing CO_2, thus decreasing the overall effectiveness of GS as a climate change mitigation strategy.

- *Ecosystem impacts*: Leakage of CO_2 could have adverse impacts on soil-dwelling animals and microbes (Sustr and Siemk, 1996; Benson et al., 2002), plants (MeGee and Gerlach, 1998; Saripalli et al., 2002), surface-dwelling animals (Benson et al., 2002), and aquatic organisms, particularly calcifying organisms (Turley et al., 2004; Miles et al., 2007; Spicer et al., 2007). Particular attention may be required to address protected or endangered species if present.

- *Groundwater and surface water quality and quantity*: Leakage of CO_2 into aquifers can have detrimental impacts on water quality. For example, the dissolution of CO_2 in the water can create acidity which can in turn dissolve metal-bearing minerals, or result in the desorption of metal and organic contaminants adsorbed to geologic formations (Jaffe and Wang, 2003; Wang and Jaffe, 2004). The pressure-induced displacement of brine or salty waters into overlying aquifers can also negatively impact water quality, and can potentially result in the loss of USDWs. Pressure changes associated with injection of CO_2 may also cause changes in flow directions in groundwater and surface water bodies and points of recharge and discharge (Nicot et al., 2006; Tsang et al., 2007). This may in turn negatively impact municipal water supplies, and the water balance of local ecosystems. The spatial area affected by pressure changes associated with injection will typically be significantly larger than the injected CO_2 plume itself, and thus, adverse impacts associated with pressure changes could potentially be experienced over very large spatial areas.

- *Geosphere*: Changes in subsurface pressure from GS can have direct impacts on the local landmass itself. Subsurface pressure changes that exceed the subsurface geologic formation's geomechanical strength could cause fracturing or reopening of faults and fracture zones (Quintessa, 2004; IPCC, 2005). Impacts could also include induced seismic activity, including earthquakes in the extreme case (Healey et al., 1968) and land deformation through uplift (Quintessa, 2004; Birkholzer et al., 2007).

In general, the overall likelihood of adverse impacts is expected to decline over time at GS sites. This assumption is based on a number of factors, including the greater permanence of secondary trapping mechanisms, such as dissolution, which decreases buoyancy, and mineralization; the anticipated return to pre-injection pressure conditions once injection stops in most cases; and improved characterization and modeling of the GS system over time (U.S. EPA, 2008).

3.3 Site Characterization and Monitoring Needs for CCS Systems

While experience from existing projects and natural and industrial analogs to GS demonstrates that CO_2 can be safely sequestered in geologic formations, there is the potential for unanticipated migration and leakage of injected CO_2 and other fluids such as brine, as well as the potential for adverse impacts caused by excessive pressure. As a result, site characterization and monitoring to evaluate potential risks are necessary components of GS projects. Specific purposes for site characterization, monitoring, and applicable technologies at CCS sites include:

- *Establishing baseline conditions.* CO_2 is ubiquitous in the environment, and concentrations vary diurnally, seasonally, and annually, and spatially. Determining background levels of CO_2 and understanding natural fluctuations is necessary to discern whether detected CO_2 is attributable to leakage from the GS site, or to other sources. In addition, many technologies, such as seismic profiling, identify CO_2 on a comparative basis, and thus measurements need to be taken prior to injection. The techniques selected to establish a baseline will be dependent upon site-specific conditions, and anticipated monitoring needs during injection. Examples of technologies that may be applied include seismic imaging; wellhead and formation pressure monitoring techniques; temperature and fluid composition measurement techniques; electrical measurements of subsurface conductivity/resistance; atmospheric and soil gas monitoring technologies; and land surface deformation monitoring technologies (Benson et al., 2004; WRI, 2008; Bacon et al., 2009; Johnson, 2009).

- *Identifying and providing oversight of targeted locations and site features.* Specific locations and site features should be identified and targeted for monitoring if they are known or suspected to have elevated risk of CO_2 leakage and adverse impacts. For example, existing wells and faults should be targeted for characterization and monitoring because of their elevated potential to act as CO_2 conduits, which can result in leakage. During site characterization, monitoring techniques can be tested and selected to target site-specific attributes (Benson et al., 2004). During injection and site closure, monitoring can help identify existing or newly developed risks and inform the application of additional, targeted monitoring techniques if needed. The specific type of monitoring technique to be used will depend upon the specific site characteristic that is being assessed, and could include seismic surveys, tracers, borehole logs, pressure measurements at the wellhead and in the formation, formation fluid sampling, surface water sampling, and air and soil gas sampling.

- *Ensuring injection controls.* Monitoring the condition of the injection well, the injection rate, and wellhead and formation pressure are important to verify the amount of CO_2 injected and to avoid leakage. Available technologies to monitor that injection controls are handled appropriately include wellhead and formation pressure gauges, core logging, and wellbore annulus pressure measurements (Benson et al., 2004; IPCC, 2005; Benson, 2007; Freifeld et al., 2009; NETL, 2009).

- *Confirming the quantity and location of injected CO_2, and detecting unanticipated leakage:* The movement and fate of injected CO_2 are influenced by injection-related factors, properties of the CO_2, and properties of the GS formations. As a result, many different subsurface parameters may need to be measured to assess the location and quantity of the injected CO_2. Existing pressure gradients and gradients induced by injection can influence CO_2 movement, and so techniques that measure the injection rate and formation pressure gradients can help monitor CO_2 in the subsurface. Other examples of techniques that may be used to confirm the location and quantity of injected CO_2 include seismic surveys; electrical and electromagnetic methods, such as electrical resistance tomography; gamma ray, resistivity and other types of logging; and fluid and mineral sampling methods (Benson et al., 2004; Benson, 2007; Bachu and Bennion, 2009; Bachu et al., 2009; NETL, 2009). Several monitoring techniques may be used to detect surface leakage, including sampling air using eddy covariance, infrared and other techniques; sampling soil gas with soil gas probes; using tracers (small quantities of a chemical compound or isotope added to trace flow patterns); monitoring for land surface deformation; measuring productivity of local flora and fauna; and sampling overlying hydrologic systems (Chabora and Benson, 2009; Darby et al., 2009; Jones et al., 2009; Schwarz et al., 2009).

- *Assessing environmental and human health impacts of leakage if they occur.* If CO_2 leaks from the targeted injection zone, adverse impacts to the environment and human health can occur. Monitoring techniques can help assess the severity of adverse impacts by providing information on the amount of leaked CO_2. Site-specific receptors may also be targeted for monitoring, such as sensitive or endangered species, or USDWs, to ensure that they are not adversely impacted by unanticipated CO_2 migration and leakage.

- *Detecting induced microseismicity.* Microseismic activity may be induced by CO_2 injection if pressures within the target zone are high enough to cause a release of accumulated strain on fault zones. Monitoring can help recognize induced microseismicity, so that mitigative actions, such as reducing the injection pressure, can be implemented.

- *Resolving liability/legal disputes.* Monitoring could potentially be used to help resolve disputes arising from unanticipated leakage of CO_2. For example, liability disputes could arise if other underground natural resources, such as minerals or oil and gas reserves, were adversely impacted by injected CO_2 that has migrated outside the target formation. Damages could be sought by parties that have an interest in the impacted resources from the legally responsible injector of the CO_2. Monitoring can assist with determining which injector is liable in the event that multiple injectors are in proximity to the damaged resources. Liability disputes could be complicated by the additional factor that projects can be in injection and post-injection site care phases at varying times; if leakage occurs while one project is operational and a nearby project is in post-injection site care phase, the leaking CO_2 could be emanating from either the closed or the currently operational project (Wilson et al., 2007; GAO, 2008; CCSReg, 2009). There may also be questions about the long-term liability and legal responsibility of leakage from sites after closure of operations.

4. CIRI Proposal and Study Site

4.1 Information on CIRI Proposal

Although the details of CIRI's proposed project are limited, we have obtained general information about their plans from the website that they have set up for this project (http://www.cirienergy.com/) and from the coastal management and exploration permit applications they submitted in late 2009 (Belowich, 2009). This section contains a brief description of their plans based on this information, recognizing that the details of their plans are not likely to emerge until after their exploratory drilling has been completed.

CIRI's presentation of their proposed project indicates that the target coal seams for UCG will be more than 650 feet (ft) deep and will be isolated from freshwater aquifers by "strong and impermeable overlying rock layers" (CIRI, 2009). Beyond these generalities, however, there have been no details provided about the thickness of the coal seams targeted; the stratigraphy of the overlying geologic units; or the quality and character of the coal beds themselves.

CIRI also indicates that they will be capturing CO_2 from their syngas stream using existing technologies. Again, however, no details have been given as to the mechanisms of capturing or sequestering the CO_2. The CIRI proposal indicated that CO_2 would be sequestered via EOR. However, for EOR to occur, CIRI would need to partner with Cook Inlet oil producers to supply their carbon stream to existing oil infrastructure. At least one of the Cook Inlet producers, Chevron, has apparently already indicated that they are not interested in this project (AlaskaCoal.org, 2009), and CIRI has since indicated that EOR may not be a viable alternative. In such case, CCS could possibly be accomplished by GS into DSFs or other geologic settings, or by re-injecting CO_2 into the burn cavities left behind by UCG. Either of these alternatives would require significant additional investigation into the geology of the targeted sequestration zones.

CIRI's exploration permit indicates that they plan to drill two deep boreholes to 2,500 ft, three boreholes to 2,000 ft, and one to 1,250 ft (Belowich, 2009). The stated goal of these boreholes is to enable stratigraphic correlation across major faults and with stratigraphic information from an existing borehole on the site. Results from deep borehole exploration could also enable identification of potential CCS targets.

4.2 Site Geology

Although information about the specific coal beds that CIRI is targeting for UCG remains limited, this section describes the general geologic setting of the proposed project, with particular attention paid to the tectonics, stratigraphy, and characteristics of coal seams that will be relevant to evaluating environmental risks of the project.

4.2.1 Coal bearing units

The Susitna lowlands region is well known for its coal resources. Barnes (1966) estimated the coal reserves in the region at 2.4 billion tons based on field mapping and aerial reconnaissance surveys. Subsequent studies have improved understanding of the depositional environment, thickness, and distribution of coal beds throughout the region (e.g., Merritt, 1990; Flores et al., 1997), as well as the role of faults in exposing different packages of coal-bearing units at the surface.

As suggested by Burton et al. (2007), a general understanding of the depositional environments of the coal beds targeted for UCG is one means of assessing their lateral continuity, their general geochemistry, and their connection to surrounding aquifers. A brief description of available geologic information is included here.

There are two major coal-bearing units present in the study area: the Beluga Formation, and the underlying Tyonek Formation. Both of these Miocene (5–23 million year) units belong to the Tertiary-aged Kenai Group, which includes interbedded clays, silts, sands, and conglomerates of a generally nonmarine origin (Barnes, 1966). Merritt (1990) describes the Tyonek Formation as the result of channel and floodplain sedimentation, and the Beluga Formation as a set of coalescing alluvial fans. More recent stratigraphic work by Flores et al. (1997) indicates that some of the beds within the Tyonek Formation may also have been tidally influenced, suggesting a fluvial-estuarine depositional environment. Flores et al. (1997) also suggest that much of the Tyonek Formation was laid down while the Castle Mountain Fault (CMF) was active; thus the courses of the rivers in which the coal beds were formed are likely to have been controlled by motion on this fault.

The coal beds in the Tyonek Formation are typically thicker than those in the Beluga Formation: Some of the Tyonek Formation coals are as much as 50–70 ft thick, while the Beluga Formation coals are typically less than 8 ft (Belowich, 2009). Given the complex geological and structural setting of the proposed exploration area, boring logs and more detailed development plans from CIRI will be necessary before the relationships between coal beds, permeable units, and faults can be evaluated.

4.2.2 Structural geology and tectonics

The Beluga and Tyonek formations are typically flat to shallowly dipping (< 15 degrees), except where locally influenced by motion along the CMF and Moquawkie (Bruin Bay) fault zone. Where these faults are present, the stratigraphic package is tilted or gently folded so that dips can be up to 35–50 degrees (Barnes, 1966). In the southwestern corner of the CIRI exploration block, the Tyonek and Beluga formations are warped by an east-northeast trending syncline, which plunges shallowly to the east (Belowich, 2009).[2] It is not clear from CIRI's plans whether the coal beds involved in this structure may be the target of their exploration further to the northeast.

The CIRI exploration block is crossed by the CMF along its northern edge, and is nearly bisected by the northeast-trending Moquawkie/Bruin Bay Fault (Figure 4). Both of these faults are high-angle, and both have accommodated significant displacement. The CMF offsets the Tyonek Formation by as much as 4,000 ft, with the northern block upthrown relative to the southern block. The Moquawkie/Bruin Bay Fault offsets the stratigraphy by an additional 2,000 ft, with the western block displaced upwards relative to the eastern block. Although the stratigraphy is generally shallowly dipping throughout the study area, motion along these faults is likely to have caused local warping and fracturing near these faults. The influence of these major faults and associated fractures on fluid migration warrants further investigation.

The entire Cook Inlet region is very active seismically (Figure 5). Recent work on portions of the CMF indicates that it is active, with the most recent dated surface rupture occurring approximately 670 years ago, and an average recurrence interval of approximately 700 years (e.g., Willis et al., 2007). Moderate earthquakes of magnitude 5.7 and 4.5 occurred along the eastern portions of the CMF in 1984 and 1996, respectively (e.g., Haeussler et al., 2002). The Moquawkie/Bruin Bay Fault has received relatively less attention in the literature; however, aligned and offset river drainages along its course in the vicinity of the exploration block are consistent with recent motion along this fault as well. These faults and fractures are potential pathways for fluid migration to the surface. The influence of seismicity on fracture generation and fluid migration at the proposed site also warrants further investigation once more detailed site plans have been released.

2. A syncline is a "U" shaped warping of geologic layers. The plunge is the direction and angle that the axis of this "U" is tilted. The 30-ft thick Beluga coal bed crops out in a "U" shape along the Beluga River canyon, and the attitude of these beds indicates that the axis of this "U" becomes deeper to the east.

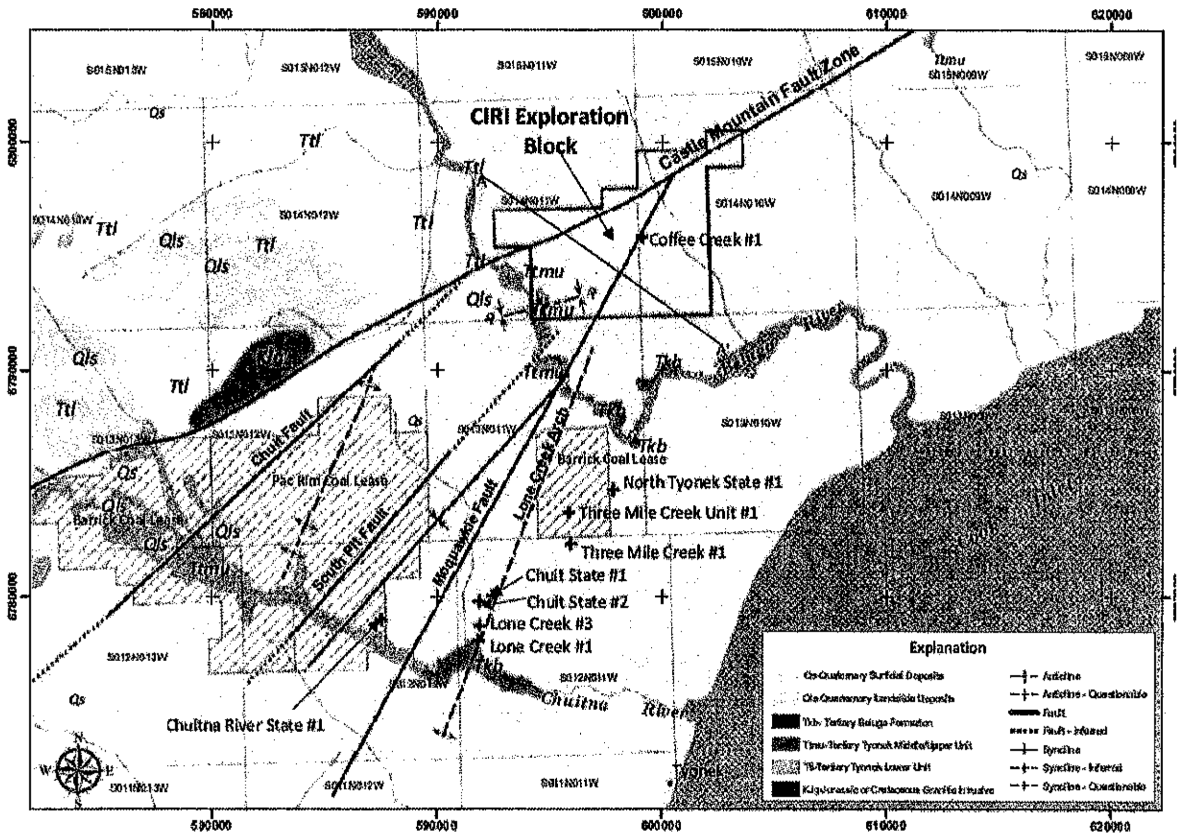

Figure 4. CIRI exploration area generalized geology.

Source: Belowich, 2009, Figure 3.

5. Environmental Monitoring for UCG and CCS

It is difficult at this stage to provide detailed comments on environmental monitoring needs at the CIRI site due to the lack of site-specific information. However, this section provides some general comments on the needs and importance of site characterization and environmental monitoring at UCG and CCS sites

The need for flexibility and responsiveness in site characterization and monitoring cannot be overemphasized for a project such as the proposal from CIRI. Geologic systems are inherently heterogeneous and complex, and their properties can be highly variable over a variety of spatial scales. As a result, environmental monitoring will likely need to be an iterative process, with data

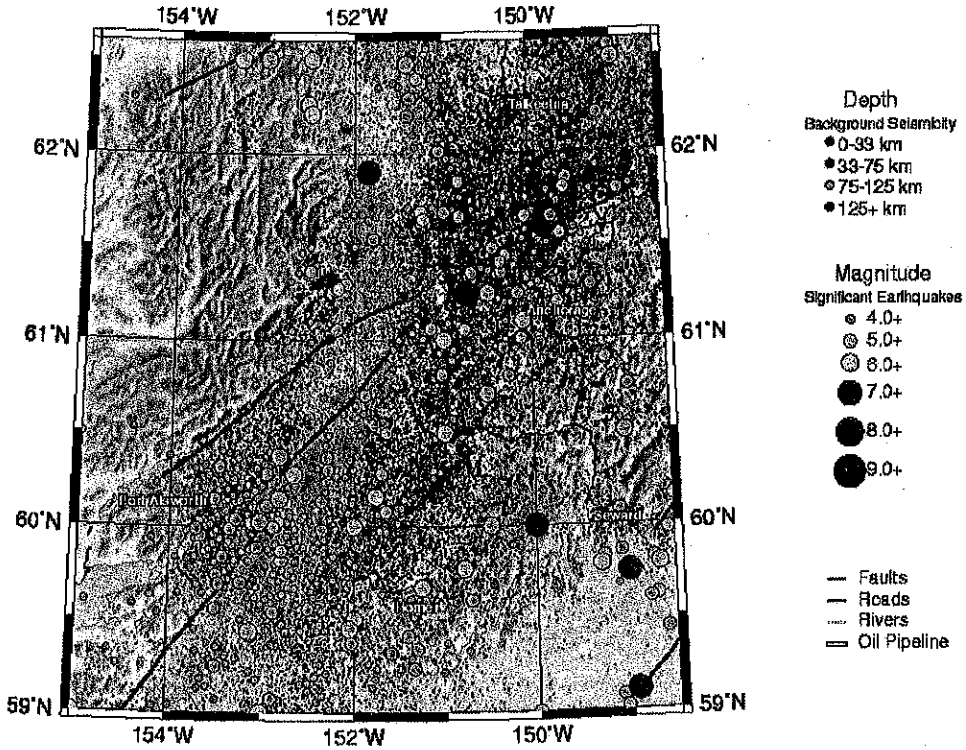

Figure 5. Cook inlet seismicity. The location of the CIRI site is approximately at the intersection of the two faults located west of Anchorage.

Source: AEIC, 2006.

gathered during initial site characterization and monitoring likely used as initial inputs for a flexible set of models (Bacon et al., 2009). Monitoring data gathered during the initial UCG burnout phase and the early CO_2 injection phase can then be used to refine models, if needed. If unanticipated conditions are detected, the location and frequency of monitoring, and employed technologies can then be altered so that monitoring occurs where the produced or injected fluids have come to be located.

Overall, the frequency of measurements may be greatest during the early part of the project, when the least is known about the site, and data are needed for model and instrument calibration. Longer time intervals between measurements may be sufficient during later phases of syngas generation and CO_2 injection. The initial start-up of both phases of the project is likely to be the most intensive period for modeling activities, including model calibration and refinement, and for verification as initial field data are collected. The intensity of modeling activities may also slow with time, once models are refined and are able to adequately predict subsurface fluid movement, location, and quantity.

The need for careful site characterization and monitoring is illustrated by experience at well-characterized GS sites such as Sleipner (North Sea), Frio (Texas), and Weyburn (Saskatchewan). At these sites, model simulations based on initially gathered site characterization data did not accurately predict the migration and location of the injected CO_2. For example, at Sleipner, the lateral dimensions of the CO_2 plume were much smaller than predicted by pre-injection model simulations. Compared to predictions, the plume spread out less laterally and more vertically. Unrecognized discontinuous silt layers within the injection zone were responsible for the unanticipated distribution of CO_2 (Johnson and Nitao, 2003). Unpredicted CO_2 migration was also observed at Frio, where the CO_2 migrated much more quickly than anticipated (Doughty et al., 2001; Hovorka et al., 2005; Kharaka et al., 2009). At Weyburn, modeled predictions of the location and shape of the CO_2 plume were partially incorrect. A series of faults at the site that were not included in the model simulations were believed to be responsible for the unanticipated results (Friedmann, 2003). At each of these sites, none of the unanticipated migration resulted in leakage, and the CO_2 remained sequestered in the intended injection zone, thus demonstrating the potential for successful storage of CO_2 in the subsurface. All of these examples, however, reinforce the need for careful, iterative site characterization; flexibility and responsiveness in monitoring activities; and the need for dynamic monitoring plans so that the location, frequency, and types of field measurements can be adjusted as needs and conditions change.

6. Conclusions and Recommendations

The project proposed by CIRI has a number of potential environmental benefits when compared to conventional coal mining. As described above, however, there remain a number of environmental risks associated with both UCG and CCS. Some of the most important of these risks are:

- The risk of groundwater contamination as a result of UCG and/or CCS
- The risk of subsidence resulting from cavity formation in the UCG burn-out zone
- The risk of syngas and/or CO_2 releases to the surface, and associated impacts on surface water resources, ecosystems, or human health
- The risk of induced microseismicity as a result of overpressurizing CCS target zones.

As it currently stands, the CIRI proposal is far too general to enable a reasoned evaluation of the environmental risks of the project. Sections 2.5 and 3.3 describe the minimum environmental characterization data that are required for such a reasoned evaluation to occur. To summarize, the data requirements for environmental characterization follow:

- Detailed stratigraphic information compiled from borehole and seismic data, including the depth, thickness, and geotechnical properties of coal seams and overlying stratigraphic units
- Geochemical and mineralogical characterization of the target coal seams for UCG, the target GS sites, and surrounding rocks, to evaluate the potential for groundwater contamination from the proposed project
- Baseline characterization of groundwater conditions, including the depth, thickness, hydraulic conductivity, and groundwater flow directions in subsurface aquifers
- Detailed geologic mapping of active and fossil fault zones in the areas proposed for UCG and CCS, along with a characterization of their hydraulic properties.

If the project proceeds, further risks to the environment can be mitigated through comprehensive site monitoring. As described in Section 5, environmental monitoring is likely to be an iterative process; however, minimum requirements for monitoring follow:

- Pressure monitoring, including monitoring of hydrostatic pressure in the UCG burnout zone to ensure inward hydraulic gradients, and monitoring of injection pressures for CCS.
- Groundwater monitoring in the areas surrounding UCG and CCS injection zones, to detect the potential for escape of contaminated groundwater.
- Air monitoring to detect potential escapes of syngas and/or CO_2 to the surface. Both of these air monitoring campaigns would require establishment of baseline conditions prior to project initiation.
- Monitoring of induced surface motions, including the potential for subsidence induced by UCG cavity formation and the potential for induced microseismicity induced by increased pressures in GS formations.

While the CIRI proposal holds some promise as a marriage of new technologies for energy exploitation, these data requirements still need to be met. Only when all of these additional data needs have been met can an informed permitting and regulation process proceed.

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Via hand delivery

Department of Environmental Quality / Water Quality Division
Attn: Kevin Frederick, Administrator
122 West 25th Street
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Cheyenne, Wyoming 82002.

03/26/2014

RE: Water Quality Division's re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.'s (Linc) proposed underground coal gasification research and development testing project (Linc UCG Gasifier 6 Project), located on lands owned by the State of Wyoming, specifically T44N, R74W, Section 36 within Campbell County

Dear Administrator Frederick,

The Wyoming Outdoor Council is the state's oldest independent conservation organization. We've worked for more than four decades to protect Wyoming's environment and quality of life for future generations.

Thank you for the opportunity to comment on Linc Energy's (Linc's) aquifer exemption request for the purposes of an underground coal gasification (UCG) demonstration project proposed approximately 15 miles west of Wright, Wyoming in Campbell County.

The Wyoming Outdoor Council has several serious concerns with Linc's application to exempt the Wyodak aquifer from the Safe Drinking Water Act for the purposes of the company's proposed UCG demonstration project. For the reasons listed below and expanded upon in the body of this letter, our organization believes that the DEQ must deny Linc's request for an aquifer exemption. Our reasons for taking this position include:

1.) Groundwater is a vital, limited resource in the Powder River Basin and removing groundwater protections is not in the public's interest.
2.) Historically, UCG has resulted in long-term aquifer contamination and Linc, specifically, has been unable to demonstrate an ability to successfully decommission its gasifiers after UCG operations cease, especially at the scale required for commercial operations.
3.) The aquifer in question is viable as a future source of drinking water.
4.) Linc has been granted the opportunity in Australia to demonstrate successful gasifier decommissioning at a scale representative of commercial operations,

but has not fulfilled that goal. Granting the same permission in Wyoming is unnecessary, unwise, and a waste of the state's valuable groundwater resources.

5.) The aquifer in question does not legally qualify for exemption and granting such an exemption would violate the Safe Drinking Water Act (SDWA).
6.) Linc has not adequately demonstrated that contamination will remain within the proposed exemption area.
7.) Linc's monitoring program is insufficient to detect excursions (movement of contamination beyond the proposed exempted area of the aquifer) resulting from the proposed UCG process.
8.) Issuing Linc's requested aquifer exemption sets a dangerous precedent for the state's interpretation and implementation of the SDWA.

1. Groundwater is a vital, limited resource in the Powder River Basin and removing protections is not in the public's interest.

Surface water is scarce in the Powder River Basin and the quantities and qualities that are available are insufficient to meet all domestic drinking water and livestock demands. Instead, the towns of Gillette and Wright and the surrounding areas must rely upon groundwater as their primary—and in most cases sole—drinking water source. Groundwater for domestic consumption in Gillette and Wright is derived largely from the Fort Union Formation,[1] which contains the Wyodak aquifer where Linc proposes to acquire an aquifer exemption. A 1995 report from the Wyoming State Engineer's Office describes the Fort Union Formation as:

> . . . [O]ne of the most prolific Tertiary-age fresh water aquifers in the arid western half of North Amercia. Certainly within the state of Wyoming, and the Powder River Basin in particular, people and industry are highly dependent on this seemingly inexhaustible and exceptional quality ground water. This is especially true when the almost total lack of surface water supplies in this area is considered.[2] (WSEO, 1995)

Groundwater supplies in the Powder River Basin are in heavy demand.[3] In response to this strain, the City of Gillette and the State of Wyoming have invested $226 million in the construction of a 42-mile pipeline to transport additional water to Gillette from wells drilled into the Madison Formation.[4] Further, should the Fort Union Formation ever become unable to serve as at least one of the primary water sources in the region due to groundwater contamination, depletion, or otherwise, "[i]t is . . . inevitable that any substantial development of the Madison aquifer will eventually lead to mining of groundwater in excess of the sustainable yield of the aquifer."[5] In other words, the Powder River Basin is already stretching what groundwater resources it has and cannot afford to lose either existing or potential sources of groundwater.

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[1] Bureau of Land Management. Buffalo Field Office. Powder River Basin Oil and Gas EIS: Technical Report – Groundwater Modeling. 2002. p 2-11, 2-30.

[2] Wyoming State Engineer's Office. Fort Union Formation Aquifer Monitoring Plan and Preliminary Aquifer Management Plan: Gillette Area Water Master Plan. 1995. p 3-1.

[3] Morrison-Maierle, Inc. B&M Long Term Water Supply Level II Study. August 8, 2007. <http://www.gillettewy.gov/index.aspx?page=1191>.

[4] City of Gillette. "Gillette Regional Master Plan Level 1 Study – Final." Oct. 2009. <http://www.gillettewy.gov/index.aspx?page=1189>.

[5] Morrison-Maierle, Inc. p 5-28.

Given the limited extent and invaluable nature of groundwater in the Powder River Basin, permitting the pollution of any groundwater which is suitable for domestic and/or livestock consumption—and thereby risking the pollution of additional sources of groundwater beyond the exempted area—is not in the public's interest and should not be approved by the DEQ.

2. Historically, UCG has resulted in long-term aquifer contamination and Linc, specifically, has been unable to demonstrate successful decommissioning after operations cease, especially at the scale required for commercial operations.

Prior tests of UCG in the 1970s in Wyoming failed and resulted in long-term groundwater contamination.[6] Additionally, according to a report commissioned by the Queensland government in Australia, "Independent Scientific Panel Final Report on Underground Coal Gasification Pilot Trials," the Independent Scientific Panel (ISP) found that Linc has been unable to demonstrate an ability to successfully decommission a gasifier using the "self-cleaning" approach, particularly at the large scale necessary for commercial operations.[7] The ISP states, "[i]f a 'clean cavity' is not able to be demonstrated, then the technology is not sufficiently well designed to be considered safe."[8] This discrepancy is especially relevant to DEQ if indeed Linc's proposed demonstration project is deemed desirable to the state because it is intended to eventually lead to UCG at a commercial scale. The ISP report reads: "…the ISP is of the opinion that the best strategies [for successful decommissioning] have not been fully developed at this time."[9]

The self-cleaning method of decommissioning proposed by Linc consists of terminating the oxidant injection to the reactor and slowly decreasing the pressure of the system to allow an influx of water to the gasifier cavity as a result of hydrostatic pressure. Gasifier pressure is (theoretically) maintained below that of the adjacent overburden and underburden aquifers and, in principle, the groundwater flow will remobilize residual tars and liquid hydrocarbons (which include benzene, toluene, xylene (BTEX), phenols, various polycyclic aromatic hydrocarbons (PAHs) and other hydrocarbons—all of which are known carcinogens), within the gasifier cavity. This is intended to suspend the contaminants so they may be pumped to the surface, treated onsite, and then disposed of at a facility in Gillette.[10]

It is important to note that the ISP report states that the success of Linc's proposed strategy for decommissioning the gasifier via the "self-cleaning" cavity approach is heavily reliant upon knowing "the composition of the cavity following operation." In *DEQ Seventh Round Comments – July 10, 2013* of Linc's exemption application, Linc writes:

> [I]n discussions with the WDEQ over the past two (2) years, it has never been established that Linc would be required to verify the size and shape of the final cavit(ies). First of all, this can be very difficult to achieve with a high degree of accuracy given known technology and

6 GasTech, Inc. "Viability of Underground Coal Gasification in the 'Deep Coals' of the Powder River Basin, Wyoming." 2007. Wyoming Business Council, Report 061507.

7 Queensland Independent Scientific Panel for Underground Coal Gasification, "Independent Scientific Panel Final Report on Underground Coal Gasification Pilot Trials." June 2013. p 34-35. http://mines.industry.qld.gov.au/assets/legislation-pdf/isp-final-report-cs-review.pdf.

8 Queensland Independent Scientific Panel for Underground Coal Gasification. p 34.

9 Queensland Independent Scientific Panel for Underground Coal Gasification. p 35.

10 Linc Application. Section 17: Reclamation Plan. p 10. *See also* Queensland Independent Scientific Panel for Underground Coal Gasification, "Independent Scientific Panel Final Report on Underground Coal Gasification Pilot Trials." June 2013. p 35.

the depth of the project...[11] (Linc Application, Section 17)

Since Linc cannot accurately determine and report to DEQ the expected gasifier cavity size and shape, especially given that the ISP report found that the morphology of some cavities from UCG processes have been found to be "toroidal, possibly due to rubble collapse" and not to "match expectations"[12] there is significant risk that the self-cleaning approach will fail and groundwater supplies will be contaminated;

In regard to the potential for contamination to travel from the cavity to overburden aquifers as a result of Linc's operations, the ISP report further states:

> . . . [I]f the post-gasification cavity is at least partially rubble-filled . . . implied by Linc Energy *(sic)* conceptual model and possibly MAZ [material affected zone] visual rendering data and accepted by the ISP; then it stands to reason that the rubble is from the overburden. This implies that the integrity of the seal [between the gasifier and the overburden aquifer] is potentially compromised. . . It is expected that a move to commercial operation and larger cavities would increase this risk. That is, it is increasingly likely that over a length of several hundred metres gas migration pathways are formed by the collapse of the cavity roof. (ISP, 38)

The aforementioned information suggests that Linc's proposed operations could likely lead to contamination of overburden aquifers; consequently, the DEQ would be wise to deny Linc's application.

The history of unsuccessful, groundwater-contaminating UCG demonstration projects in Wyoming, the unproven decommissioning method proposed by Linc— particularly at the scale that would be necessary if Linc were to truly demonstrate the feasibility of commercial-scale operations in the state, and Linc's own admission that its final cavity size(s) and shape(s)—though critical to the success of their decommissioning strategy—cannot be determined, and evidence of overburden collapse and potential creation of contamination pathways in Linc's projects in Austraila, all indicate that the approval of Linc's application is likely to lead to groundwater contamination in an already water-stressed region of the state. For the aforementioned reasons related to Linc's proposed UCG process, WOC believes the DEQ has a duty to reject Linc Energy's application in the public interest.

3. The aquifer in question is viable as a future source of drinking water.

Quality

Contrary to Linc's assertion in the company's application, the groundwater present in the Wyodak coal aquifer is of sufficient quality to be considered a future underground source of drinking water (USDW). At just over 500 mg/L total dissolved solids (TDS), it is a suitable drinking water aquifer. The Fort Union Formation is the most important and commonly used water supply aquifer in the Powder River Basin. Two independent expert studies of Linc's application commissioned and co-commissioned by WOC (a letter to DEQ (enclosed) from Dr. Robert Puls and a technical memorandum from Stratus Consulting, Inc.) have confirmed that the depth, location, yield, and

[11] DEQ Seventh Round Comments – July 10, 2013. p 16 of 37.

[12] Queensland Independent Scientific Panel for Underground Coal Gasification. p 36.

quality of the Wyodak aquifer does not preclude future use as a drinking water source.[13] This is especially the case "as availability of water for human and ecological uses becomes more critical."[14] Dr. Robert Puls writes of Linc's characterization of the Wyodak aquifer:

> None of the chemical constituents noted [by Linc to indicate the unviability of the Wyodak as a future source of drinking water] pose any adverse health risks or would restrict the aquifer for use as a potable drinking water supply and classification as an underground source of drinking water. (Puls, 1)

Dr. Puls concludes:

> These [aquifer exemption] decisions must be arrived at carefully and it requires demonstrating the exempted aquifer is not likely to be used as a future drinking water source. I do not believe Linc has met this threshold. (Puls, 3)

Quantity

The Wyoming State Geological Survey (WSGS) released a report in 2013 citing groundwater level recovery throughout the Fort Union Formation including within the Wyodak aquifer.[15] Linc did not consider the WSGS report in its application, leaving the company's calculations of the available quantity of groundwater in doubt;[16] this shortcoming indicates reason to question all of the hydrologic calculations the company uses in its request for an aquifer exemption.[17]

4. Linc has been granted the opportunity in Australia to demonstrate successful gasifier decommissioning at a scale representative of commercial operations, but has not fulfilled that goal. Granting the same permission in Wyoming is unnecessary, unwise, and a waste of the state's valuable groundwater resources.

Despite the opportunity provided by the Queensland government, Linc, to-date, has been unable to show that its proposed processes, particularly its decommissioning methods, are effective at a scale representative of commercial production.[18] The ISP Report to the Queensland government reads:

> Neither company [Linc or Carbon Energy] has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. . . sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. . . neither company had completed a burn of sufficient duration to create a final cavity of the dimensions that are expected under a commercial process. Until this is done it is difficult to come to a final conclusion regarding the technology. . . the ISP believes it would be pre-emptive to consider commercial scale. . .the gasifiers currently operating should be permitted to continue until a cavity of significant dimensions is available for full

[13] Stratus Consulting. Memorandum: Review of Linc Energy Wyoming's proposed Wyodak Coal aquifer exemption. January 2014. p 2, 12-13. (Enclosed). *See Also*: Letter from Dr. Robert Puls RE: Linc Energy Wyoming's proposed UCG R & D Project. March 7, 2014. (Enclosed).

[14] Letter from Dr. Robert Puls RE: Linc Energy Wyoming's proposed UCG R & D Project. March 7, 2014. (Enclosed).

[15] Stafford, James E. and Seth J. Wittke. Wyoming State Geological Survey. 2012 Coalbed Natural Gas Regional Groundwater Monitoring Update: Powder River Basin, Wyoming. 2013. p 15.

[16] Stratus Consulting. p 2, 8-9

[17] Stratus Consulting. p 2, 8-9.

[18] Queensland Independent Scientific Panel for Underground Coal Gasification. p 17 and 35.

and comprehensive demonstration. At that time, commercial scale UCG facilities could be considered. (ISP Executive Summary)

The company's request for demonstration latitude in Wyoming when it has been unable to satisfactorily fulfill the same goal in Australia should be a red flag for the DEQ. Granting Linc permission to pollute valuable potential drinking water supplies and risk the contamination of current drinking water supplies when the company has failed to complete a similar project in Australia is an unnecessary waste of the state's natural resources and offers little reason to have confidence that Linc will successfully fulfill its claimed goal of successful – environmentally sound – operation in Wyoming.

5. The aquifer in question does not legally qualify for exemption and granting such an exemption would violate the Safe Drinking Water Act (SDWA).

The purpose of the Safe Drinking Water Act (SDWA) is to protect underground sources of drinking water.[19] According to federal regulations, EPA or a delegated state cannot approve an aquifer exemption if the aquifer is currently being used as a drinking water source or has the potential to be used in the future as a drinking water source.[20] The Wyodak aquifer clearly has this potential.[21]

The DEQ's public notice announcing the March 26th, 2014 public meeting on this issue states that:

> WQD believes that the area of the aquifer re-classified by WQD meets EPA's criteria for exemption because groundwater within this portion of the aquifer is not being used as a source of drinking water, and it cannot now, nor in the future serve as a source of drinking water *because it contains minerals that are expected to be commercially producible, considering their quantity and location* (emphasis added).

For reference, the specific language of 40 C.F.R. 146.4(b), the regulation WQD relies upon in the above quoted conclusion, reads:

> An aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in § 146.3 may be determined under § 144.7 of this chapter to be an "exempted aquifer" for Class I-V wells if . . . :
>
> . . .
>
> (b) It cannot now and will not in the future serve as a source of drinking water because:
>
> (1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible. (40 C.F.R. 146.4(b))

Acknowledging that Linc's application is for a research project, the aquifer exemption request is based upon the presumption of commercial production. First, Linc has not demonstrated in their

[19] 42 U.S.C. § 1421(b)(1)(B); SDWA § 300h(b)

[20] 40 C.F.R. § 146.4

[21] Stratus Consulting. p 2, 12-13. *See Also*: Letter from Dr. Robert Puls RE: Linc Energy Wyoming's proposed UCG R & D Project. March 7, 2014.

application that the formation contains commercially producible minerals. Second, the company plans to produce syngas, not coal, which is the substance Linc asserts is a commercially producible "mineral." Even if the DEQ does consider characterization of syngas (as opposed to coal) appropriate under the producible "mineral" definition, the "approximately one million standard cubic feet per day (MMscfd) of synthesis gas or 'syngas'" Linc proposes to create has no commercial purpose; Linc intends to flare all of it. [22] Further, a commercial-scale quantity of syngas, if ultimately demonstrated by Linc to be present in the Wyodak aquifer, does not in itself justify an exemption if that quantity merely exists, but the method of proposed production is unproven and therefore those minerals cannot reasonably be expected to be "producible." Therefore, an aquifer exemption approval by the DEQ would be premature and contrary to statute. If the DEQ approves the aquifer exemption at this stage, it would be made on the *presumption* that (1) the Wyodak aquifer could produce commercial scale syngas (which, again, is not a mineral as required by 40 C.F.R. 146.4(b)), when the DEQ not only lacks information in the exemption application to show that the Wyodak aquifer contains commercial scale quantities, but also lacks information that shows (2) Linc's proposed UCG processes are at least capable of successfully producing at a commercial scale (i.e. in all phases of the operational life cycle: site selection, commissioning, operation, decommissioning, and restoration[23]). In fact, in the ISP Report, the DEQ actually has information to the contrary. The ISP explains that Linc has yet to demonstrate an ability to successfully operate UCG processes at a scale representative of commercial development[24] and that the Queensland government has prohibited Linc from conducting commercial operations until it can prove it has such a capability because "[i]f a 'clean cavity' is not able to be demonstrated then the technology is not sufficiently well designed to be considered safe.[25] We urge the DEQ not to ignore this information. Granting the aquifer exemption would risk Wyoming's valuable groundwater and could "imperil the public health and impair domestic, agricultural . . . and other beneficial uses"[26] that rely upon the groundwater resources in the Fort Union Formation.

6. Linc has not demonstrated that contamination will remain within the proposed exemption area.

Linc has not demonstrated that contamination will remain within the proposed exemption area. According to a thorough report by Stratus Consulting, calculations in Linc's application are based on inappropriate values and assumptions leading to inaccuracies in its application. Contrary to the claims in Linc's application, evidence suggests that the geologic and hydrologic characteristics of the area requested for exemption by Linc Energy:

a. enable communication between the aquifer requested for exemption and other aquifers,
b. enable possible amplification of that communication by the UCG process,
c. are indicative of higher flow velocities than cited in Linc Energy's application, and
d. indicate a high likelihood for loss of hydraulic control during the UCG process.[27]

[22] Linc Application. Section 13.14.3: Commercial Production Potential of the Ore Deposits. p 3.14-7.
[23] Queensland Independent Scientific Panel for Underground Coal Gasification. Executive Summary.
[24] Queensland Independent Scientific Panel for Underground Coal Gasification. Executive Summary.
[25] Queensland Independent Scientific Panel for Underground Coal Gasification. p 17, 34 and 35.
[26] Wyoming Statute 35-11-102: Policy and Purpose. *Wyoming Environmental Quality and Industrial Development Information and Siting Act.* 2012 Ed.
[27] Stratus Consulting. p. 2, 12-13.

The detailed study by Stratus Consulting Inc. (enclosed) explains these problems in more detail. The neglect of variability and uncertainty related to figures used in Linc's calculations, the resultant errors in Linc's application and the company's subsequent inability to guarantee the prevention of groundwater contamination outside of the proposed exemption area are sufficient reasons for the DEQ to deny Linc's request for an aquifer exemption.

7. Linc's monitoring program is insufficient to detect excursions (movement of contamination beyond the proposed exempted area of the aquifer) resulting from the proposed UCG process.

Linc's proposed monitoring program does not include a broad enough list of parameters, such as those used in previous monitoring programs in the state (e.g. related to the Rock Mountain 1 UCG test). Importantly, Linc's proposed groundwater monitoring program does not consider dangerous contaminants likely to be mobilized by the UCG process, including known carcinogens such as benzene and polycyclic aromatic hydrocarbons (PAHs).[28] The current, incomplete list of constituents to be monitored could feasibly allow groundwater contamination to move beyond the proposed exemption area undetected.[29] The list of constituents in the monitoring program must be expanded for Linc's project in order to include all parameters known to be associated with groundwater contamination from UCG operations.

8. Issuing Linc's requested aquifer exemption sets a dangerous precedent for the state's interpretation and implementation of the SDWA.

Granting an aquifer exemption in an aquifer otherwise suitable as an USDW solely because of the presence of coal, as Linc is requesting, would establish an unacceptable and dangerous precedent for the manner in which the state of Wyoming interprets and implements the SDWA. If this precedent is set, it presents the opportunity for further aquifer exemptions in other coal-bearing portions of the Fort Union Formation and puts at risk additional valuable and limited drinking water sources across a widespread area. The consequences of such a precedent could be disastrous for current and future water users in the water-scarce Powder River Basin. We strongly urge the DEQ to avoid creating such a precedent and deny Linc's aquifer exemption request.

Conclusion

In conclusion, we urge the State of Wyoming not to grant the exemption of the Wyodak aquifer for the purposes of Linc Energy's underground coal gasification demonstration project. Groundwater is a vital resource in the Powder River Basin; water that is suitable as an underground source of drinking water, such as the Wyodak aquifer, must be protected now and for future generations. Further, Linc's proposed production of syngas to be flared for a research project using an unproven method of extraction does not demonstrate the presence of a commercially producable mineral in the Wyodak aquifer; consequently, we believe that granting an aquifer exemption in this case violates the Safe Drinking Water Act.

We respectfully request that the DEQ give significant consideration to the Independent Scientific Panel Report to the Queensland government and heed its warnings regarding evidence of Linc's

[28] Stratus Consulting. p 3, 21.
[29] Stratus Consulting. p 21.

inability to protect groundwater over the long-term and at a scale large enough to support commercial production.

At a minimum, DEQ should wait to allow Linc to move forward in Wyoming until the company has completed the projects it has already begun in Australia and successfully demonstrated its ability to decommission large (commercial-scale) cavities there. In the meantime, DEQ would have time to further evaluate the UCG process and its unique risks and develop appropriate regulations to adequately protect Wyoming's precious groundwater resources. We believe that proceeding with Linc's project at this time would set an unacceptable and dangerous precedent for Wyoming's interpretation of the SDWA, thus threatening the health and welfare of its citizens.

Thank you for your sincere consideration of these comments and its enclosures. We look forward to DEQ's response.

Sincerely,

Amber L. Wilson

Amber L. Wilson
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Wyoming Outdoor Council
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Enclosures:

- Stratus Consulting Inc. Technical Memorandum: Review of Linc Energy Wyoming's proposed Wyodak Coal aquifer exemption. January 2014.
- Letter from Dr. Robert Puls to Administrator Kevin Frederick dated March 7th, 2014
- Dr. Robert Puls' Curriculum vitae

Additional references:

- International Scientific Panel Report on Underground Coal Gasification Pilot Trials. Queensland, Australia government. June 2013. Can be found online at: http://mines.industry.qld.gov.au/assets/legislation-pdf/isp-final-report-cs-review.pdf

March 7, 2014

Department of Environmental Quality / Water Quality Division
Attn: Kevin Frederick, Administrator
122 West 25th Street
Herschler 4W
Cheyenne, Wyoming 82002

Mr. Frederick:

Background
Linc Energy Wyoming (Linc) has proposed an underground coal gasification (UCG) research and development project for the Wyodak Coal aquifer in the Fort Union Formation in Campbell County, Wyoming. As part of the application process, Linc has requested an aquifer exemption and groundwater reclassification for the Wyodak Coal aquifer in and around their project site. At the request of the Wyoming Outdoor Council (WOC), I have reviewed certain portions of the Linc application and provide the following comments:

The Wyodak Aquifer Can Be Classified as a Suitable Drinking Water Aquifer in the Future
The Wyodak aquifer is suitable to be a drinking water aquifer in the future. It is a geological "formation," group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring as defined in the UIC Program. The total dissolved solids (TDS) content of the aquifer is well below the 10,000 mg/L TDS threshold that defines an underground source of drinking water according to the UIC Program. The water quality of the Wyodak is comparable to the Felix aquifer, which currently serves as a potable drinking water supply. Linc has failed to provide sufficient data concerning the "yield" of the Wyodak, particularly given the heterogeneous nature of the system, which they refer to repeatedly in their own documents. I have the following more specific comments:

1) Linc suggests that the Wyodak aquifer is unsuitable for drinking water based on several factors:
   a) High levels of iron and manganese that exceed Secondary Maximum Contaminant Levels (SMCLs) for drinking water
   b) Presence of bis (2-ethyl) phthalate in some samples that exceed the Primary Drinking Water Standard
   c) Low yield (about 1 gallon per minute) and depth
   d) TDS values (501-579 mg/L) slightly above SMCL (500 mg/L) for drinking water

None of the chemical constituents noted above pose any adverse heath risks or would restrict the aquifer for use as a potable drinking water supply and classification as an underground source of drinking water. The U.S. Environmental Protection Agency (EPA) has not set maximum contaminant levels (MCL) for iron and manganese in the National Primary Drinking Water Regulations. Secondary maximum contaminant levels (SMCL)

recommended in the National Secondary Drinking Water Regulations are set for esthetic reasons and are not enforceable by EPA, but are intended as guides to the States. The SMCL for iron is 0.3 milligrams per liter (mg/L) and the SMCL for manganese is 0.05 mg/L. Samples collected by Linc or its contractors show a high degree of variability in these parameters and other constituents and the report relies heavily on the "total" metal analyses to demonstrate an exceedance for Fe and Mn. Virtually all of the "dissolved" values for Fe and Mn fall below the SMCL. The use of high-speed submersible pumps for ground water sampling can routinely result in artificially turbid samples where the difference between "total" and dissolved" is consistent with Linc results. Samples with elevated turbidity caused by the sampling procedure often result in significant differences between "total" and "dissolved" due to the presence of colloids or larger particles entrained in the sample. Constituents like Fe, Mn and Ra preferentially sorb to clay and iron oxide particles causing this difference. Turbidity results for most wells are very high and there is a suggestion in one analytical report that samples were lab filtered as opposed to field filtered which would further exaggerate this difference. EPA and USGS guidance is field filtration for "dissolved" analysis, which would be appropriate for these wells.

The presence of bis (2-ethyl) phthalate in some samples is most likely due to PVC, plastic tubing associated with well construction materials or sampling apparatus, or laboratory procedures. This is a commonly known artifact compound found in ground water samples (Wisconsin Dept Natural Resources, Publication WA 1011, Rev. 2002). Its presence usually dictates that the entity responsible for the sampling reevaluate their sampling procedures, sampling equipment and laboratory procedures to exclude it as an artifact. Linc did not do this.

A single hydraulic conductivity value of 0.06 ft/day was used for Linc's aquifer exemption calculation; this, in an aquifer that even they admit is heterogeneous. They also clearly had trouble locating the screened intervals in the aquifer, with 4 of 7 having issues of crossover into the Underburden aquifer. The changing conditions of the aquifer imposed from 10 years of CBM production have clearly complicated the ability to accurately establish meaningful ground water aquifer properties. More samples and tests should therefore have been done for this aquifer (the target for the aquifer exemption), not less than was done for the Overburden and Underburden aquifers. It is common to use wells around 1100 feet deep and deeper for municipal potable water supply wells. In fact, many domestic wells in this part of the state are significantly deeper than 1100 feet and municipal wells near Gillette are as deep as 4500 ft. (http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html).

TDS values in slight exceedance of the SMCL again are not enforceable from a drinking water standpoint and many water supply districts are increasingly using such waters as drinking water sources in the face of dwindling available supplies.

Other Comments
Many of the selected parameters used for the aquifer exemption are limited (single tests), and ignore aquifer heterogeneity. This creates a large amount of uncertainty. There is no

scientifically defensible uncertainty analysis associated with these parameters put forward by Linc in their application.

Another concern is the assumption of radial flow away from the test site. If the aquifer was a homogeneous porous medium (I have yet to see such a case in the real world), this conceptual model might hold water. But, even Linc understands it is not and indeed it may be highly fractured, resulting in preferential flow paths and much faster travel times for contaminant excursions than those proposed by Linc.

A "Best Practices in Underground Coal Gasification" report by Lawrence Livermore National Lab (contract W-7405-Eng-48) states that "Suitable future UCG locations should be located at depths where local aquifers consist of saline, nonpotable water, with stratigraphic seals, with structural integrity, including no possibility of cavity roof caving that would create connectivity with other adjacent potable aquifers." This document is largely based on experiences in the Hoe Creek site in the Powder River Basin. Linc has not shown that the aquifer in question can be described as above. There is therefore, significant uncertainty associated with the suitability of the chosen site. This means that there is also significant uncertainty that hydrocarbons in quantity and location are expected to be "commercially producible" from this formation. Wyoming should not want to risk losing a potential useable drinking water source with this much uncertainty regarding a positive outcome of the proposed Linc 'test'.

Concluding Comments

EPA is seeing more aquifer exemption requests with the rise in energy extraction activities across the U.S..As availability of water for human and ecological uses becomes more critical, there is also increased interest in the use of deeper groundwater as a drinking water resource. The number of deep public water supply wells has increased significantly in the western United States during the past couple decades and therefore, the number of locations that can be "reasonably expected" to serve as future drinking water supplies is also increasing. Many CBM aquifers in Colorado and Wyoming have been and are being used as drinking water aquifers. Given the pace of unconventional oil and gas extraction activities and current high production rates, I do not believe that this test is worth the potential contamination of a useable drinking water aquifer.

An Aquifer Exemption removes an aquifer or a portion from protection as a USDW under SWDA. These decisions must be arrived at carefully and it requires demonstrating the exempted aquifer is not likely to be used as a future drinking water source. I do not believe Linc has met this threshold.

Sincerely yours,

Robert W. Puls

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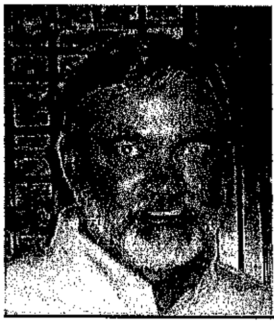

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UNIVERSITY OF ARIZONA, Department of Soil and Water Science. Tucson, AZ. Ph.D. Soil and Water. 1986.

UNIVERSITY OF WASHINGTON, College of Forestry. Seattle, WA. Masters Forest Resources.1979.

UNIVERSITY OF WISCONSIN, Department of Soil Science, Madison, WI. B.S. Soil Science and Natural Resources. 1978.

UNIVERSITY OF NOTRE DAME, College of Arts and Sciences, South Bend, IN. 1968-1970.

Dr. Robert Puls recently served as EPAs Technical Lead on a new National Research Program: Hydraulic Fracturing and Drinking Water Resources. This program was initiated in 2010 at the direction of the U.S. Congress. As Technical Lead he was responsible for the coordination of all phases of the research program, which involved multiple EPA labs and centers of excellence within EPA's Office of Research & Development (ORD). Dr. Puls has more than 80 peer-reviewed publications and more than 150 publications on ground water remediation, ground-water sampling, and ground-water contaminant transport and fate processes. He recently led a major effort involving federal, state, and local partners to investigate the feasibility of using in-situ methods to reduce arsenic contamination in drinking water. Prior integrated, multidisciplinary led efforts have evaluated the use of permeable reactive barriers for ground water remediation and the use of more effective and efficient methods for sampling ground water systems. Dr. Puls is internationally recognized as a leader in the development and evaluation of permeable reactive barriers and has made numerous invited presentations at international meetings. Dr. Puls has chaired and participated in numerous Agency and interagency work groups. He served for 5 years as Director of Research at the Ground water and Ecosystems Restoration Division (GWERD) in Ada, OK, and 2 years as Laboratory Director of GWERD before accepting the National Leadership position on the Hydraulic Fracturing Study. He currently is the Director of the Oklahoma Water Survey at the University of Oklahoma and Associate Professor in the College of Atmospheric and Geographic Sciences. As Director, he continues to be involved in water resource protection issues related to oil and gas operations in the state of Oklahoma.

Employment

UNIVERSITY OF OKLAHOMA, COLLEGE OF ATMOSPHERIC AND GEOGRAPHIC SCIENCES, 301 David L. Boren Pkwy. Suite 3550, 4 Partners Place, Norman, OK 73072
01/01/12 – present, Director, Oklahoma Water Survey, Associate Professor

U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT (ORD), NATIONAL RISK MANAGEMENT RESEARCH LABORATORY (NRMRL), GROUND WATER AND ECOSYSTEMS RESTORATION DIVISION (GWERD)
P.O. Box 1198, Ada, OK. 74820, 8/87 – 12/11.

03/10 – 12/11, Agency National Program Technical Lead, Hydraulic Fracturing and Drinking Water Resources, Ground Water & Ecosystems Restoration Division, National Risk Management Research Laboratory, USEPA

06/08 – 03/10, **Acting Director,** Ground Water and Ecosystems Restoration Division

- In addition to Director of Research responsibilities outlined below, also now responsible for the safe operation and management of the R.S. Kerr Research Center, the facility, its research programs, supporting programs, and federal staff. The Center employs about 120 personnel including federal staff, contractors and cooperators.

10/03 – 06/08, **Director of Research**, Ground Water and Ecosystems Restoration Division

- Responsibilities include providing the direction and management of the research program within the Division which includes research directed at the protection and restoration of ground water and surface water resources
- Responsible for management of resources used to conduct the Divisions intramural and extramural research program (>$6 million/yr) and overall

Laboratory operating budget of >$15 million/yr.

- As a recognized expert in the Divisions areas of research, serves as a technical advisor to the Agency's operating programs, reviews and evaluates the work of other technical groups, presents briefings for Agency staff and technical information at professional seminars and international exchange programs
- Performs research in the areas of innovative ground water remediation technologies, fate and transport of nanomaterials in the subsurface, and source water protection of underground sources of drinking water, in particular, innovative ways of mitigating arsenic in ground water drinking water supplies

10/98 - 9/03 Supervisory Environmental Scientist and Chief, Subsurface Remediation Branch

- Responsibilities include supervision of Subsurface Remediation Research Branch for the protection and restoration of ground water and surface water resources
- Coordination, management and direction of in-house remediation research to answer regional and program office needs
- Management of extramural and inter-agency research agreements, and
- Management of in-house contract research
- Performance of research in the areas of innovative ground water remediation technologies, fate and transport of nanomaterials in the subsurface, and source water protection of underground sources of drinking water.

8/87 - 9/98, Research Soil Scientist GS 15 *(promotion via EPA-ORD Technical Qualifications Board Process)*

Senior Research Soil Chemist

Principal Investigator for multi-agency, multi-disciplinary research involving the fate, transport and remediation of inorganic contaminants in subsurface systems.

Research has included the following:

- sorption-desorption processes of inorganic and organic contaminants
- inorganic colloidal transport processes in the subsurface,
- application of innovative remediation techniques (permeable reactive barriers) to hazardous waste sites,
- the development and evaluation of innovative, cost-effective and representative methods to sample ground water and
- in situ geochemical methods to mitigate elevated levels of arsenic in drinking water supplies.

WESTINGHOUSE HANFORD COMPANY - BASALT WASTE ISOLATION PROJECT, U.S. Department of Energy. Richland, WA. 8/86 - 8/87. Senior Geochemist.

Project Officer and Senior Scientist in charge of directing, supervising, and managing the laboratory sorption work performed for the Project by Battelle, Pacific Northwest Laboratory. Part of an interdisciplinary research team studying the transport and fate of radionuclides in confined basalt aquifers in central Washington for the disposal of high level radioactive wastes.

DEPARTMENT OF SOIL AND WATER SCIENCE, UNIVERSITY OF ARIZONA.

Tucson, AZ. 8/82-8/86. Research Associate.

Performed research on mechanisms and kinetics of metal sorption on soil clays. Assisted with research into the effectiveness of using soils for propane gas removal via sorption and microbiological breakdown for Johnson Wax Company. Instructor for Analytical Soil Chemistry Laboratory Course.

SOIL AND LAND USE TECHNOLOGY, INC.

Columbia, MD. 8/80-8/82. Senior Soil Scientist.

Project Leader for soil surveys on the White River National Forest, Colorado and the King Range National Conservation Area, California (Part I). Senior Soil Scientist for feasibility studies involving the introduction of new crops and biomass production for alternative energy use.

WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES.

Longview, WA. 5/79-8/80. Forest Soil Specialist.

Performed soil surveys of state of Washington forest lands and correlated timber productivity to soil-type.

Leadership

- EPA National Technical Lead for study on the relationship between hydraulic fracturing for oil and gas resources and protection of drinking water resources. March 2010 – December 2011.
- Acting Director of NRMRL division of 50 federal staff responsible for leading 25 Principal Investigators in a diverse research program focused on the protection and restoration of ground water and surface water resources. The research program addresses multiple programs, and as Director, provides for the safe and efficient operation of a stand-alone research facility. In addition to the 50 federal staff, the Robert S. Kerr Research Center houses an additional 80 non-federal support staff with a total operating budget of more than 15 million dollars. (Ada, OK), June 2008 – present.

- Director of Research of same division charged with leading and providing the scientific direction and management of the research program and management of resources used to conduct the divisions intramural and extramural research program (approx. $6 million/yr). 2003 - 2008
- Branch Chief, Subsurface Remediation Branch. Supervised 15 staff scientists engaged in innovative subsurface remediation research, primarily addressing the restoration of ground water resources. The program was primarily field-based with projects throughout the U.S. and done in collaboration with EPA Program offices, EPA regions, DoD, USCG, DOE, states and other partners.1998 – 2003
- As Chair, Interagency Ground Water Research Coordination Work Group (EPA, DoD, DOE, NSF, NIEHS), led interagency effort to identify research areas of common interest among the different government agencies, inform each other of respective research programs and foster collaboration on research across agencies. 2006 – 2008.
- As Co-Chairman, EPA's Remedial Technology Development Forum (RTDF) on Permeable Reactive Barriers (DOE, DoD, Dupont, GE, EPA) led interagency and inter-governmental and private industry group to coordinate on research, development and application of permeable reactive barriers for ground water remediation. This effort was primarily responsible for the widespread acceptance of this technology and served as a model for collaboration.
- As research team leader led an Agency-wide effort to establish consistent and effective methods for ground water sampling at hazardous waste sites. The emphasis was on accurate assessment of contaminant loading and transport in ground water systems. Methods used in the past had introduced substantial uncertainty into the accuracy of samples, particularly for metals. The effort involved coordination with EPA Program offices and all 10 EPA regional offices as well as other EPA labs and other government agencies.

Honors & Awards

National, Inter-Agency Awards

- USEPA Bronze Medal 2012. For rollout of USEPA National Study Plan on "Hydraulic Fracturing and Drinking Water Resources".
- U.S. Department of the Interior National *Partners in Conservation Award* for aquifer storage and recharge research collaboration with Bureau of Reclamation, Chickasaw Indian Tribe, Oklahoma Water Resources Board, Oklahoma Department of Environmental Quality, Oklahoma Climatological Survey, National Oceanic Atmospheric Administration, and Oklahoma State University. May 7, 2009
- National Environmental Excellence Award for Best Available

Environmental Technology, National Association of Environmental Professionals, 2003. For robust remediation strategy to treat hexavalent chromium in soil and ground water below active governmental aircraft service center.

- USEPA Science Achievement Award in Waste Management. 1998. Presented in Association with The Air & Waste Management Association. For Outstanding Basic and Applied Research that has Advanced the Development and Application of Permeable Reactive Barriers to Remediate Contaminated Ground Water. Presented by Carol S. Browner.
- USEPA Bronze Medal, 2010. For Outstanding Achievements in the research and Field Demonstration of Innovative Technology for Groundwater remediation at the ASARCO East Helena Smelter.
- USEPA/ORD Scientific and Technological Achievement Award (**STAA**), 2008, for Systematic Research on Cost-Effectively and Efficiently Removing Groundwater Nitrate Using agricultural By-Products
- USEPA Award of Excellence for work on Recovery Efforts, Hurricane Katrina, 2007
- USEPA/ORD Scientific and Technological Achievement Award (**STAA**), 2005, for Leading Edge Science on the Mechanisms of removal of Arsenic and Nitrate from Groundwater Using Zerovalent Iron in Permeable Reactive barriers
- USEPA/ORD Scientific and Technological Achievement Award (**STAA**), 2004, for Developing an Innovative, Scientifically Rigorous and Practical Method for Remediation of Arsenic in Ground Water

Interagency Committee / Workgroup Membership

- Ground Water Protection Council, Education and Research Foundation, 2012 – present.
- ASTM Committee D18.21, Soil and Rock: Groundwater and Vadose Zone Investigations, 2012-present
- ASTM Committee D18.26, Hydraulic Fracturing, 2012-present
- Member, Advisory Board, Water Technologies for Emerging Regions (WaTER) Center, University of Oklahoma, 2012-present
- Oklahoma Governors Work Group on Aquifer Recharge/Reuse 2008 - present
- Oklahoma Water Resources Research Institute Advisory Board, 2007 - present
- Member, Interstate Technology Regulatory Council (ITRC) panel for permeable reactive barriers, 1998- 2005; 2009 - 2011
- Chair, Interagency Ground Water Research Coordination Work Group (EPA, DoD, DOE, NSF, NIEHS), 2006 - 2009
- Co-Chairman, EPA's Remedial Technology Development Forum (RTDF)

on Permeable Reactive Barriers (DOE, DoD, Dupont, GE, EPA), 1995-present.

- Interagency Work Group (DOE, USGS, EPA, NRC, USDA), Models for Reactive Transport in Subsurface Systems, 2003- 2007.
- All One Cleanup Program (Office of Solid Waste and Emergency Response, USEPA), Groundwater Task Force (members includes different EPA offices, EPA regions and several state environmental representatives), 2002 - 2006.
- Advisory Board, U.S. Geological Survey Toxic Substances Hydrology Program, Norman, OK Landfill, 1995- 2001.
- Innovative Treatment Remediation Demonstration (ITRD) Program Advisory Panel, Department of Energy, 1996- 1998. Tuba City Uranium Mill Tailings Remedial Assessment (UMTRA) Groundwater Project.
- National Research Council, Commission on Geosciences, Environment, and Resources, Advisory Panel on reorganization of U.S. Bureau of Mines, 1994-1996

Affiliations

- Editorial Advisory Board (current), Land Contamination and Reclamation Journal
- American Chemical Society
- American Geophysical Union
- National Ground Water Association

Peer-Reviewed Publications

Su, C., R.W. Puls, T.A. Krug, M.T. Watling, S.K. O'Hara, J.W. Quinn, and N.E. Ruiz. 2012. A Two and Half-year-performance Evaluation of a Field Test on Treatment of Source Zone Tetrachloroethene and its Chlorinated daughter Products Using Emulsified Zero Valent Iron Nanoparticles. *Water Research,* 46:5071-5084.

Puls, R.W. 2011. Contributing author, EPA's Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, EPA/600/R-11/122, November 2011

Puls, R.W. 2010. Opportunity for Stakeholder Input on Criteria for Selecting Case Studies for Consideration in EPA's Hydraulic Fracturing Research Study.

http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroout.cfm#hfcomments

Puls, R.W. 2010. Opportunity for Stakeholder Input on Conceptual Model for Potential Impacts to Drinking Water Resources from Hydraulic Fracturing. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroout.cfm#hfcomments

Puls, R.W.. 2010. Water Availability and Management of Water Resources, Oklahoma Town Hall Meeting of Water Plan for OK

Smith, S.J., S.T. Paxton, S.C. Christensen, R.W. Puls and J.R. Greer. 2009. Determination of Flow Contribution and Water Quality With Depth in Public-Supply Wells and Investigation of Low-Cost Arsenic Remediation Through Well Modification. EPA/600/R-09/036

Su, C. and R.W. Puls. 2008. Arsenate and Arsenite Sorption on Magnetite: Relations to Ground Water Arsenic Treatment Using Zerovalent Iron and Natural Attenuation, *Water, Air and Soil Pollution*, 193:65-78.

Su, C. and R.W. Puls. 2007. Utilization of zero-valent iron for arsenic removal from groundwater and wastewater. In I.M.C. Lo, R. Surampalli, and K.C.K. Lai (Eds.), *American society of civil engineers, zero-valent iron reactive materials for hazardous waste and inorganics removal* (pp. 111-150). Reston, VA: ASCE Chapter 8.

Ford, R.G., Wilkin, R.T., and R.W. Puls 2007 Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 1 - Technical Basis for Assessment, EPA/600/R-07/139

Ford, R.G., Wilkin, R.T., and R.W. Puls. 2007. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 2: Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium, EPA/600/R-07/140

Su, C. and R.W. Puls. 2007. Removal of added nitrate in the single, binary, and ternary systems of cotton burr compost, zerovalent iron, and sediment: Implications for groundwater nitrate remediation using permeable reactive barriers, *Chemosphere* 67(8): 1653-1662.

Su, C. and R.W. Puls. 2007. Removal of added nitrate in cotton burr compost, mulch compost, and peat: Mechanisms and potential use for groundwater nitrate remediation. *Chemosphere*, 66(1): 91-98.

Puls. R.W. 2006. Long-Term Performance of Permeable Reactive Barriers: Lessons Learned on Design, Contaminant Treatment, Longevity, Performance Monitoring and Cost – An Overview. In Viable Methods of Soil and Water Pollution Monitoring, Protection and Remediation, Editor: Irene Twardowska, Kluwer Academic Publishers

Barcelona, M.J., M.D. Varljen, R.W. Puls, D. Kaminski. 2005. Ground Water Purging and Sampling Methods: History vs. Hysteria. Ground Water Monitoring & Remediation 25 (1): 52-62.

Su, C. and R.W. Puls. 2004. Significance of Iron (II,III) Hydroxycarbonate Green Rust in Arsenic Remediation Using Zerovalent Iron in Laboratory Column Tests. *Environmental Science and Technology*, 38(19): 5224-5231.

Su, C. And R.W. Puls. 2004. Nitrate Reduction by Zerovalent Iron: Ligand Effects of Formate, Oxalate, Citrate, Chloride, Sulfate, Borate, and Phosphate. *Environmental Science and Technology,* 38(9); 2715-2720.

Wilkin R.T. and R.W. Puls. 2004. Evaluation of Permeable Reactive Barrier Performance, Prepared under the auspices of the Member Agencies of the Federal Remediation Technologies Roundtable, EPA/542/R-04/004.

Wilkin R.T. and R.W. Puls. 2003. Capstone Report on the Application, Monitoring, and Performance of Permeable Reactive Barriers for Ground-Water Remediation. Volume 1: Performance Evaluations at Two Sites, EPA/600/R-03/045a.

Su, C. and R.W. Puls. 2003. In Situ Remediation of Arsenic in Simulated Groundwater Using Zerovalent Iron: Laboratory Column Tests on Combined Effects of Phosphate and Silicate. *Environmental Science and Technology*, 37(11) 2582-2587.

Lin, Z. and R.W. Puls. 2003. Potential Indicators for the Assessment of Arsenic Natural Attenuation in the Subsurface. *Advances in Environmental Research*, 7, 825-834.

Paul, C.J., M.S. McNeil, F.P. Beck Jr., P.J. Clark, R.T. Wilkin, and R.W.Puls. 2003. Capstone Report on the Application, Monitoring, and Performance of Permeable Reactive Barriers for Ground-Water Remediation. Volume 2: Long-Term Monitoring of PRBs: Soil and Ground Water Sampling Performance Evaluations at Two Sites, EPA/600/R-03/045b.

Wilkin, R. T., R.W. Puls and G.W. Sewell. 2002. Long-term Performance of Permeable Reactive Barriers Using Zero-valent Ion: An Evaluation at Two Sites. EPA/600/S-02/001.

Powell, R.M., P.D. Powell and R.W. Puls. 2002. Economic Analysis of the Implementation of Permeable Reactive Barriers for Remediation of

Contaminated Ground Water. EPA/600/R-02/034.

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Khan, F.A., and R.W. Puls. 2001. In Situ Abiotic Detoxification of Hexavalent Chromium in the Capillary Fringe Zone. *Ground Water Monitoring and Remediation*, 23(1):77-84.

Su, C. and R.W. Puls. 2001. Arsenate and Arsenite Removal by Zero-Valent iron: Effects of Phosphate, Silicate, Carbonate, Borate, Sulfate, Chromate, Molybdate, and Nitrate, Relative to Chloride. *Environmental Science and Technology*, 35(22) 4562-4568.

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Su, C., and R.W. Puls. 2001. Arsenate and Arsenite Removal by Zero-Valent Iron: Kinetics, Redox Transformation, and Implications for In Situ Groundwater Remediation. *Environmental Science and Technology*, 35(7) 1487-1492.

Lin, Z. and R.W. Puls. 2001. Studies of Interfacial Reactions Between Arsenic and Minerals and its Significance to Site Characterization. *Environmental Geology*, 40:1433-1439.

Paul, C.J., F.A. Khan and R.W. Puls. 2001. In Situ Reduction of Chromate-Contaminated Soils. In Handbook of Groundwater Remediation of Trace Metals, Radionuclides, and Nutrients with Permeable Reactive Barriers, Editors: D.L. Naftz, S.J. Morrison, J.A. Davis, and C.C. Fuller, Academic Press

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Chattopadhyay, S. and R.W. Puls. 2000. Forces Dictating Colloidal Interactions Between Viruses and Soil. *Chemosphere*, 41:1279-1286.

Puls, R.W., D.W. Blowes, R.W. Gillham. 1999. Long-Term Performance Monitoring for Permeable Reactive Barrier at the USCG Support Center, Elizabeth City, NC, *Journal of Hazardous Materials*, 68:109-124.

Khan, F. and R.W. Puls. 1999. Reductive Detoxification and Immobilization of Chromate Present in Soils. *Hydrological Science and Technology*, 15:138-144.

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Su, C. and R.W. Puls. 1999. Kinetics of Trichloroethene Reduction of Zero-valent Iron and Tin: Pretreatment Effect, Apparent Activation Energy, and Intermediate Products. *Environ. Sci. Technol.* 33(1): 163-168.

Puls, R.W. and C.J. Paul. 1998. Discrete-Level Ground-Water Monitoring System for Contaminant and Remedial Performance Objectives. *Journal of Environmental Engineering*, 124(6): 549-553.

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Puls, R.W. 1994. Ground Water Sampling for Metals. In Sampling of Environmental Materials for Trace Analysis, ed. B. Markert, VCH Publ., Weinheim, Federal Republic of Germany.

Puls, R.W., C.J. Paul, D. Clark, and J. Vardy. 1994. Transport and Transformation of Hexavalent Chromium Through Soils and Into Ground Water. *Journal of Soil Contamination*, 3(2):203-224.

Puls, R.W., C.J. Paul, D. Clark, J. Vardy, and C. Carlson. 1994. Characterization of Chromium-Contaminated Soils Using Field-Portable X-Ray

Fluorescence. *Ground Water Monitoring and Remediation*, 14(3): 111-115.

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Puls, R.W. and R.M. Powell. 1993. Laboratory Studies on the Stability and Transport of Inorganic Colloids Through Natural Aquifer Material. In Manipulation of Groundwater Colloids for Environmental Restoration, Lewis Publ., Boca Raton, FL., ed. J.F. McCarthy and F. Wobber.

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Selected Conference Proceedings

Puls, R.W. Risk Management Best Practices for Oil & Gas Operations Using Hydraulic Fracturing, Ground Water Protection Council, Annual Meeting, Nashville, TN, Sep 25, 2012.

Puls, R.W. Protecting Water Resources throughout the Hydraulic Fracturing Lifecycle: Lessons Learned and Additional Research Needs. Battelle International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 2012.

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Selected Invited Presentations to International Meetings

Considerations for hydraulic fracturing and groundwater and surface water protection: lessons learned in the U.S. **Unconventional Shale Gas and Freshwater Resources, Madrid, Spain, Mar 7, 2012**

Long-Term Performance of Permeable Reactive Barriers: Lessons Learned on Design, Contaminant Treatment, Longevity, Performance Monitoring and Cost – An Overview, **NATO Programme Security Through Science Advanced Workshop, Viable Methods of Soil and Water Pollution Monitoring, Protection and Remediation** (Keynote address), Krakow, Poland, June 27 – Jul 1, 2005.

Long-Term Performance of Permeable Reactive Barriers: Lessons Learned, Future Directions, **1st International Symposium on Permeable Reactive Barriers** (Keynote address), Belfast, Northern Ireland, March 14-14, 2004.
Cost Analysis for Permeable Reactive Barriers for Remediation of Ground Water, **3rd International Conference on Remediation of Chlorinated and Recalcitrant Compounds**, Monterrey, CA, May 20-23, 2002.

Permeable Reactive Barriers for Ground water Remediation, Keynote Address, **Permeable Reactive Barriers Net Workshop: PRB Technology and its Current Status.** Belfast Northern Ireland, April 25-27, 2001.

Permeable Reactive Barriers for Inorganic Contaminants, **Permeable Reactive Barriers Net Workshop: PRB Technology and its Current Status.** Belfast Northern Ireland, April 25-27, 2001.

PRB Regulatory Aspects and Implementation, **Permeable Reactive Barriers Net Workshop: PRB Technology and its Current Status**. Belfast Northern Ireland, April 25-27, 2001.

Long-term Performance of Permeable Reactive Barriers: An Update on a U.S. Multi-Agency Initiative, **ConSoil 2000**, Sep 18-22, 2000, Leipzig, Germany.

Long-term Performance Assessment of Permeable Reactive Barriers to Remediate Contaminated Ground Water. 2000. **Fourth USA/CIS Joint Conference/Hydrologic Issues of the 21st Century: Ecology, Environment and Human Health**, San Francisco, November 7-10, 1999.

Performance Monitoring of Permeable Reactive Barriers to Remediate Contaminated Groundwater. 1999. **Society for Environmental Toxicology and Chemistry-Europe**, 9th Annual Meeting, Quality of Life and Environment in Cultured Landscapes. May 25-29, 1999, Leipzig, Germany.,

Emplacement Verification and Long-term Performance Monitoring for Permeable Reactive Barriers at USCG Support Center, Elizabeth City, NC. **GQ >98 International Conference**: Groundwater Quality: Remediation and Protection, Tubingen, Germany, Sep 21-25, 1998.

The Application of Permeable Reactive Barriers to Remediate Ground water. **NATO/CCMS** Pilot Study Meeting, Vienna, Austria, February 22-28, 1998.

The Application of Passive Ground Water Remediation Technologies in the US : Experiences and Recommendations. **International Workshop** on Passive Systems for In Situ Remediation of Ground Water and Soil. University of Dresden, Dresden, Germany. May 2-3, 1996.

Toward a Better Understanding of the Complex Geochemical Processes Governing Subsurface Contaminant Transport. **International Conference and Workshop**, International Hydrological Society, "Transport and Mass Exchange Processes in Sand and Gravel Aquifers: Field and Modeling Studies". October 1-4, 1990, Ottawa, Canada.

Other Invited Presentations

Chromium Chemistry in the Subsurface, Region VII invited presentation, Kansas City, MO, May 5, 2009

The Application of PRB Technology at Two Sites: Lessons Learned After 7 Years of Performance Monitoring, **AFCEE Technology Transfer Workshop**, San Antonio, TX, February 24 - 27, 2003.

Collection of Design Data: Site Characterization for Permeable Reactive Barriers, **AFCEE Technology Transfer Workshop,** San Antonio, TX, February 24 - 27, 2003.

Performance Monitoring of a Permeable Reactive Barrier to Remediate Chlorinated Solvent Contaminated Ground Water. 1999. **EPA Innovative Clean-up Approaches: Investments in Technology Development, Results & Outlook for the Future**, Nov 2-4, 1999, Bloomingdale, IL.

Emplacement Verification and Long-term Performance Monitoring Permeable Reactive Barriers for Cr(VI) Ground Water Remediation. **National Research Council** Committee on Technologies for Cleanup of Subsurface Contaminants in the DOE Weapons Complex. Richland, WA, May 15, 1998.

Remediation of Ground Water Using In-Situ Permeable Reactive Barriers: Chromate and Other Inorganic Contaminants, **American Society of Civil Engineers** Annual Meeting, Chicago, IL, June 8-9,1998.

The Application of Low-Flow and Passive Ground-Water Sampling Techniques at Hazardous Waste Sites. Workshop on Low-Flow Sampling in Ground Water, sponsored by **Maine Department of Environmental Protection**, Portland, Maine, May 29, 1996.

In-Situ Metals Remediation of Contaminated Soils and Ground Water. **Department of Interior**, Hazardous Materials Conference, May 17-19, 1994, Phoenix, AZ.

Groundwater Sampling and Sample Preservation, **Oklahoma Society of Environmental Professionals First Annual Meeting**, Oklahoma City, Oct. 29, 1993.

Collection of Representative Ground-water Samples. Seventh National Outdoor Action Conference, **National Ground Water Association** (NGWA), Las Vegas, Nevada, May, 1993.

Subsurface Chemical Processes Affecting Contaminant Fate and Transport. **University of Oklahoma**, School of Civil Engineering and Environmental Science. December 13, 1991, Norman, OK.

Ground Water Sampling for Inorganics. **Superfund Technical Support Project** General Meeting, November 5-7, 1991, Ada, OK.

Acquisition of Representative Ground Water Samples. Interagency Workshop, **Department of Energy**, Savannah River Laboratory, March, 1991, Augusta, GA.
Causes and Effects of Well Turbidity. **Superfund Technical Support Project** General Meeting, December 3-5, 1990, Athens, GA.

Selected Other Oral Presentations

ARSENIC IN DRINKING WATER SUPPLY WELLS: A MULTI-AGENCY, COMMUNITY-BASED, RESEARCH PROJECT. **23rd Annual International Conference on Contaminated Soils, Sediments and Water** to be held at the University of Massachusetts, Amherst, MA, October 15-18, 2007

ARSENIC IN DRINKING WATER: Using Sound Science for Risk Management and Assisting Community Decision-Makers, A Multi-Agency Community-Based, Research Project **, EPA Science Forum,** Washington D.C., 2005.

Long-term Performance of Permeable Reactive Barriers to Remediate Contaminated Ground Water. **Geological Society of America (GSA) Annual Conference**, Reno, NV, November 13-17, 2000.

Potassium Permanganate and Clinoptilolite Zeolite for In Situ Treatment of Ground Water Contaminated with Landfill Leachate: Laboratory Study. **American Geophysical Union(AGU) Annual Meeting**, San Francisco, December 14-19, 2000.

Emplacement Verification and Long-Term Performance Monitoring for Permeable Reactive Barrier at USCG Support Center, Elizabeth City, NC, **GQ >98 International Conference, Groundwater Quality: Remediation and Protection**, Tubingen, Germany, Sep 21-25, 1998.

Permeable Reactive Barriers in Ground Water. Workshop presented at **National Ground Water Association Outdoor Action Conference**, April 1-3, 1997, Las Vegas, NV.

Remediation of Chromate-Contaminated Ground Water Using An In Situ Permeable Reactive Mixture: Field Test, Elizabeth City, North Carolina, **American Chemical Society**, Division of Environmental Chemistry, April, 1997, San Francisco, CA.

Assessment of Natural Attenuation of Hexavalent Chromium in Ground Water: USCG Support Center, Elizabeth City, North Carolina. **HSRC/WERC Joint Conference on the Environment**, May 21-23, 1996, Albuquerque, New Mexico.

Corrosive and Geochemical Mechanisms Influencing In-Situ Reduction of Chromate by Metallic Iron. **American Chemical Society**, Division of Environmental Chemistry, April 2-7, 1995 Anaheim, CA.

In-Situ Remediation of Ground Water Contaminated with Chromate and Chlorinated Solvents Using Zero-Valent Iron: A Field Study. **American Chemical Society**, Division of Environmental Chemistry, April 2-7, 1995, Anaheim, CA.

In-Situ Metals Remediation of Contaminated Soils and Ground Water. **Department of Interior**, Hazardous Materials Conference, May 17-19, 1994, Phoenix, AZ.

Chromate Reduction and Remediation Utilizing the Thermodynamic Instability of Zero-Valence Iron. **Water Environment Federation**, Innovative Solutions for Contaminated Site Management, March 3-6, 1994, Miami, FL.

Mobilization of Dissolved and Colloid-Associated Arsenic in Subsurface Systems. **American Chemical Society** Annual Meeting, March 13-18, 1994, San Diego, CA.

Use of Low-Flow and Passive Sampling Techniques in Sampling Ground Water. **American Chemical Society** Annual Meeting, March 13-18, 1994, San Diego, CA.

Development of Techniques for In-Situ Biotreatment of Soil and Ground Water. I & EC Symposium, **American Chemical Society**, September 19-21, 1994, Atlanta, GA

Use of Low-Flow or Passive Sampling Techniques for Sampling Ground Water. Ground Water Sampling Workshop, **USEPA**, Nov. 30-Dec 1-2, 1993, Dallas, TX.

Reduction of Cr(VI) to Cr(III) by Subsurface Anaerobic Microorganisms. Metal Speciation and Contamination of Aquatic Sediments Workshop, June 8-11, 1993, Jekyll Island, GA.

Colloidal Transport in Sandy Aquifer Material: Surface and Aqueous Chemical Effects. **American Geophysical Union**, Fall Meeting, Dec. 7-11, 1992, San Francisco, CA.

Surfactant-Enhanced Transport of Iron Oxide Colloids Through Natural Porous Media: Surface Chemical Effects. **American Chemical Society** - 66th Annual Colloid and Surface Science Symposium. June 14-17, 1992, Morgantown, WV.

Distribution, Speciation, and Transformation of Chromium in Contaminated Soils and Aquifer Sediments. **American Chemical Society** Annual Meeting - Symposium on Redox Transformations of Inorganic and Organic Species. April 5-10, 1992, San Francisco, CA.

Chromium Speciation and Distribution on Contaminated Soils and Shallow Aquifer Material. **American Society of Agronomy/Soil Science Society of America** Annual Meetings, Oct 27-31, 1991, Denver, CO.

Electrostatic Repulsive Effects on the Mobility of Inorganic Colloids in Subsurface Systems. **American Chemical Society** - 65th Annual Colloid and Surface Science Symposium - Colloid and Interfacial Aspects of Groundwater and Soil Cleanup, June 17-19, 1991, Norman, OK.

Colloidal Fe_2O_3 Transport Studies in Laboratory Model Systems Using Shallow Aquifer Systems. **American Chemical Society** Annual Meeting - Symposium on Shallow Aquifer Chemistry, April 15-18, 199, Atlanta, GA.

Stability and Transport of Inorganic Colloids Through Contaminated Aquifer Material. **USGS** Toxic Substances Hydrology Technical Meeting, March, 1991, Monterey, C.A.

Causes and Effects of Well Turbidity. **USEPA** Superfund Technical Support Project General Meeting, December 3-5, 1990, Athens, GA.

Laboratory Studies on the Stability and Transport of Inorganic Colloids Through Natural Aquifer Material. In Proceedings, Concepts in Manipulation of Groundwater Colloids for Environmental Restoration Workshop, sponsored by **U.S. Department of Energy,** October 16-18, 1990, Manteo, NC.

Transport of Fe^{59}-labeled Iron Oxide Colloids in Laboratory Columns Using Natural Aquifer Material. **American Geophysical Union**. Symposium on "Particle Transport in the Subsurface and its Geochemical Impact", Spring Meeting, June, 1990, Baltimore, Maryland.

Sampling of Ground Water for Inorganics - Pumping Rate, Filtration, and Oxidation Effects. Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods. **NWWA**. Las Vegas Hilton, Las Vegas, Nevada, May, 1990.

Effects of pH, solid/solution ratio, ionic strength, and organic acids on Pb and Cd sorption on kaolinite. **International Conference on Metals in Soils**, Water, Plants and Animals. May, 1990, Orlando, Florida.

Determination of Conditional Stability Constants for Aqueous Metal-Organic Complexes Using Kaolinite. **American Society of Agronomy/Soil Science Society of America** Annual Meetings, Oct 10-15, 1989, Las Vegas, NV.

Transport of Colloidally Associated Inorganic Contaminants in an Alluvial Aquifer in Arizona. Poster Presentation at Workshop entitled "Metal Speciation and Transport in Ground waters. Sponsored by **USEPA, Office of Exploratory Research**. 1989 Jeykll Island, GA.

Complexometric Reactions Involving Lead, Kaolinite and Organic Acids - Implications for Contaminant Transport in the Subsurface. **American Geophysical Union** - International Association of Hydrologic Sciences Symposium on "Physical, Chemical and Biological Processes Governing Transport of Contaminants in the Subsurface," 1989 AGU Spring Meeting, Baltimore, MD.

Ground Water Sampling for Metals Analyses. **Superfund Technology Support Project**, Fall General Meeting 1988, Seattle, WA.

Colloidal Considerations in Sampling Ground Water for Inorganics, Pinal Creek, Globe, AZ. Mobility of Colloidal Particles in the Subsurface: Chemistry and Hydrology of Colloid-Aquifer Interactions. International Series of Interactive Seminars (ISIS), sponsored by **U.S. Dept of Energy**, 1988, Manteo, NC.

Sorption and Desorption of Uranium, Selenium, and Radium in a Basalt

Geochemical Environment. Ground Water Geochemistry Conference, **NWWA**, Hyatt Regency Denver, 1988, Denver, CO.

ATTACHMENT 4

TREC, Inc.
Engineering & Environmental Management
A Woodard & Curran Company

900 Werner Court, Suite 150
Casper, WY 82601

Phone (307) 265-0696
Fax (307) 265-2498

March 24, 2014

RECEIVED
MAR 26 2014
WATER ... WYOM...

WDEQ / Water Quality Division
122 West 25th Street
Herschler 4W
Cheyenne, Wyoming 82002
Attention: Kevin Fredrick, Administrator

RE: Linc UCG Gasifier 6 Project

Dear Mr. Frederick:

This letter is written to urge approval of Linc Energy's (Linc) application for a proposed Underground Coal Gasification (UCG) pilot in northeastern Wyoming. Linc has developed and submitted to WDEQ a detailed Research and Development application for the UCG pilot in accordance with WDEQ guidance and input. In one of the most rigorous and well-vetted applications review processes that TREC has been involved in, Linc's application has undergone eight rounds (16 months) of review by highly qualified WDEQ staff and consultants. Generally, this level and length of review exceeds efforts usually reserved for a traditional mine application. Therefore, I have the upmost confidence that Linc and WDEQ have conducted a very thorough evaluation of the technical and environmental facets of this project.

There have been a number of successful UCG trials in the State of Wyoming, and Linc has unrivaled experience in UCG with development of multiple generations of gasifier technology and 50 years of operational experience to draw from. Linc's comprehensive investigation in their site selection and experience makes this R&D project a valuable asset in Wyoming's energy strategy that balances energy development with environmental issues and mitigates potential environmental impacts. Furthermore, energy research and development efforts are a positive approach that can buffer the traditional cycle of boom and bust in Wyoming's energy economy. UCG can add value and diversity to Wyoming's energy portfolio while responsibly adding jobs and tax revenues.

Sincerely,

Ray DeLuna

Ray DeLuna,
Deputy Regional Manager
TREC, Inc.

March 20,2014

Dollie Iberlin
414 N. Burritt
Buffalo, Wy. 82834

I just read an article about "Andy and his Pond' in Uinta county, and how the EPA is responding to his particular case. If even handedness is going to be considered, what will be your response to Linc Energy if the Fort Union water quality is compromised by their underground coal gasification project north of Wright, Wy.

Linc Energy came to me about a project on a school section on my place. What little I know about their plans was enough for me to question if this process has enough history to justify experimenting in Wyoming.

I think that clean water should be our most protected resource. We are a semi-arid state that should give great consideration to compromising any of our aquifers.

Concerned,

Dollie Iberlin

Dollie Iberlin

RECEIVED
MAR 2 6 2014
WATER QUALITY DIVISION
WYOMING

Robert B. Kayser
518 Cold Springs Road
Douglas, WY 82633
March 24, 2014

Kevin Frederick, Administrator
Water Quality Division
Department of Environmental Quality
122 West 25th Street
Herschler 4W
Cheyenne, WY 82002

Re: Comments on Linc UCG Gasifier 6 Project

Dear Mr. Frederick:

I am a Registered Professional Geologist with over fifty years of experience in evaluating the geological characteristics of energy development projects. I am familiar with the geologic and groundwater conditions present in Linc's proposed underground coal gasification test site near Wright, Wyoming. Further, I have recent experience in coal gasification projects using PRB coal.

I would like to go on record as **strongly supporting** the Linc UCG Gasifier 6 Project. The risks of groundwater contamination outside of the test site are extremely limited as there is very little vertical communication between water bearing coal beds and shallower sandstone aquifers. The perimeter well control design is completely adequate to control horizontal communication beyond the site. It should be noted that the lower Tertiary sandstone aquifers throughout the PRB are essentially already water saturated so it would be difficult to displace that connate water with water migrating from a UCG operation. Our experience elsewhere in the PRB fully supports this conclusion.

Underground coal gasification (UCG) is an extremely important technology for the long term energy security of our country. The surface minable coal resource in the PRB is relatively small compared to the UCG mineable coal. UCG has the potential to utilize that very large coal resource with minimal surface disturbance and minimal air pollution risk. The synthesis gas produced by UCG can be used for electric power generation, diesel fuel production, gasoline production and other petrochemicals. The CO_2 produced from the conversion of CO through the water gas reaction is easily recovered for beneficial use in enhanced oil recovery in the many existing oil reservoirs in the PRB. UCG is the partial oxidation of the coal and because of that the CO_2 is recovered pre-combustion rather than post-combustion. This is an important distinction for those worried about CO_2 losses to the atmosphere.

Test projects such as this one proposed by Linc Energy are crucial to our future energy security. The test protocol is well designed and we need the information from this test to evaluate the efficacy of UCG as a future energy source. We should not be lulled into a false sense of security concerning the apparent abundance of new oil production from tight sands and shale. The country faces a serious long term supply shortfall in liquid hydrocarbons and UCG is probably the best opportunity we have to solve the supply problem. The technologies for producing gasoline and diesel fuel from coal synthesis gas are well developed and UCG appears to be the best hope for the conversion of coal to those fuels.

For all of the above reasons I strongly support the Linc project and recommend that you approve the reclassification of the ground water and proposed aquifer exemption.

Sincerely,

Robert B. Kayser
Registered Geologist

Edith S. Cook
7019 Bomar Drive
Cheyenne, WY 82009
(307) 220-3519; e104cook@gmail.com

March 21, 2014

DEQ Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

Dear Mr. Frederick,

RE: Linc Hearing on March 26

Though I cannot attend the hearing in Wright, here are my comments regarding your proposed exemption or reclassification of the aquifer portion in question. As I understand it, DEQ based its decision on a 1983 agreement between the State of Wyoming and the US EPA that sets parameters for underground injection control.

Linc's application, reproduced on your website, shows that test burns would cover an 80-acre portion of the aquifer, at a depth of 1,100-feet. Coal would be ignited with oxygen and swamped with steam to convert the coal into "syngas." Linc plans to exhaust 1000 tons of coal to produce "approximately one million standard cubic feet of syngas per day"; it avers that conversion would proceed "without adverse environmental impact" even though the syngas would be flared off. A million cubic feet of gas, burning daily, without adverse consequences to the environment and surrounding communities?

After the D & R phase, Linc plans full-scale commercial production in Wyoming, though its Australian attempts have been problematical. On government behest, an independent scientific panel (ISP) studied the two companies, Linc Energy and Carbon Energy, that have undertaken UCG trials in Queensland, then submitted its report in 2013.

The report notes failed wellheads; mechanical design problems relating to ignition and injection; inadequate construction material for production wells. These were "lessons learned" that rectified problems in hindsight. Unresolved issues remain, however: "downstream" contamination from underground temperatures of up to 1500 degrees Celsius that produce "serious contaminants" when the chemicals escape into the surrounding environment. ISP notes that Linc's assessments have been "retroactive," after a "hazard event" had occurred. As concerns risk assessment, no "core integrated framework" exists.

Site-selection is crucial, the "single most important" aspect for risk-based evaluation. ISP recommends that site selection be based on geological surveys, hydrogeological modeling, and assessment of community and environmental contexts. Appropriate baseline studies should ascertain the (possibly toxic) compounds existing in the coal-seam aquifers. ISP recommends that governments establish rigorous guidelines.

Local residents' objections to Linc's Wyoming proposal will note that water needs in the area are increasing. Linc's application claims that the aquifer portion it seeks will not in future be used for drinking water because of its "mineral producing" potential: It contains hydrocarbons that may be "commercially producible." Yet the Fort Union aquifer contains good quality water at just over 500 total dissolved solids (TDS), and the Fort Union Formation is a commonly-used water supply in the Powder River Basin. Even at depth of 1,000 feet or more, several aquifers within the Gillette area serve both the city and surrounding subdivisions.

Linc's application states that DEQ requested a "demonstration project" prior to full-scale operations. The company claims it has "operated a demonstration facility in Chinchilla, Queensland, Australia, since 1999," where it continues to make synthetic crude "while maintaining environmental compliance."

The ISP report shows, however, that the Linc Queensland facilities are "pilot" that never progressed to "demonstration" projects. While small-scale projects are manageable (barely), their expansions become huge liabilities. Though the UCG industry has made strides in the past 30 years, progress has been limited. ISP notes that UCG is relatively new in Australia and that, globally, UCG experiments are far and few between.

Linc has been "unable to demonstrate" effective cleanup. According to ISP, "rubble from gasified coal (ash and tar)," from "collapsed overburden," and from "disturbed underburden" hinder the decommissioning. ISP notes lack of monitoring systems and "failure of infrastructure." Risk-based plans have yet to be developed. ISP notes lack of critical alarm systems that would permit rapid intervention, and lack of safety instrument systems. Sometimes, spills and "contamination plumes" proceeded directly into soils and water wells.

ISP recommended to the Queensland government that Linc continue for six months, provided the company "immediately propose, test, and establish" a planning and action process that shows its commitment to decommissioning. Linc must demonstrate environmental safety via "event-based milestones." A risk protocol for decommissioning should include a "conceptual model," a relevant "numerical model," and future action "based on sampling." Long-term critical risks must be assessed, and besides, an underground cavity of "significant dimensions" must exist for "full comprehensive demonstration." Governmental guidelines need to include establishing "Go/No Go gates" for decisions regarding development of any site; until then, "no commercial facility should be commenced." ISP cautions against any further ignitions until long-term environmental safety can be demonstrated.

Clearly, before the Linc project goes any further in Wyoming, site selection needs rigorous scrutiny. Next, Wyoming should wait until Linc has cleaned up its Queensland operation, which will give state and federal governments time to develop the UCG guidelines recommended in the Queensland report. A copy of the 50-page report was submitted to DEQ sometime ago.

Sincerely,

Edith Cook

March 20, 2014

WDEQ/Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street
Cheyenne, WY 82002

RE: Linc Energy's Aquifer Exemption Request

Dear Mr. Frederick:

I worked for the WDEQ for 25 years. I was involved with the termination of two historical underground coal gasification (UCG) projects, the U.S. D.O.E's Hoe Creek project and ARCO's Rocky Hill project. Neither of these projects was successful by common measures. Neither project restored groundwater quality to preburn conditions, much less to drinking water standards. The same general conclusions apply to other historical UCG projects in Wyoming. The UCG process is unproven in Wyoming geologic strata.

To date the companies conducting UCG projects in Wyoming have not demonstrated a fundamental, scientifically-based interest in restoring groundwater quality. As a whole the UCG technology has not proven its ability to restore groundwater quality. Linc Energy certainly has not demonstrated interest in or ability to restore groundwater quality.

I urge the WDEQ/Water Quality Division to reject Linc Energy's requested aquifer exemption for its UCG project in Section 36, T.44N., R.74W. of Campbell County, Wyoming.

Sincerely,
Bob Giurgevich
332-B North Jefferson Street
Sheridan, WY 82801

DEQ / Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Bldg. 4W
Cheyenne, WY 82002

Al Carlson
PO Box 16
Story, WY 82842

I'm writing about the hearing on the Fort Union Wyodak Aquifer Exemption to take place on March 26th.

Having grown up in Gillette, I encourage you to oppose the Aquifer Exemption for the following reasons:

*The Fort Union Aquifer is the most commonly used water supply aquifer in the Powder River Basin.

*The process to be used by Linc Energy pollutes groundwater by using benzene, toluene, & many other hydrocarbons, all of which are known to cause cancer.

*An independent scientific panel has cautioned the Queensland, Australia government that a pilot project of Linc Energy's should not be allowed to expand until the company can demonstrate successful cleanup & decommissioning.

*This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc already holds several hundred leases on 184,000 acres, and this project could be used to justify further exemptions in other areas.

*The water needs of the Gillette area are steadily increasing, and good quality water like that provided by the Fort Union Aquifer must be protected.

Sincerely,

Al Carlson

884 Steinle Rd
Douglas, WY 82633
March 21, 2014

DEQ/Water Quality Division
Keven Frederick, Administrator

Dear Sir: Regarding: Fort Union Wyodak Aquifer Exemption

I oppose this exemption for these reasons:

1. This aquifer contains good quality drinking and livestock water.

2. The gasification process pollutes groundwater by at least 6 hydrocarbons, all of them are carcinogens.

3. DEQ did <u>not</u> consider water quality in determining if it should be exempted from the Safe Drinking Water Act protection. I feel that should have been very important in such a long lasting decision.

4. Where is the proof that this process will not contaminate or leak through to other formations? Why should the people, wildlife, & livestock be at risk for the sake of one Company to make money on an experiment that could have such long lasting effects?

5. This case could set a dangerous precendent for more use of Fort Union Aquifers and others. Water is such a precious commodity in Wyoming and indeed every where. Let's not jepordize what we all hold dear for the sake of a money making experiment.

6. I am not against the idea of the process, but feel it needs more information. Why not wait until the pilot project in Australia is completed and given a "green light"?

Sincerely,
Jewell A. Reed

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MAR 21 2014

WATER QUALITY DIVISION
WYOMING

DEQ/Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

March 19, 2014

Dear Sir or Madam:

I am writing to oppose WQD's re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.

We need to protect our aquifers for our future generations. Water shortage is only going to get worse. If we inadvertently pollute our precious water sources, it will be a disaster for the next generations. We already have had a "sentinel event" in the contamination of the Pavillion water supply. Let's not open the door to an even larger disaster.

Thanks for your attention;

Perry Cook
656 North Fork Road
Lander, Wy

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MAR 2 4 2014
WATER QUALITY DIVISION
WYOMING

Val Snyder

831 Badger Creek Rd

Sheridan, Wy 82801

DEQ/ Water Quality Division

Kevin Frederick, Administrator

123 West 25th Street, Herschler Building 4W

Cheyenne, Wy. 82002

This letter concerns the proposed Linc Energy experimental project in the Wright, Wyoming area.

There are a number of reasons this aquifer exemption MUST NOT BE GRANTED .
1 Any action which may degrade the quality of the aquifer is foolish beyond imagination, only 2.5% of earth's water is suitable for drinking, only 1% is easily accessible. Wyoming is not blessed with a surplus of potable quality water, to risk any of this most valuable asset is foolish. There is no life without water, period.

2 Currently there are more than 200 coal seam fires burning, Centralia Penn. coal seam fire has burned for 50 years, with more than 4 MILLION dollars spent to extinguish it,to NO AVAIL. Australia's burning mountain has burned for more than 6000 years, it is estimated these fires contribute 40 tons of mercury to our atmosphere each year. This type of fire is not easily extinguished, or even brought under control. If this experiment must proceed, it should utilize an already burning seam.

3 There is no proven effective way of extinguishing this type of fire once ignited, or is this also part of the experiment? Why would the State Of Wyoming risk the destruction of it's coal resources when existing extraction methods provide all the coal our nation requires?

4 Ground water is the principal source of water for municipalities in the United States. If the aquifer is contaminated, HOW WILL ITS QUALITY BE RESTORED?

WHY SHOULD WYOMING'S MOST PRECIOUS RESOURCES BE IMPERILED FOR THE POSSIBLE PROFIT OF A FOREIGN CORPORATION?

5 The Wyoming DEQ is charged with protecting the environmental assets of the state,property of the citizens of Wyoming. Our health, water, air, and land are not replaceable commodities.

6 If these valuable assets are damaged, the livelihoods and the health of the citizens impared, what is the available recourse upon a foreign corporation? If the upcoming TPP is enacted, there will be none, remedy and restoration will be impossible.

7 The Linc Energy corporation has done similar projects in it's home country of Australia, and has yet to complete a clean-up. To allow a corporation from the other side of the earth to imperil the life blood of our state is a violation of your duties and calls into question the real goals of the DEQ. Approval threatens not only our most precious resource, but the credibility and legitimacy of your department and the whole administration.

Wyoming Citizen, Val Snyder

March 21, 2014

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MAR 2 1 2014
WATER QUALITY DIVISION
WYOMING

DEQ/Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

re: Fort Union Wyodak Aquifer Exemption

Dear Mr Frederick,

I strongly oppose the Aquifer exemption. The Fort Union Formation is a valuable source of quality drinking water--the most commonly used in the entire Powder River Basin. It is incomprehensible to me that we would take the chance--no matter how remote--of polluting this precious groundwater. Additionally, Linc Energy is not a shining star, as demonstrated by the caution delivered to the Queensland, Australia, Government by an independent scientific panel. Why even consider allowing a company which has failed to demonstrate successful aquifer cleanup and decommissioning in another country to experiment with our drinking water?

Please protect our good quality water by rejecting this exemption. Thank you for your consideration.

Sincerely,

Pamela E Marks

Pamela E. Marks

March 7, 2014

Department of Environmental Quality / Water Quality Division
Attn: Kevin Frederick, Administrator
122 West 25th Street
Herschler 4W
Cheyenne, Wyoming 82002

Mr. Frederick:

Background
Linc Energy Wyoming (Linc) has proposed an underground coal gasification (UCG) research and development project for the Wyodak Coal aquifer in the Fort Union Formation in Campbell County, Wyoming. As part of the application process, Linc has requested an aquifer exemption and groundwater reclassification for the Wyodak Coal aquifer in and around their project site. At the request of the Wyoming Outdoor Council (WOC), I have reviewed certain portions of the Linc application and provide the following comments:

The Wyodak Aquifer Can Be Classified as a Suitable Drinking Water Aquifer in the Future
The Wyodak aquifer is suitable to be a drinking water aquifer in the future. It is a geological "formation," group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring as defined in the UIC Program. The total dissolved solids (TDS) content of the aquifer is well below the 10,000 mg/L TDS threshold that defines an underground source of drinking water according to the UIC Program. The water quality of the Wyodak is comparable to the Felix aquifer, which currently serves as a potable drinking water supply. Linc has failed to provide sufficient data concerning the "yield" of the Wyodak, particularly given the heterogeneous nature of the system, which they refer to repeatedly in their own documents. I have the following more specific comments:

1) Linc suggests that the Wyodak aquifer is unsuitable for drinking water based on several factors:
   a) High levels of iron and manganese that exceed Secondary Maximum Contaminant Levels (SMCLs) for drinking water
   b) Presence of bis (2-ethyl) phthalate in some samples that exceed the Primary Drinking Water Standard
   c) Low yield (about 1 gallon per minute) and depth
   d) TDS values (501-579 mg/L) slightly above SMCL (500 mg/L) for drinking water

None of the chemical constituents noted above pose any adverse heath risks or would restrict the aquifer for use as a potable drinking water supply and classification as an underground source of drinking water. The U.S. Environmental Protection Agency (EPA) has not set maximum contaminant levels (MCL) for iron and manganese in the National Primary Drinking Water Regulations. Secondary maximum contaminant levels (SMCL) recommended in the National Secondary Drinking Water Regulations are set for esthetic reasons and are not enforceable by EPA, but are intended as guides to the States. The SMCL for iron is 0.3 milligrams per liter (mg/L) and the SMCL for manganese is 0.05 mg/L. Samples collected by Linc or its contractors show a high degree of variability in these parameters and other constituents and the report relies heavily on the "total" metal analyses to demonstrate an exceedance for Fe and Mn. Virtually all of the "dissolved" values for Fe and Mn fall below the SMCL. The use of high-speed submersible pumps for ground water sampling can routinely result in artificially turbid samples where the difference between "total" and dissolved" is consistent with Linc results. Samples with elevated turbidity caused by the sampling procedure often result in significant differences between "total" and "dissolved" due to the presence of colloids or larger particles entrained in the sample. Constituents like Fe, Mn and Ra preferentially sorb to clay and iron oxide particles causing this difference. Turbidity results for most wells are very high and there is a suggestion in one analytical report that samples were lab filtered as opposed to field filtered which would further exaggerate this difference. EPA and USGS guidance is field filtration for "dissolved" analysis, which would be appropriate for these wells.

The presence of bis (2-ethyl) phthalate in some samples is most likely due to PVC, plastic tubing associated with well construction materials or sampling apparatus, or laboratory procedures. This is a commonly known artifact compound found in ground water samples (Wisconsin Dept Natural Resources, Publication WA 1011, Rev. 2002). Its presence usually dictates that the entity responsible for the sampling reevaluate their sampling procedures, sampling equipment and laboratory procedures to exclude it as an artifact. Linc did not do this.

A single hydraulic conductivity value of 0.06 ft/day was used for Linc's aquifer exemption calculation; this, in an aquifer that even they admit is heterogeneous. They also clearly had trouble locating the screened intervals in the aquifer, with 4 of 7 having issues of crossover into the Underburden aquifer. The changing conditions of the aquifer imposed from 10 years of CBM production have clearly complicated the ability to accurately establish meaningful ground water aquifer properties. More samples and tests should therefore have been done for this aquifer (the target for the aquifer exemption), not less than was done for the Overburden and Underburden aquifers. It is common to use wells around 1100 feet deep and deeper for municipal potable water supply wells. In fact, many domestic wells in this part of the state are significantly deeper than 1100 feet and municipal wells near Gillette are as deep as 4500 ft. (http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html).

TDS values in slight exceedance of the SMCL again are not enforceable from a drinking water standpoint and many water supply districts are increasingly using such waters as drinking water sources in the face of dwindling available supplies.

Other Comments

Many of the selected parameters used for the aquifer exemption are limited (single tests), and ignore aquifer heterogeneity. This creates a large amount of uncertainty. There is no scientifically defensible uncertainty analysis associated with these parameters put forward by Linc in their application.

Another concern is the assumption of radial flow away from the test site. If the aquifer was a homogeneous porous medium (I have yet to see such a case in the real world), this conceptual model might hold water. But, even Linc understands it is not and indeed it may be highly fractured, resulting in preferential flow paths and much faster travel times for contaminant excursions than those proposed by Linc.

A "Best Practices in Underground Coal Gasification" report by Lawrence Livermore National Lab (contract W-7405-Eng-48) states that "Suitable future UCG locations should be located at depths where local aquifers consist of saline, nonpotable water, with stratigraphic seals, with structural integrity, including no possibility of cavity roof caving that would create connectivity with other adjacent potable aquifers." This document is largely based on experiences in the Hoe Creek site in the Powder River Basin. Linc has not shown that the aquifer in question can be described as above. There is therefore, significant uncertainty associated with the suitability of the chosen site. This means that there is also significant uncertainty that hydrocarbons in quantity and location are expected to be "commercially producible" from this formation. Wyoming should not want to risk losing a potential useable drinking water source with this much uncertainty regarding a positive outcome of the proposed Linc 'test'.

Concluding Comments

EPA is seeing more aquifer exemption requests with the rise in energy extraction activities across the U.S..As availability of water for human and ecological uses becomes more critical, there is also increased interest in the use of deeper groundwater as a drinking water resource. The number of deep public water supply wells has increased significantly in the western United States during the past couple decades and therefore, the number of locations that can be "reasonably expected" to serve as future drinking water supplies is also increasing. Many CBM aquifers in Colorado and Wyoming have been and are being used as drinking water aquifers. Given the pace of unconventional oil and gas extraction activities and current high production rates, I do not believe that this test is worth the potential contamination of a useable drinking water aquifer.

An Aquifer Exemption removes an aquifer or a portion from protection as a USDW under SWDA. These decisions must be arrived at carefully and it requires demonstrating the exempted aquifer is not likely to be used as a future drinking water source. I do not believe Linc has met this threshold.

Sincerely yours,

Robert W. Puls

Robert W. Puls, Ph.D.
www.robertpulsenvironmentalconsulting.com

MAR 20 2014

March 17, 2014

DEQ / Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Bldg. 4W
Cheyenne, WY 82002

Lucky G. Lambdin
116 Upper Prairie Dog Rd
Banner, WY 82832

Dear Mr. Frederick:

This letter to you concerns the hearing on the Fort Union Wyodak Aquifer Exemption which will take place on March 26th.

I am writing to you to encourage your *opposition* to the Aquifer Exemption for the following reasons:

*The Fort Union Aquifer is the most commonly used water supply aquifer in the Powder River Basin.

*The process to be used by Linc Energy pollutes groundwater by using benzene, toluene, & many other hydrocarbons, all of which are known to cause cancer.

*An independent scientific panel has cautioned the Queensland, Australia government that a pilot project of Linc Energy's should not be allowed to expand until the company could demonstrate successful cleanup & decommissioning.

*This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc already holds several hundred leases on 184,000 acres. This project could be used to justify further exemptions in other areas.

*The water needs of the Gillette area are steadily increasing. Good quality water like that provided by the Fort Union Aquifer must be protected.

Thank you kindly for your time & interest in this matter.

Very sincerely,

Lucky G. Lambdin

Lucky Lambdin.

2360 Road 217
Cheyenne, WY 82009
March 14, 2014
Email: in_wyoming@yahoo.com
Phone: 307-778-7159

Mr. Kevin Frederick
Administrator
Department of Environmental Quality
Water Quality Division
122 West 25th Street
Cheyenne, WY 82002

Dear Mr. Frederick:

We wish to oppose the aquifer exemption for Linc for the Fort Union aquifer north of Wright, Wyoming. We are long-time Wyoming residents and believe:

1. This is good quality, potable water.

2. In a High Plains (near desert environment) it would be detrimental to Wyoming's economic growth to sacrifice this aquifer by allowing processes that pollute groundwater to known carcinogens such as benzene, toluene, and a host of others.

3. The company has not demonstrated successful aquifer cleanup in its home country of Australia.

4. This aquifer should be protected by the Safe Drinking Water Act.

5. The need for good quality water for nearby cities, such as Gillette, will only grow. We cannot afford to sacrifice this aquifer for a few dollars in the here and now.

Sincerely,
Charles and Marilyn Ham

Charles and Marilyn Ham

258 S. Linden Ave.
Sheridan, WY 82801
March 12, 2014

MAR 17 2014

Kevin Frederick, Administrator
DEQ/Water Quality Division
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

Dear Mr. Frederick,

Linc Energy is proposing to build an experimental underground coal gasification project a few miles north of Wright, Wyoming. The process would take place within the Fort Union aquifer in the Wyodak coal seam at about 1,100 feet deep. But an aquifer exemption for the Fort Union Formation would set a dangerous precedent for other areas of the Powder River Basin and across the state.

I oppose the aquifer exemption for several reasons, including the following. The aquifer contains good quality water at just over 500 total dissolved solids (TDS), making it a suitable drinking water aquifer. The Fort Union is the most important and commonly used water supply aquifer in the Powder River Basin. The process pollutes groundwater by creating benzene, toluene, ethylbenzene, xylenes, phenols, and polycyclic aromatic hydrocarbons—all of which are known carcinogens. The company has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until Linc could demonstrate successful aquifer cleanup and decommissioning.

DEQ failed to consider the quality of the water in assessing whether it should be exempted from Safe Drinking Water Act protection, and they confirmed that this would be the first aquifer exemption for the Fort Union Formation in the Powder River Basin and the first time DEQ has exempted an aquifer of drinking water quality.

This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc Energy holds coal leases on 333 state sections—covering over 184,000 acres. This project could be used to justify future aquifer exemptions for development in other areas.
There are many aquifers 1,000 feet or deeper within the Gillette area that serve both the city and surrounding subdivisions, and the water needs of the local area are only increasing. Good quality water like this should be protected for future generations.

Thank you, and please do what you can to protect our water.

Don Crecelius

Don Crecelius

MAR 17 2014

Kevin Frederick, Administrator
DEQ/Water Quality Division
122 West 25th Street, Herschler Building 4W
Cheyenne, Wyoming 82002

3/14/2014

Strong objections and firm opposition to Fort Union Wyodak Aquifer Exemption

Linc Energy is proposing to build an experimental underground coal gasification project a few miles north of Wright, Wyoming. The project is on a state section at 36 T44N R 74W. The process will take place within the Fort Union aquifer in the Wyodak coal seam at about 1,100 feet

The aquifer contains good quality water at just over 500 total dissolved solids (TDS) making it a suitable drinking water aquifer. The Fort Union is the most important and commonly used water supply aquifer in the Powder River Basin.

The process pollutes groundwater by creating benzene, toluene, ethylbenzene, xylenes, phenols, and poly cyclic aromatic hydrocarbons- all of which are know carcinogens.

The company has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until Linc could demonstrate successful aquifer cleanup and decommissioning.

DEQ failed to consider the quality of the water in assessing whether it should be exempted from Safe Drinking Water Act protection, and they confirmed that this would be the first aquifer exemption for the Fort Union Formation in the Powder River Basin and first time DEQ has exempted an aquifer of drinking water quality.

This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc Energy hold coal leases on 333 state sections- covering 184,000 acres. This project would be used to justify future aquifer exemptions for development in other areas.

There are many aquifers 1,000 feet or deeper within the Gillette area that serve both the city and surrounding subdivisions, and the water needs of the local area are only increasing. Good quality water like this should be protected for future generations.

Sincerely,

Joanna V Taylor

Joanna V. Taylor
601 Hemlock St.
Buffalo, Wyoming 82834
307 684 7765
jotaylr@tribcsp.com

Wyoming

Kevin Frederick <kevin.frederick@wyo.gov>

Fwd: Linc Energy UCG Gasifier 6 Project Groundwater Re-classification:

1 message

Keith Guille <keith.guille@wyo.gov> Tue, Mar 18, 2014 at 10:22 AM
To: Kevin Frederick <kevin.frederick@wyo.gov>

Keith Guille
Public Information Officer
Wyoming Department of Environmental Quality
keith.guille@wyo.gov
307-777-6105
307-631-3084

---------- Forwarded message ----------
From: **Andrew J Blair** <ablair344@bresnan.net>
Date: Tue, Mar 18, 2014 at 9:15 AM
Subject: re: Linc Energy UCG Gasifier 6 Project Groundwater Re-classification:
To: keith.guille@wyo.gov

Dear DEQ,

I am concerned about Linc's application for an exemption to the Clean Water Act based on the following issues:

1. The Wyodak aquifer in the Fort Union Formation contains good quality water, meaning it could serve as a future drinking water source. In the face of limited water supplies, this is a crucial fact that shouldn't be ignored. At just over 500 total dissolved solids, it is a suitable drinking water aquifer. The Fort Union is the most important and commonly used water supply aquifer in the Powder River Basin.

Linc claims that existing constituents in the aquifer – including high levels of iron and manganese and the presence of bis(2-ethyl) phthalate in some samples – render the aquifer undesirable as a potable water source. Contrary to their suggestions though, none of the chemical constituents noted by Linc pose any adverse health risks or would restrict the Wyodak aquifer as a source of potable drinking water. This is especially important given the limited availability of water supplies in northeastern Wyoming.

2. The UCG Process produces dangerous groundwater contaminants.
The process pollutes groundwater via the production of benzene, toluene, ethylbenzene, xylenes, phenols, and polycyclic aromatic hydrocarbons—all are known carcinogens.

The company has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until Linc could demonstrate successful aquifer cleanup and decommissioning.

3. Linc's proposed UCG process could lead to contamination of other water sources.
This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union

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MAR 2 1 2014

WATER QUALITY DIVISION

WYOMING

March 18, 2014

Buffalo, Wyo. 82834

Dear Sirs

I recently read in the Casper Star Tribune about the Linc Energy proposal to build an experimental underground coal gasification plant down by Wright. As a lifetime resident of the Powder River Basin, I am adamantly opposed to the idea of pumping chemicals into a formation that contains good drinking water. The article mentioned above failed to give any details about this company's pilot program in Australia. Maybe it would behoove the DEQ to do a little research before opening the door for this exemption.

Thank you

Fred K. Gray

Fred K. Gray
798 North Burritt Ave
Buffalo, Wyol 82834
307 684 2244

March 18, 2014

DEQ/Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

Dear Mr. Frederick,

I am a rancher whose ranch lies 28 miles west of Gillette. We depend on good drinking water for our personal uses as well as for our livestock. On behalf on my family I oppose the aquifer exemption requested by Linc Energy.
First of all, DEQ failed to consider the quality of the water in assessing whether it should be exempted from the Safe Drinking Water Act Protection, and it is also the first time that DEQ has exempted an aquifer of drinking water quality. Secondly, this case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. This project could be used to justify future aquifer exemptions for development in other areas. But foremost, the Fort Union is the most commonly used water supply aquifer in the Powder River Basin and the process proposed by Linc Energy will pollutes groundwater by creating benzene, phenols and many other known carcinogens.
I wish to thank you for taking into consideration the reasons of my opposition to the aquifer exemption requested by Linc Energy.

Sincerely,

Bernadette Barlow

Bernadette Barlow
1625 Buffalo cut across road
Gillette, WY 82718

3/19/14

To Mr. Kevin Frederick,

Water is a concern in Wyoming - keeping water safe + secure is a big issue - DEQ failed to investigate the Fort Union aquifer when it was considering giving Linc Energy the Ok to build an underground coal gasification project -

Please keep the water safe for people, agriculture, and animals by saying NO to this project - Safe water is being sacrificed for what? It will never be safe again if industry pollutes it with the chemicals used for fracking ——

Thanks

Ann Fuller
PO Box 481 Big Horn

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MAR 2 1 2014

WATER QUALITY DIVISION

WYOMING

March 17, 2014

DEQ/ Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, Wy 82002

Re: Ft. Union Wyodak Aquifer Exemption requested by Linc Energy

Dear Mr. Herschler,

I hereby request that the subject request for exemption be declined based on the following:
- Linc Energy has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until the company could demonstrate successful acquirer cleanup and decommissioning.
- The subject acquifer contains good quality water at just over 500 total dissolved solids, making it a suitable drinking water aquifer. The Fort Union is the most important and commonly used water supply aquifer in the Powder River Basin.
- The process pollutes ground water by creating benzene, toluene, ethylbenzene, xylenes, phenols, and polycyclic aromatic hydrocarbons-all of which are known carcinogens.
- DEQ failed to consider the quality of water in assessing whether it should be exempted from Safe Drinking Water Act Protection, and they confirmed that this would be the first acquifer exemption for the Fort Union Formation in the Powder River Basin, and the first time DEQ has exempted an aquifer of drinking water quality.
- The case, therefore sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc Energy holds coal leases on state sections containing over 184,000 acres. Approval of this project could be used as a precedent to justify future aquifer exemptions for development in other areas.

Very Truly Yours,

Tudor J. Marks

Tudor J. Marks
12 Sandstone Circle
Sheridan, Wy 82801

DEQ/Water Quality Division
Kevin Frederick, Administrator
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

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To Whom It May Concern:

I put forth these reasons opposing the aquifer exemption for the Fort Union aquifer in the Wyodak coal seam.

1. The aquifer contains good quality water, making it a suitable drinking water aquifer.

2. The process pollutes groundwater by creating such chemicals as benzene, toluene, ethylbenzene, among others.

3. The company has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until Linc could demonstrate successful aquifer cleanup and decommissioning.

4. DEQ failed to consider the quality of water in assessing whether it should be exempted from Safe Drinking Water Act protection, and they confirmed that this would be the first aquifer exemption for the Fort union Formation in the Powder River Basin and the first time DEQ has exempted an aquifer of drinking water quality.

5. This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc Energy holds coal leases on 333 state sections--covering over 184,000 acres. This project could be used to justify future aquifer exemptions for development in other areas.

6. There are many aquifers 1,000 feet or deeper within the Gillette area that serve both the city and surrounding subdivisions, and the water needs of the local area are only increasing. Good quality water like this should be protected for future generations.

Thank you,

Evelyn and Marvin Griffin
P.O. Box 21
Pavillion, WY 82523

egriffin@wyoming.com

Kevin Frederick, Administrator
DEQ/Water Quality Division
122 West 25th Street, Herschler Building 4W
Cheyenne, WY 82002

RECEIVED
MAR 19 2014

March 12, 2014

It has come to my attention that Linc Energy is proposing to build an experimental underground coal gasification project a few miles north of Wright, Wyoming. The project is on a state section at 36 T44N R 74W. The process will take place within the Fort Union aquifer in the Wyodak coal seam at about 1,100 feet deep. An aquifer exemption for the Fort Union Formation would set a dangerous precedent for other areas of the Powder River Basin and across the state.

I oppose the aquifer exemption for several reasons, including the following. The aquifer contains good quality water at just over 500 total dissolved solids (TDS), making it a suitable drinking water aquifer. The Fort Union is the most important and commonly used water supply aquifer in the Powder River Basin. The process pollutes groundwater by creating benzene, toluene, ethylbenzene, xylenes, phenols, and polycyclic aromatic hydrocarbons—all of which are known carcinogens. The company has a pilot project in Australia, and an independent scientific panel recently cautioned the Queensland government that no new projects should be allowed until Linc could demonstrate successful aquifer cleanup and decommissioning.

DEQ failed to consider the quality of the water in assessing whether it should be exempted from Safe Drinking Water Act protection, and they confirmed that this would be the first aquifer exemption for the Fort Union Formation in the Powder River Basin and the first time DEQ has exempted an aquifer of drinking water quality.

This case sets a dangerous precedent for future exemptions of drinking water aquifers in the Fort Union Formation. Linc Energy holds coal leases on 333 state sections—covering over 184,000 acres. This project could be used to justify future aquifer exemptions for development in other areas.
There are many aquifers 1,000 feet or deeper within the Gillette area that serve both the city and surrounding subdivisions, and the water needs of the local area are only increasing. Good quality water like this should be protected for future generations.

E Heyward

E. Heyward
719 Emerson St.
Sheridan, WY 82801

Earth HOPE

Within a flourishing web of life, just and compassionate human communities

March 17, 2014

MAR 19 2014

DEQ/Water Quality Division
Kevin Frederick, Administrator
RE: **Fort Union Wyodak Aquifer Exemption**

Dear Sir,

I am writing to express my grave concerns about the **Fort Union Wyodak Aquifer Exemption.** Along with air quality, what can be more important than water? Water is life. You, your family, and all of us depend on safe, clean water. You know this.

The Fort Union Aquifer is good quality water and the most commonly used water supply aquifer in the Powder River Basin.

The proposed gasification project creates carcinogenetic compounds. As a cancer survivor, I know the serious threat these compounds are to our health. It is unconscionable to allow their possible escape into our water supply.

So far, Linc has not demonstrated successful aquifer cleanup and decommissioning. Are Wyoming, our citizens and environment, going to become an experiment? The DEQ failed to consider the quality of the water in assessing whether this aquifer should be exempted from the Safe Drinking Water Act protection. As a Wyoming resident, I find this irresponsible. It sets a precedent that puts our entire state's water quality at risk. Seems extremely dangerous to me.

Many aquifers in the Gillette area serve our families and businesses. The water needs of this region are only increasing. Good quality water is far more valuable than coal derived energy.

Good quality water belongs to present and future generations. I strongly petition your protection of our **Fort Union Wyodak Aquifer**. Do not approve this exemption.

Sincerely,
Sister Marya Grathwohl
Sister Marya Grathwohl

Officially Sponsored by the Sisters of St. Francis, Oldenburg, IN

P.O. Box 489, Dayton, WY 82836 Phone: 307-751-9161 E-mail: earth_hope@vcn.com

To: DEQ / WQD

Atten: Kevin Fredrick

From: Niobrara Conservation District

Note:

Hard copy is in the mail.

Heidi L. Sturman

Niobrara Conservation District
Box 659 - Lusk, WY 82225 - (307) 334-2953

Department of Environmental Quality/Water Quality Division
Atten: Kevin Fredrick, Administrator
122 West 25th St.
Herschler 4W
Cheyenne, WY 82002

March 25, 2014

RE: WQDs' re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.'s proposed UCG, R&D Project

The Niobrara Conservation District (NCD) would like to thank the DEQ for the opportunity to comment on the above project. Drinking water, potential drinking water sources and good quality water in general is such a limited resource it deserves the highest degree of protection. These comments are written understanding the difficult job the DEQ takes on regulating the use of and protection of the resources of Wyoming. The following outlines the issues the NCD has with this project.

1.) The NCD understands that coal is a producible mineral.

However, the process of underground coal gasification is not a proven, commercial method of mining. The pilot projects discussed in the EQC hearing (Hoe Creek and Carbon County), as well as, the pilot projects in Australia have not been completed to the point of viable, economic production. Linc Energy Operations, Inc., after 13 years of a pilot project, chose to close and move their operations in Chinchilla, Queensland, Australia rather than to work with the findings of the Independent Scientific Panel to demonstrate safe decommissioning of the aquifer and a design for safe, viable commercial production. The Executive Summary of the ISP Report states:

"The ISP is of the opinion that for commercial UCG operations in Queensland in practice first decommissioning must be demonstrated and then acceptable design for commercial operations must be achieved within an integrated risk-based framework."[1]

These findings seem reasonable for the protection of such a valuable resource as water. Although coal is a producible mineral, via conventional mining with reclamation, the UCG method of production has successfully shown small scale production but has not demonstrated commercial scale production or more importantly the restoration and reclamation component of production.

The EQC Hearing "Findings of Fact", page 5 states:

19. The license requires the aquifer to be restored to it's pre-development quality.
20. The process for clean up at the conclusion of the project is called Rocky Mountain 1 CRIP Cavity Decommissioning process. This process has been shown to be successful in cleaning up a site similar to the proposed site. LINC EXHIBIT 19 and 20

Rocky Mountain 1, Underground Coal Gasification Test, Hanna, Wyoming, Groundwater Evaluation, Final Report is dated 1988 – 1993, well before the initiation of the Linc Energy Pilot Project in Chinchilla, Queensland, Australia in 1999. We would question why Linc Energy did not use this process during the Chinchilla Project time frame to demonstrate its ability to restore the aquifer. If the process is presently being used at the Chinchilla site, is it successful there as well.

Understanding this is a research and development license, we would still question the use of the UCG project as a basis to re-classify and exempt an aquifer from classification protections.

2.) The Statement of Basis 13.14.5.2 WDEQ Groundwater Classification Based on Ambient Quality states:

WDEQ can classify the water as Class I based on the technical practicability and economic reasonableness of treating ambient water quality to meet use suitability standards. In this case, Wyodak groundwater is found closely associated with commercial; deposits of minerals and is Class V (Mineral Commercial)

In the EQC Hearing Proceedings, page 78 – 81 there is a discussion about the primary drinking water standards. It was stated that the aquifer had no constituents that exceeded those standards, however, total dissolved solids and the sodium absorption ratio were the parameters above the recommendations for Class I groundwater, which prompted the reclassification to Class III, which then allowed for the Class V classification and exemption. However, these parameters do not prohibit the aquifer from being used as a drinking water source in the future. The re-classification and exemption from protections does remove a potential drinking water source from future generations, especially since, as stated above its use was technically and economically reasonable.

3.) Linc Energy Operations Statement of Basis, section *Excursions*, details how excursions from the production zone are to be handled.

NCD would ask that protocols be added as to when production will be shut down due to the advancement of an excursion (as it reaches the excursion wells, etc.) and/or the length of time an excursion may exist before shut down is required. These shut down triggers would help limit the continued addition of contaminant materials to the surrounding aquifer while the excursion is being dealt with. NCD also feels there should be a limit to the number of excursions before requiring production shut down. Multiple excursions would demonstrate a lack of control of the production process to maintain protection of the surrounding resources.

4.) The Linc Energy Operations Statement of Basis states under the section *Reporting*:

"Progress reports submitted to the WDEQ-LQD six (6) months after completion of the demonstration period and every six (6) months thereafter until groundwater restoration and surface reclamation is complete."

The NCD would request there be a time limit set on the restoration and reclamation process. This process must be demonstrated that it can be completed in a timely manner.

5.) The Statement of Basis section *13.14.7.2 Process Description* states:

"Gasifier 6 will maintain gasification operations for 90 to 120 days."

The Independent Scientific Panel Report Executive Summary states:

"Both companies (Linc Energy and Carbon Energy) *have demonstrated capability to commission and operate a gasifier. Neither company has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. The ISP remains open to the possibility that the concept is feasible. However sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. Important work has been undertaken but more is yet to be done. For example, neither company has gained access to a gasified cavity, sampled it and provided information on the current contents and condition of surrounding materials.*

At mid-2012, neither company had completed a burn of sufficient duration to create a final cavity of the dimensions that are expected under a commercial process. Until this is done it is difficult to come to a final conclusion regarding the technology."[1]

The NCD questions what the project is to demonstrate. According to the above documentation commissioning and operating a gasifier has been adequately demonstrated. However, after a 13 year pilot project, Linc Energy had not yet demonstrated that this process was at a level for commercial production nor had they demonstrated decommissioning and restoration of the aquifer. Linc Energy has proposed 90 -120 days of gasification, a much shorter time frame than the 13 years spent on the Australia project. What is the actual purpose of this demonstration? As well, what happens after the 120 days (opportunities for extensions, decommissioning, restoration, commercial production, etc.) and what is the time line? It seems this needs addressed prior to project initiation.

Again we would like to thank the DEQ for the opportunity to comment on this process.

Respectfully,

Heidi L. Sturman

Heidi L. Sturman
For Kevin L. Gaukel, Chairman
Niobrara Conservation District

References

[1]INDEPENDENT SCIENTIFIC PANEL REPORT ON UNDERGROUND COAL GASIFICATION PILOT TRIALS
June 2013
Queensland Independent Scientific Panel for Underground Coal Gasification (ISP)
Professor Chris Moran, Director, Sustainable Minerals Institute, The University of Queensland.
Professor Joe da Costa, School of Chemical Engineering, The University of Queensland.
Em. Professor Chris Cuff, C&R Consulting, Townsville Queensland.

ATTACHMENT 5

WQD Public Hearing
Linc UCG Gasifier & Proj; Groundwater Classification
Wright, WY
March 26, 2014

Please Sign In

Name	Address	Email / Phone
Don Fischer	2100 W. 5th St. Sheridan	Don.Fischer@wyo.gov
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Brian Dewaloo	PO Box 789 Glenrock WY 82637	brian-dewaloo@lincenergy.com
Ray DeLuna	900 Werner Court, Suite 150	rdeluna@treccorp.com
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Jill Morrison	934 N Main St Sheridan	672-5807
Wendy Lowe	643 E. 3RD St Casper, WY 82601	
Kevin Frederick	Herschler Bldg Cheyenne, WY	777.5985
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[illegible]	Box 72 Wright WY. 82732	307-299-3377
[illegible]	Box 246 Wright WY 82732	
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Jim Thompson	P.O. Box 259, WRIGHT WY 82732	
Kerry & Gilo Clark	2652 Clark [illegible]	82718
Travis Meyers	113 Aster Ln Gillette 82716	307.751.7269
Danny Preston	Town Hall Councilman Wright	307-660-2131
Marion Loomis	Box 866, Cheyenne WY	
Stephanie Joyce	Dept 3940 U.W.	307-766-0809
[illegible] Jensen	PO BOX 1169	307-689-9184
MARK PEPPER	Box 1750 Glenrock	307-259-6903
Amber Wilson	262 Lincoln St Lander	amber@wyomingoutdoorcouncil.org
Denise Ebzery, Sen. Barrasso	2 N Main St Sheridan WY	denise-ebzery@barrasso.senate.gov
[illegible]		

NAME ADDRESS EMAIL

[illegible] Denver, Co

Paul Ludwicka Denver, Co

John L. Deobald Wright, WY P.O. Box 314, 82732

~~Sherman Knudtson~~ Wright —

Bill Shank Wright

Janet Eldredge Wright - High Plains Sentinel News

L. J. Turner 605 Turnercrest Gillette

~~[illegible] Box 408 Wright Wyo 82732~~

Mike Moore 320 A Moore Rd. 939-1253
Gillette, Wy 82718 680-6984

Pat Haller PO Box 421 Wright Wy

John Flocchini 7835 Hwy 59 Gillette, WY 82718

Don Cossins PO BOX 778 Wright, WY 82732

Pat Thomson 8053 Hwy 59 Gillette 82718

Bill Fortner P.O. Box 1013 Gillette Wy 82717

Roger Rasmussen P.O. Box 125 Wright 82732

Charles Jeffery 209 Big Horn St Wright Wy 82732

Nick Van Wyhe 4512 Running W. Drive #205 Gillette, 82718 nick.vanwyhe@hdrinc.com

Brenda Schladweiler PO Box 3337 Gillette 82717 [redacted] schlad@vcn.com

Brandi Beecher Harlow Bx 70 Wright 82732

Karla Oksanen 205 Battle Cry Ln. 82716

Eric Barlow HD 3 Wy House of Rep.

Ralph Kingan	Box 77
Danny Preston, Town Hall Councilman	PO Box 70
Tex Adams	03 Wagensen Road
Karla Oksanen	205 Battle Cry Lane
Amber Wilson	262 Lincoln Street
Shannon Anderson	934 North Main Street
Jill Morrison	934 North Main Street
Jim Thompson	PO Box 259
Peter Wold	1615 Brookview Drive
Marion Loomis	Box 866
John Flocchini	7835 Highway 59
L.J. Turner	605 Turnercrest
Ray DeLuna	900 Werner Court, Suite 150
Pat Fuller	PO Box 421
Mike Moore	320 A Moore Road
Bill Fortner	PO Box 1013
Angie Jensen	PO Box 1169
Mark Pepper	Box 1750
John Deobald	PO Box 314
Bernice Groves	Box 408
Janet Eldridge, High Plains Sentinel	PO Box 457
Brian Deurloo	PO Box 789
Wendy Lowe	643 East 3rd Street
Leroy Van Broggerman	Box 570
Mary Melaragno	Box 3948
Matt Stottlemyre	3927 Axel Ave
Travis Myers	113 Aster Lane
Stephanie Joyce	Dept 3940 University of Wyoming
Denise Ebzery	2 North Main Street
John L. Deobald	PO Box 314
Jon cossins	PO Box 778
Pat Thompson	8053 Hwy 59
Roger Rasmussen	PO Box 125
Charles Jeffery	209 Big Horn Street
Nick Van Wyhe	4512 Running W Drive #205
Brenda Schadweiler	PO Box 3337
Brandi Beecher Harlow	Box 70
Eric Barlow	1625 A Buffalo Cut Across Road

Ray DeLuna	Trec Inc. 900 Werner Ct. Suite 150
Dollie Iberlin	414 N. Burritt
Robert Kayser	518 Cold Springs Road

Edith S. Cook	719 Bomar Drive
Bob Giurgevich	332-B North Jefferson Street
Al Carlson	PO Box 16
Jewell A. Reed	884 Steinle RD
Perry Cook	656 North Fork Road
Val Snyder	831 Badger Creek Road
Pamela E. Marks	NO ADDRESS GIVEN
Robert W. Puls	www.robertpulsenvironmentalconsulting.com
Lucky Lambdin	116 Upper Prairie Dog Rd
Charles and Marilyn Ham	2360 Road 217
Don Crecelius	258 S. Linden Ave.
Joanna V. Taylor	601 Hemlock Street
Fred K. Gray	798 North Burritt Ave
Bernadette Barlow	1625 Buffalo Cut Across Road
Ann Fuller	PO Box 481
Tudor J. Marks	12 Sandstone Circle
Evelyn and Marvin Griffin	PO Box 21 Pavillion
E. Hayward	719 Emerson St.
Sister Marya Grathwohl	PO Box 489
Heidi L. Sturman	Niobrara Conservation District PO Box 659
Roger Rasmussen	PO Box 125
Peter Wold	139 W. 2nd St. Ste 200
John Wold	139 W. 2nd St. Ste 200
Jill Morrison	PRBRC 934 N. Main Street
Bob LeResche	PRBRC 934 N. Main Street
Timothy M. Moore	320 A. Moore Road
Nancy Sorenson	7241 US Hwy 14-16
Ralph Kingan	Box 77
Danny Preston, Town Hall Councilman	Box 70
Tex Adams	03 Wagensen Road

Wright, WY 82732
Wright, WY 82732
Gillette, WY 82716
Gillette, WY 82716
Lander, WY 82520
Sheridan, WY 82801
Sheridan, WY 82801
Wright, WY 82732
Casper, WY 82604
Cheyenne, WY 82003
Gillette, WY 82718
Gillette, WY 82716
Casper, WY 82601
Wright, WY 82732
Gillette, WY 82718
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Glenrock, WY 82637
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Glenrock, WY 82637
Casper, WY 82601
Story, WY 82842
Gillette, WY 82717
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Laramie, WY 82070
Sheridan, WY 82801
Wright, WY 82732
Wright, WY 82732
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Gillette, WY 82718

Casper WY 82601
Buffalo WY 82834
Douglas WY 82633

Cheyenne WY 82009
Sheridan WY 82801
Story WY 82842
Douglas WY 82633
Lander WY 82520
Sheridan WY 82801

No physical address
Banner WY 82832
Cheyenne WY 82009
Sheridan WY 82801
Buffalo WY 82834
Buffalo WY 82834
Gillette WY 82718
Big Horn WY 82420
Sheridan WY 82801
Pavillion WY 82523
Sheridan WY 82801
Dayton WY 82836
Lusk WY 82225
Wright WY 82732
Casper WY 82601
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Gillette WY 82718
Arvada WY 82831
Wright WY 82732
Wright WY 82732
Gillette WY 82716

ATTACHMENT 6

Public Notice

The Wyoming Department of Environmental Quality's (DEQ) Water Quality Division (WQD) will hold a public hearing in Wright, Wyoming on March 26, 2014 at the Wright Branch Library, 305 Wright Blvd, Wright Wyoming, from 4:00 PM to 7:00 PM. The public may specifically comment on WQD's re-classification of groundwater and proposed aquifer exemption for Linc Energy Operations, Inc.'s (Linc) proposed underground coal gasification research and development testing project (Linc UCG Gasifier 6 Project), located on lands owned by the State of Wyoming, specifically T44N, R74W, Section 36 within Campbell County.

On August 29, 2013 the DEQ WQD submitted to the US Environmental Protection Agency (EPA) a Statement of Basis describing WQD's re-classification of groundwater associated with the proposed project. The re-classification applies only to groundwater located within an area of approximately 80 acres in the Wyodak coal seam. In accordance with Water Quality Rules and Regulations, WQD determined that groundwater within this localized area, for the purpose of the Linc Project, may be re-classified as Class V (Mineral Commercial) groundwater since it is closely associated with commercial deposits of minerals (e.g. coal) and, with concurrence from EPA, meets the criteria for exempting this portion of the aquifer within the Wyodak coal seam as an Underground Source of Drinking Water (USDW). Public notice of WQD's groundwater re-classification was published in the Gillette News-Record for four (4) consecutive weeks, starting on September 6, 2013. A public hearing before the Environmental Quality Council (EQC) on Linc's proposed operations, including the groundwater re-classification, was held on November 14 and 15, 2013 in Cheyenne. On January 24, 2014, the DEQ issued the research and development license to Linc, conditioned on both adequate bonding and EPA's issuance of the aquifer exemption, which is required prior to injection. WQD believes that the area of the aquifer re-classified by WQD meets EPA's criteria for exemption because groundwater within this portion of the aquifer is not being used as a source of drinking water, and it cannot now, nor in the future serve as a source of drinking water because it contains minerals that are expected to be commercially producible, considering their quantity and location.

Written comments may be submitted in advance of the public hearing to the following address: Department of Environmental Quality/Water Quality Division, Attn: Kevin Frederick, Administrator, 122 West 25th Street, Herschler 4W, Cheyenne, Wyoming 82002. Oral and written comments will be accepted until the public comment period closes at the end of the hearing.

An electronic copy of this notice, the Statement of Basis, and the November 14, 2013 public hearing transcript is available at: http://deq.state.wy.us/wqd/events/index.asp

In accordance with the Americans with Disabilities Act, special assistance or alternative formats will be made available upon request for individuals with disabilities. Please provide at least three (3) weeks advance notice for such requests.

ATTACHMENT 7

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
DENVER, CO 80202-1129
Phone 800-227-8917
http://www.epa.gov/region08

Ref: 8P-W-UIC

JAN 28 2014

Mr. Todd Parfitt, Director
Wyoming Department of
Environmental Quality (WDEQ)
Herschler Building
122 West 25th Street
Cheyenne, Wyoming 82002

Re: Linc Energy Aquifer Exemption Request

Dear Mr. Parfitt:

As discussed in our telephone conversations last week, I am writing to clarify the process on the Linc Energy aquifer exemption request. The WDEQ forwarded the Environmental Quality Council Order of January 9, 2014, to the U.S. Environmental Protection Agency Region 8. However, to satisfy EPA's requirements, EPA expects WDEQ to hold an additional public hearing on the Linc Energy aquifer exemption request. The EPA will wait to make a decision on this aquifer exemption request until after the WDEQ completes its additional public process and forwards all comments, a response to comments, its decision and any other documents associated with the public participation process related to the Linc Energy aquifer exemption request. Consistent with the State/EPA MOA, the EPA intends to make a final determination on this request within 20 days of receipt of these documents.

Please contact me or Sadie Hoskie of my staff at (303) 312-6390 with questions or concerns regarding this matter.

Sincerely,

Shaun L. McGrath
Regional Administrator

ATTACHMENT 8

Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Matthew H. Mead, Governor

Todd Parfitt, Director

January 24, 2014

Amber Wilson
Environmental Quality Coordinator
Wyoming Outdoor Council
262 Lincoln St
Lander, WY 82520

RE: Response to Objections of Linc Energy Underground Coal Gasification Research and Development License Application - TFN 5 5/128.

Dear Ms. Wilson,

The Environmental Quality Council (EQC) heard the objections to Linc Energy Underground Coal Gasification (UCG) Research and Development (R&D) license application from the Powder River Basin Resource Council (PRBRC) on November 14 and 15, 2013. The EQC denied the PRBRC objections in written findings on January 9, 2014. The EQC did not recommend any changes to the Linc Energy UCG R&D license application. Therefore, no changes were made to the license application in response to the objections from PRBRC.

As of the date of the issuance of this response letter, the EPA has not finalized Linc's aquifer exemption as a revision to the Wyoming Department of Environmental Quality's (WDEQ) Underground Injection Control (UIC) program. The WDEQ has placed a special condition on the license approval requiring Linc not to operate under this license until the aquifer exemption has been finalized.

Please find enclosed the Findings of Fact and Conclusions of Law from the EQC and a copy of the approved Linc Energy UCG R&D license application. The WDEQ believes the EQC's consideration of and responses to PRBRC's objections, as evidenced in the Finding of Fact and Conclusions of Law and EQC hearing transcript, to be comprehensive enough to address the comments you outlined in your letter dated October 22, 2013. The WDEQ obligation to provide a response to your comments is therefore satisfied by this attached Findings of Fact and Conclusions of Law from the EQC.

Should you have any question, please contact the Land Quality Division Administrator, Nancy Nuttbrock by phone at 307-777-7046 or by email at Nancy.Nuttbrock@wyo.gov

Sincerely,

Todd Parfitt
Director, Department of Environmental Quality

cc: File – TFN 55/128
Wendy Cheung, Denver, EPA
Nancy Nuttbrock, Deputy Director, Administrator, Land Quality Division, WDEQ
Kevin Frederick, Administrator, Water Quality Division, WDEQ

FILED

JAN 0 9 2014

Jim Ruby, Executive Secretary
Environmental Quality Council

BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
STATE OF WYOMING

IN RE LINC ENERGY OPERATIONS, Inc.	)	**DOCKET NO. 13-4804**
TFN 5 5/128	)	
	)	**FINDINGS OF FACT,**
	)	**CONCLUSIONS OF LAW,**
	)	**AND ORDER.**

On the 14TH day of November, 2013 at 9:00 a.m. the above entitled matter came on for final hearing in Cheyenne, Wyoming. The Hearing Officer was Vice Chairman David Searle. Council members present in person were, Vice-Chairman David Searle, Councilmen Tim Flitner, Andy Schwartz, and Dr. David Bagley and Councilwoman Meghan Lally. Present via video conference was Chairman Tom Coverdale and Councilman Rich Fairservis. The hearing lasted two days. On the second day Councilman Flitner, Chairman Coverdale and Councilman Fairservis appeared by phone.

Representing the Department of Environmental Quality was Jeremiah Williamson, Senior Asst. Attorney General. Representing Linc Energy was Bruce Salzburg. Representing the Petitioners was Shannon Anderson.

Present and testifying on behalf of the Department was Mark Rogaczewski, Program Manager, Land Quality Divison of DEQ; Muthu Kuchanur, Geology Supervisor Land Quality Division of DEQ and Don Fischer, North District Geological Supervisor, Groundwater Divison of DEQ. Present and testifying on behalf of Linc Energy was Brian Deurloo, General Manager of Clean Energy Wyoming, and Tom Osborne, Principal Hydrologist for Hydro Solutons Inc.. Testifying on behalf of the Petitioners was Jill Morrison, Organizer for Powder River Basin Resource Council. The Petitioner also called as a witness Kevin Frederick, Administrator, Water

Quality Division of DEQ.

Prior to the final hearing in this matter the Council heard arguments as to whether the EQC had jurisdiction over the issue of an aquifer exemption. After consideration of the briefs filed and oral arguments of the parties the Council found that it did have jurisdiction over the aquifer exemption issue.

The following Exhibits were offered and received. DEQ 1. LINC 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, and 29. PRBRC 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, and 32

The following Exhibit was offered but not received: PRBRC 15.

PRBRC offered and then withdrew exhibit PRBRC 22.

FINDINGS OF FACT

1. Linc Energy (Linc) filed an application with the Land Quality Division of the Wyoming Department of Environmental Quality (DEQ) for an in situ mining license.

2. Based upon the review of the initial application the DEQ required Linc to first obtain a research and development license, pursuant to Wyo. Rev. Stat. Section 35-11-431 to demonstrate the feasibility of the process in Wyoming.

3. Linc then filed an application for a research and development license for in situ mining of the Wyodak formation through a gasification mining process.

4. The DEQ and Linc participated in 8 rounds of discussions regarding the technical aspects of the application

5. The Department published their intent to issue a R&D license to mine to the Company for four consecutive weeks beginning on the 6th day of September and ending on the 23rd day of September 2013. Contained within the notice was the notice of the Department's issuance of a

groundwater aquifer reclassification and a groundwater aquifer exemption.

6. The public had 30 days to comment on the proposed R&D license and the aquifer reclassification and exemption. On the 21st day of October, 2013 the Powder River Basin Resource Council (PRBRC) filed objections and request for hearing to the Departments intention to issue the R&D license.

7. The grounds for objection were:

a. The coal seams of the Fort Union Formation are regional aquifers, providing critical water resource to landowners and local governments.

b. The approval of Linc's request to reclassify and exempt this portion of the Fort Union Formation will set a dangerous precedent for future contamination from underground coal gasification and other industrial projects in the Powder River Basin, threatening the viability of this regional aquifer as a continued source of water

8. The project is estimated to last from 90 to 120 days. LINC EXHIBIT 1 13.14-9

9. The mining area is 80 acres in surface area located approximately 10 miles to the west of Wright, Wyoming. Wright is approximately 38 miles south of Gillette, Wyoming.

10. The coal seam and aquifer are called the Wyodak formation and at the time of the R&D license application was classified a Class III aquifer.

11. The Wyodak aquifer contains a seam of coal (hydrocarbon) that is approximately 30 feet thick and through the gasification process will be converted to a syngas that can then be processed into a variety of fuels. LINC EXHIBIT 1 PAGE 13.14-9

12. The aquifer at the location of the project produces 1 gallon per minute of water.

13. There are two rings of monitoring wells that provide critical information regarding the test site. The first ring, consists of 20 project trend wells that are utilized to control the

hydrostatic pressures within the overburden, underburden and the aquifer surrounding the gasifier. The second ring consists of 17 excursion wells that will monitor the aquifer to determine whether any contaminates have migrated from the test site. LINC EXHIBIT 1 PAGE 13.14-15

14. There are not any domestic, commercial or industrial wells within the boundaries of the permit area. The closest wells are two shut in coalbed methane wells. These two wells are just on the outside of the permit boundaries. The next closest wells are two commercial oil wells that are approximately 1 mile from the permit boundary. There aren't any potable-use wells within three miles of the project boundary. LINC EXHIBIT 1 PAGE 13.14-5; and LINC EXHIBIT 11; LINC EXHIBIT 14; and LINC EXHIBIT 15; and LINC EXHIBIT 16.

15. The coal seam is bounded by an interburden of sandstone, siltstone and shale with a thickness ranging from 104 feet to 332 feet. The overburden is comprised of shale and the overburden is from 24 to 30 feet in the vicinity of the project site. The underburden is comprised of shale and is approximately 10 feet thick in the area of the project site. LINC EXHIBIT 1 PAGE 13.14-4 AND 13.14-5 AND 13.14-7; LINC EXHIBIT 22.

16. If an excursion were to occur it is estimated that upon discovery the excursion could be reversed within one day. Based upon a contaminate fate and transport analysis of chloride and benzene any excursion of chloride would only be able to travel 200 feet from its source in the Wyodak aquifer in 5.8 to 10.8 years. In the overburden the same release would take 31.8 to 187 years to travel 200 feet and in the underburden it would take 9.4 to 26.2 years. For benzene it would take 100,000 years in the Wyodak, 38.1 to 262 in the overburden and 10.9 to 31.2 in the underburden. LINC EXHIBIT 1 PAGE 13.14-16

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without contamination of groundwater.

18. Linc Energy is a majority owner of Yerostigaz, a commercial UCG facility in Uzbekistan which has 50 years of experience using coal gasification .

19. The license requires the aquifer to be restored to it's pre-development quality.

20. The process for clean up at the conclusion of the project is called Rocky Mountain 1 CRIP Cavity Decommissioning process. This process has been shown to be successful in cleaning up a site similar to the proposed site. LINC EXHIBIT 19 and 20

21. The target coal seam potentiometric surface has been lowered substantially from CBM development. The potentiometric levels within the coal seam are about 320 feet lower than the underburden aquifer and about 80 feet lower than the overlying overburden aquifer. LINC EXHIBIT 1 13.14-7

CONCLUSIONS OF LAW

22. The EQC has jurisdiction over the parties and the subject matter of this proceeding pursuant to W.S. 35-11-112(a)(iv) and 406(k) and the Memorandum of Agreement between the State of Wyoming and the United States Environmental Protection Agency entered into in April 1983. LINC EXHIBIT 3

23. All notice requirements have been met.

24. Linc Energy's application meets all statutory and regulatory requirements. DEQ EXHIBIT 1.

25. None of the grounds enumerated in W.S. 35-11-406(k) exist to deny the issuance of Linc Energy license TFN 5 5/128.

26. The aquifer in the license area is a hydrocarbon bearing aquifer that is currently classified as a Class III aquifer by DEQ. The aquifer meets the requirements for classification as a Class

V aquifer.

27. The aquifer in the license area is not currently serving as a source for drinking water.

28. The aquifer in the license area will not in the future serve as a source of drinking water because it is not economically feasible.

29. The Petitioners bear the burden of proof to show that one of the statutory grounds enumerated in W.S. 35-11-406(k) exist to deny the issuance of Linc Energy R&D license TFN 5 4/191.

30. The burden of proof is preponderance of the evidence.

31. The Petitioner has failed to meet that burden.

32. Linc Energy's R&D license application is complete. The license application complies with all statutory and regulatory requirements.

ORDER

WHEREFORE, it is HEREBY ORDERED that the R&D license identified in **TFN 5 5/128** be issued by the DEQ to Linc Energy Operations Inc.

DATED this 9th day of January, 2014.

David Searle, Presiding Officer
Environmental Quality Council

CERTIFICATE OF SERVICE

I, Tyffanne Rowan, certify that at Cheyenne, Wyoming, on the 10th day of January, 2014, I served a copy of the foregoing **FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER** by electronic mail to the following:

Jeremiah Williamson
Asst. Attorney General
jeremiah.williamson@wyo.gov

Nancy Nuttbrock
Land Quality Administrator
nancy.nuttbrock@wyo.gov

Shannon Anderson
Powder River Basin Resource Council
sanderson@powderriverbasin.org

Bruce Salzburg
Attorney for Linc Energy Operations, Inc.
BSalzburg@crowell.com

Todd Parfitt
Director, DEQ
Todd.Parfitt@wyo.gov

T. Rowan

Tyffanne Rowan, Office Assistant
Environmental Quality Council
122 W. 25th, Rm. 1714
Herschler Bldg.
Cheyenne, WY 82002
Phone: 307-777-7170
FAX: 307-777-6134

January 24, 2014

Andrea Issod
Staff Attorney
Sierra Club Environmental Law Program
85 Second St, Second Floor
San Francisco, CA 94105

RE: Response to Objections of Linc Energy Underground Coal Gasification Research and Development License Application - TFN 5 5/128.

Dear Ms. Issod,

The Environmental Quality Council (EQC) heard the objections to Linc Energy Underground Coal Gasification (UCG) Research and Development (R&D) license application from the Powder River Basin Resource Council (PRBRC) on November 14 and 15, 2013. The EQC denied the PRBRC objections in written findings on January 9, 2014. The EQC did not recommend any changes to the Linc Energy UCG R&D license application. Therefore, no changes were made to the license application in response to the objections from PRBRC.

As of the date of the issuance of this response letter, the EPA has not finalized Linc's aquifer exemption as a revision to the Wyoming Department of Environmental Quality's (WDEQ) Underground Injection Control (UIC) program. The WDEQ has placed a special condition on the license approval requiring Linc not to operate under this license until the aquifer exemption has been finalized.

Please find enclosed the Findings of Fact and Conclusions of Law from the EQC and a copy of the approved Linc Energy UCG R&D license application. The WDEQ believes the EQC's consideration of and responses to PRBRC's objections, as evidenced in the Finding of Fact and Conclusions of Law and EQC hearing transcript, to be comprehensive enough to address the comments you outlined in your letter dated October 21, 2013. The WDEQ obligation to provide a response to your comments is therefore satisfied by this attached Findings of Fact and Conclusions of Law from the EQC.

Should you have any question, please contact the Land Quality Division Administrator, Nancy Nuttbrock by phone at 307-777-7046 or by email at Nancy.Nuttbrock@wyo.gov

Sincerely,

Todd

Todd Parfitt
Director, Department of Environmental Quality

cc: File – TFN 55/128
Wendy Cheung, Denver, EPA
Nancy Nuttbrock, Deputy Director, Administrator, Land Quality Division, WDEQ
Kevin Frederick, Administrator, Water Quality Division, WDEQ

FILED

BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
STATE OF WYOMING

JAN 0 9 2014

Jim Ruby. Executive Secretary
Environmental Quality Council

IN RE LINC ENERGY OPERATIONS, Inc.	)	**DOCKET NO. 13-4804**
TFN 5 5/128	)	
	)	**FINDINGS OF FACT,**
	)	**CONCLUSIONS OF LAW,**
	)	**AND ORDER.**

On the 14TH day of November, 2013 at 9:00 a.m. the above entitled matter came on for final hearing in Cheyenne, Wyoming. The Hearing Officer was Vice Chairman David Searle. Council members present in person were, Vice-Chairman David Searle, Councilmen Tim Flitner, Andy Schwartz, and Dr. David Bagley and Councilwoman Meghan Lally. Present via video conference was Chairman Tom Coverdale and Councilman Rich Fairservis. The hearing lasted two days. On the second day Councilman Flitner, Chairman Coverdale and Councilman Fairservis appeared by phone.

Representing the Department of Environmental Quality was Jeremiah Williamson, Senior Asst. Attorney General. Representing Linc Energy was Bruce Salzburg. Representing the Petitioners was Shannon Anderson.

Present and testifying on behalf of the Department was Mark Rogaczewski, Program Manager, Land Quality Divison of DEQ; Muthu Kuchanur, Geology Supervisor Land Quality Division of DEQ and Don Fischer, North District Geological Supervisor, Groundwater Divison of DEQ. Present and testifying on behalf of Linc Energy was Brian Deurloo, General Manager of Clean Energy Wyoming, and Tom Osborne, Principal Hydrologist for Hydro Solutons Inc.. Testifying on behalf of the Petitioners was Jill Morrison, Organizer for Powder River Basin Resource Council. The Petitioner also called as a witness Kevin Frederick, Administrator, Water

Quality Division of DEQ.

Prior to the final hearing in this matter the Council heard arguments as to whether the EQC had jurisdiction over the issue of an aquifer exemption. After consideration of the briefs filed and oral arguments of the parties the Council found that it did have jurisdiction over the aquifer exemption issue.

The following Exhibits were offered and received. DEQ 1. LINC 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, and 29. PRBRC 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, and 32

The following Exhibit was offered but not received: PRBRC 15.

PRBRC offered and then withdrew exhibit PRBRC 22.

FINDINGS OF FACT

1. Linc Energy (Linc) filed an application with the Land Quality Division of the Wyoming Department of Environmental Quality (DEQ) for an in situ mining license.

2. Based upon the review of the initial application the DEQ required Linc to first obtain a research and development license, pursuant to Wyo. Rev. Stat. Section 35-11-431 to demonstrate the feasibility of the process in Wyoming.

3. Linc then filed an application for a research and development license for in situ mining of the Wyodak formation through a gasification mining process.

4. The DEQ and Linc participated in 8 rounds of discussions regarding the technical aspects of the application

5. The Department published their intent to issue a R&D license to mine to the Company for four consecutive weeks beginning on the 6th day of September and ending on the 23rd day of September 2013. Contained within the notice was the notice of the Department's issuance of a

groundwater aquifer reclassification and a groundwater aquifer exemption.

6. The public had 30 days to comment on the proposed R&D license and the aquifer reclassification and exemption. On the 21st day of October, 2013 the Powder River Basin Resource Council (PRBRC) filed objections and request for hearing to the Departments intention to issue the R&D license.

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a. The coal seams of the Fort Union Formation are regional aquifers, providing critical water resource to landowners and local governments.

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8. The project is estimated to last from 90 to 120 days. LINC EXHIBIT 1 13.14-9

9. The mining area is 80 acres in surface area located approximately 10 miles to the west of Wright, Wyoming. Wright is approximately 38 miles south of Gillette, Wyoming.

10. The coal seam and aquifer are called the Wyodak formation and at the time of the R&D license application was classified a Class III aquifer.

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12. The aquifer at the location of the project produces 1 gallon per minute of water.

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hydrostatic pressures within the overburden, underburden and the aquifer surrounding the gasifier. The second ring consists of 17 excursion wells that will monitor the aquifer to determine whether any contaminates have migrated from the test site. LINC EXHIBIT 1 PAGE 13.14-15

14. There are not any domestic, commercial or industrial wells within the boundaries of the permit area. The closest wells are two shut in coalbed methane wells. These two wells are just on the outside of the permit boundaries. The next closest wells are two commercial oil wells that are approximately 1 mile from the permit boundary. There aren't any potable-use wells within three miles of the project boundary. LINC EXHIBIT 1 PAGE 13.14-5; and LINC EXHIBIT 11; LINC EXHIBIT 14; and LINC EXHIBIT 15; and LINC EXHIBIT 16.

15. The coal seam is bounded by an interburden of sandstone, siltstone and shale with a thickness ranging from 104 feet to 332 feet. The overburden is comprised of shale and the overburden is from 24 to 30 feet in the vicinity of the project site. The underburden is comprised of shale and is approximately 10 feet thick in the area of the project site. LINC EXHIBIT 1 PAGE 13.14-4 AND 13.14-5 AND 13.14-7; LINC EXHIBIT 22.

16. If an excursion were to occur it is estimated that upon discovery the excursion could be reversed within one day. Based upon a contaminate fate and transport analysis of chloride and benzene any excursion of chloride would only be able to travel 200 feet from its source in the Wyodak aquifer in 5.8 to 10.8 years. In the overburden the same release would take 31.8 to 187 years to travel 200 feet and in the underburden it would take 9.4 to 26.2 years. For benzene it would take 100,000 years in the Wyodak, 38.1 to 262 in the overburden and 10.9 to 31.2 in the underburden. LINC EXHIBIT 1 PAGE 13.14-16

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CONCLUSIONS OF LAW

22. The EQC has jurisdiction over the parties and the subject matter of this proceeding pursuant to W.S. 35-11-112(a)(iv) and 406(k) and the Memorandum of Agreement between the State of Wyoming and the United States Environmental Protection Agency entered into in April 1983. LINC EXHIBIT 3

23. All notice requirements have been met.

24. Linc Energy's application meets all statutory and regulatory requirements. DEQ EXHIBIT 1.

25. None of the grounds enumerated in W.S. 35-11-406(k) exist to deny the issuance of Linc Energy license TFN 5 5/128.

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ORDER

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DATED this 9th day of January, 2014.

David Searle, Presiding Officer
Environmental Quality Council

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I, Tyffanne Rowan, certify that at Cheyenne, Wyoming, on the 10th day of January, 2014, I served a copy of the foregoing **FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER** by electronic mail to the following:

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Asst. Attorney General
jeremiah.williamson@wyo.gov

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Land Quality Administrator
nancy.nuttbrock@wyo.gov

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sanderson@powderriverbasin.org

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Attorney for Linc Energy Operations, Inc.
BSalzburg@crowell.com

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T. Rowan

Tyffanne Rowan, Office Assistant
Environmental Quality Council
122 W. 25th, Rm. 1714
Herschler Bldg.
Cheyenne, WY 82002
Phone: 307-777-7170
FAX: 307-777-6134

ATTACHMENT 9

FILED

JAN 0 9 2014

Jim Ruby, Executive Secretary
Environmental Quality Council

BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
STATE OF WYOMING

IN RE LINC ENERGY OPERATIONS, Inc.	)	**DOCKET NO. 13-4804**
TFN 5 5/128	)	
	)	**FINDINGS OF FACT,**
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DATED this 9th day of January, 2014.

David Searle, Presiding Officer
Environmental Quality Council

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jeremiah.williamson@wyo.gov

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Tyffanne Rowan, Office Assistant
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FAX: 307-777-6134

ATTACHMENT 10

(Copies can be obtained by contacting Wyoming Reporting Service, Inc. at 1-800-444-2826)

ATTACHMENT 11

(Copies can be obtained by contacting Wyoming Reporting Service, Inc. at 1-800-444-2826)

ATTACHMENT 12

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
DENVER, CO 80202-1129
Phone 800-227-8917
http://www.epa.gov/region08

OCT 25 2013

Ref: 8P-W-UIC

Mr. Kevin Frederick
Wyoming Department of
Environmental Quality (WDEQ)
Water Quality Division
Herschler Building
122 West 25th Street
Cheyenne, Wyoming 82002

Re: Linc Energy
UCG Demonstration Gasifier #6 Project
Wyodak Coal, Fort Union Formation
Aquifer Exemption
Campbell County, Wyoming

Dear Mr. Frederick:

We have reviewed the application as well as other supporting information provided by Linc Energy and the WDEQ and at this time have no comments regarding your aquifer exemption request.

This letter will serve as an interim response until the Environmental Protection Agency is notified of the results of the public participation process. At the close of this process, and after EPA has the opportunity to review any comments received and WDEQ's response to comments, we will provide a final response approving or disapproving the aquifer exemption request.

Please contact Wendy Cheung of my staff at 303-312-6242 with questions or concerns regarding this matter.

Sincerely,

for Derrith R. Watchman-Moore
Assistance Regional Administrator
Office of Partnerships and Regulatory Assistance

ATTACHMENT 13

October 21, 2013

Administrator of the Land Quality Division of the Department of Environmental Quality
Herschler Building
122 West 25th Street
Cheyenne,WY 82002

Thomas Coverdale
Chairman, Environmental Quality Council
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Linc Energy Operations, Inc.
317 West Birch St.
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Re: Sierra Club's Opposition to Linc Energy's request for an aquifer reclassification for experimental underground coal gasification project

Sierra Club writes to strongly oppose Linc Energy's ("Linc") proposed research and development license for underground coal gasification and proposed aquifer reclassification and exemption. This short-term experimental project is highly likely to contaminate a high quality aquifer. Because the impacted aquifer is a source of drinking water or could be, the reclassification and exemption would violate the Safe Drinking Water Act ("SDWA"), EPA's regulations implementing the SDWA, and corresponding state laws and regulations.

The Sierra Club, founded in 1892, is the nation's oldest and largest grassroots environmental organization. The Wyoming Chapter of the Sierra Club is a non-profit member-supported, public interest organization that promotes conservation of the Wyoming natural environment by influencing public policy decisions— legislative, administrative, legal, and electoral. The Wyoming Sierra Club has more than 800 members in the state. Sierra Club's 1.3

million members nationwide are dedicated to the protection and preservation of the natural and human environment, including protecting public health. The Sierra Club's most important current priority is to advance smart, clean energy solutions that address the critical problems of global warming and our nation's dependence on fossil fuels.

Linc proposes to carry out a high-risk experimental underground coal gasification project on a state section of land in Campbell County that overlies the Fort Union Formation. The proposal is to convert coal to a syngas underground through chemical reactions that oxidize the coal, ignite it and convert it into a syngas that is transported to the surface through a production well. Gasifying coal underground carries significant risk, including "excessive subsidence, groundwater influx, mixing of aquifers (or water bearing strata), and groundwater contamination."[1] Past attempts at underground gasification in the Powder River Basin contaminated groundwater and were considered failures. [2]

In order to receive an exemption under SDWA, an applicant must demonstrate that the aquifer is not currently a drinking water source and is not likely to be used as a drinking water source in the future. Under 40 C.F.R. § 146.4, aquifer exemptions are available if the aquifer:

> a) Does not currently serve as a source of drinking water, and
> b) It cannot now and will not in the future serve as a source of drinking water because:
>
> > (1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.
> > (2) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;
> > (3) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or
> > (4) It is located over a Class III well mining area subject to subsidence or catastrophic collapse.

EPA instructs that aquifers or portions of aquifers can only be exempted when they have "no real potential to be used as drinking water sources."[3]

Linc does not qualify for an aquifer exemption because the Fort Union Formation is used by private landowners for domestic and livestock watering purposes, and it also provides significant water resources to municipalities and water districts.[4] Linc's extremely risky

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[1] Gas Tech, *Viability of Underground Coal Gasification in the "Deep Coals" of the Powder River Basin, Wyoming*, June 2007, at 3.
[2] *Id.* at 8, 18-19; *see also* Linc Application at 14-6 to 14-7.
[3] 45 Fed. Reg. 33,290, 33,328 (May 19, 1980); *see also*, *Id.* at 33,330 (an exempted aquifer is an aquifer or portion of an aquifer that would otherwise qualify as a USDW, but has no actual potential for providing drinking water).
[4] *See* Wyoming State Engineer's Office, *Background: Time Limited Water Haul Permits from the Fort Union Formation in Campbell County*, April 9, 2008, available at http://tinyurl.com/longpcb ("The City of Gillette and all other water users in the vicinity of Gillette depend solely on ground

proposal to ignite coal underground carries a significant risk of contaminating the Fort Union Formation.

Moreover, the portion of the Fort Union Formation where Linc proposes its project has some of the best groundwater quality in the region and could, with reasonable foreseeability, be used as a future source of drinking or livestock water in the near future. Although coal is present in the aquifer, the water quality is high and the coal is not commercially producible. EPA's regulations provide that the aquifer can be exempted only if "it cannot now and will not in the future serve as a source of drinking water *because* . . . [it] contain[s] minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible."[5] In this case the minerals present in the aquifer do not prevent the aquifer from being a future source of drinking water. This is clear based on Linc's own water sampling data which shows that the aquifer has good water quality, and in fact has a lower TDS concentration than many other portions of the Fort Union Formation that are currently used for drinking water purposes. Since underground coal gasification is not commercially viable and the proposed project is a short-term demonstration project, Linc has not demonstrated that that the coal is "expected to be commercially producible."

High quality groundwater is a precious human resource in the state of Wyoming. The state cannot afford to sacrifice high quality drinking water in the Fort Union Formation for the benefit of an ill-conceived 6-month demonstration project. Sierra Club urges the Wyoming Department of Environmental Quality, the Wyoming Environmental Quality Council, and EPA to reject Linc's request for an aquifer exemption. Sierra Club requests notice of further developments on this project.

Sincerely,

Andrea Issod, Staff Attorney
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water for their water needs."); *See e.g.*, HKM Engineering, *Northeast Wyoming River Basins Water Plan*, Appendix E, *available at* http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html (showing that most municipalities and water districts in Campbell County use water from Fort Union wells).

[5] 40 C.F.R. § 146.4(b)(1) (emphasis added).

Wyoming Outdoor Council
wyomingoutdoorcouncil.org

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Administrator Nancy Nuttbrock
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Wyoming Department of Environmental Quality
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Cheyenne, WY 82002
Nancy.nuttbrock@wyo.gov

RE: Public notice – Linc Energy Operations, Inc. application for underground coal gasification research and development license

Dear Administrator Nuttbrock,

The Wyoming Outdoor Council is Wyoming's oldest environmental advocacy organization. We have been working to protect Wyoming's people, wildlife and lands since 1967. We write to express our concern with Linc Energy Operations, Inc.'s recent application for an underground coal gasification research and development license.

Specifically, we are concerned with the request for an aquifer exemption within the Fort Union Formation. We believe that granting such an exemption is a violation of the Safe Drinking Water Act (SDWA).

The application cites the following as reason for an aquifer exemption to be granted under the Underground Injection Control program:

> The aquifer exemption is being requested under the following criteria:
> a) It does not currently serve as a source of drinking water; and
> b) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

This interpretation of the SDWA exemption criteria is far too narrow and interprets the law counter to the true intention of the SDWA. The EPA's policy priority is to protect groundwater aquifers that are current sources of drinking water or aquifers that are capable of being future sources of drinking water. It is a twisted misinterpretation of the law to allow an exemption when 1.) The exemption area in question is within a heavily relied upon aquifer regionally and contamination cannot be guaranteed to remain only within the exemption area boundaries and 2.) The quality of the water within the proposed exemption area is not prohibitive to its future use as an underground source of drinking water.

The Fort Union Formation, within which the exemption is proposed, is a heavily used, regional aquifer. The Fort Union Formation is used by private water users as well as by the City of Gillette as a primary water source[1] in an already water-scarce region.[2] Linc Energy Operations cannot demonstrate that their activities will not result in contamination spreading beyond the specified area of the aquifer to other portions of the Fort Union Formation that are used as a drinking water supply or could be used as a drinking water supply. This uncertainty is acknowledged within the Linc Energy Operation's application itself, "[o]ne of the research and development objectives of the project is to refine techniques and procedures to establish hydraulic control of not only the Gasifier 6 cavity but also of the pressures within the surrounding groundwater system" (Linc Application at 13.14-13).

Furthermore, the water quality in the area of the aquifer proposed for exemption from SDWA is of good enough quality and is relatively shallow enough to be feasibly used as a source of drinking water in the future; something that may be of particular importance in the already water-scarce Powder River Basin. Linc's own water quality testing acknowledges that the water is of good enough quality that it wouldn't be economically infeasible to treat (Linc Application at 13.14-6). Additionally, given the current status of the Fort Union Formation as a principle source of water for the City of Gillette shows that clearly, water taken from the Fort Union Formation is of good enough quality for human consumption. To exempt an aquifer with such favorable conditions is in clear opposition to the EPA's policy priority stated above, "to protect groundwater aquifers that are capable of being future sources of drinking water."

Thank you for the opportunity to provide our input. We look forward to following the review of Linc Energy Operations's application throughout the process.

Sincerely,

Amber L. Wilson

Amber Wilson
Environmental Quality Coordinator
Wyoming Outdoor Council
262 Lincoln St.
Lander, WY 82520
307-332-7031 ext. 20

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[1] HKM Engineering. *Northeast Wyoming River Basins Water Plan*, Appendix E. Web. http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html

[2] Due to concerns about water shortage, the state of Wyoming and City of Gillette chose to invest in a 217 million dollar pipeline to pipe water 42 miles to Gillette from a well in the Madison formation.

ATTACHMENT 14

FILED

BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
STATE OF WYOMING

OCT 2 1 2013

Jim Ruby, Executive Secretary
Environmental Quality Council

Objections to Linc Energy's Proposed Research & Development License for Underground Coal Gasification and the Proposed Reclassification & Exemption of a Portion of the Fort Union Formation	)))))	Docket No. 13-4804

OBJECTIONS AND REQUEST FOR HEARING

Pursuant to W.S. § 35-11-406(k) and the Wyoming Department of Environmental Quality ("WDEQ") Rules of Practice and Procedure, Powder River Basin Resource Council ("PRBRC" or "Resource Council") hereby files these objections and request for hearing related to Linc Energy's ("Linc") proposed research and development license for underground coal gasification and proposed aquifer reclassification and exemption.

Specifically, and as discussed in detail below, the reclassification and exemption of the proposed aquifer would violate the Safe Drinking Water Act ("SDWA"), EPA's regulations implementing the SDWA, and corresponding state laws and regulations.

In support of this protest, the Resource Council advises WDEQ and the EQC as follows:

Name and Address of Protestant and Protestant's Counsel

The name of Protestant is Powder River Basin Resource Council. The Resource Council's address is: 934 N. Main St., Sheridan, WY 82801. Legal counsel for Protestant is Shannon Anderson, Staff Attorney, Powder River Basin Resource Council, 934 N. Main St., Sheridan, WY 82801.

The Action, Decision, Order or Permit upon Which a Hearing Is Requested and Objection is Made

This request involves the proposed research and development license for Linc to carryout underground coal gasification activities in Section 36, Township 44 North, Range 74 West in

Campbell County, Wyoming. Specifically, the objections involve the proposed reclassification and exemption of certain aquifers as part of the license application.

Basis for Objections and Request for Hearing

The coal seams of the Fort Union Formation are regional aquifers, providing critical water resources to landowners and local governments in our arid state. The geology and relatively good water quality make the Fort Union Formation a preferred source of groundwater for domestic and livestock purposes in the Powder River Basin. As explained by Dr. John Bredehoeft, a retired USGS scientist:

> The coal beds are not very porous; the porosity is thought to be 0.4 percent. However, the coal beds are reasonably permeable because of the fractures (cleats) within the coal. The coals often contain better quality water than the surrounding sand aquifers; in places the coal beds are the most permeable aquifers. For these reasons the coal beds are often the preferred aquifers for groundwater development.

John Bredehoeft, *Comments on Wyoming and Montana Final Environmental Impact Statement on the Development of Coal-Bed Methane*, available at http://www.powderriverbasin.org/assets/Uploads/files/final/expertfeisjohnbredehoeft.pdf.

As explained below, Linc's proposed underground coal gasification project will irreversibly damage a portion of the Fort Union Formation and will contaminate this source of good quality water. The portion of the Fort Union Formation where Linc proposes its project has some of the best groundwater quality in the region. Equally important, approval of Linc's request to reclassify and exempt this portion of the Fort Union Formation will set a dangerous precedent for future contamination from underground coal gasification and other industrial projects in the Powder River Basin, threatening the viability of this regional aquifer as a continued source of water.

I. Overview of Linc's Proposed Project and Aquifer Exemption Request

Linc proposes to carry out an experimental underground coal gasification project on a state section of land in Campbell County. Underground coal gasification (or "UCG") converts coal to a syngas through chemical reactions underground. The process oxidizes the coal, igniting it and converting it into a syngas that is transported to the surface through a production well. Linc plans to flare off all gas produced from the project.

The underground coal gasification process is not without risk and past projects, both commercial and experimental, have resulted in the long-term contamination of aquifers. As explained in a report to the Wyoming Business Council, "The major concerns with the UCG process are excessive subsidence, groundwater influx, mixing of aquifers (or water bearing strata), and groundwater contamination." Gas Tech, *Viability of Underground Coal Gasification in the "Deep Coals" of the Powder River Basin, Wyoming*, June 2007, at 3, excerpts attached. Of particular note, the Hoe Creek I, II, and III projects carried out by the Department of Energy in the Powder River Basin, were considered failures and led to the contamination of groundwater. *Id.* at 8, 18-19; *see also* Linc Application at 14-6 to 14-7. Linc's project is likewise experimental and not without risk. Linc admits that its process is not fully refined and that through the pilot project, Linc plans to "refine techniques and procedures to establish hydraulic control" of the gasifier with the goals of learning how to maintain groundwater flow and pressures. *Id.* at 14-29.

It is highly likely that Linc's project will irreversibly damage the aquifer used for underground coal gasification. Linc's permit application states that ungasified components such as "ash, char, fine grained sediment, and other mineralogy associated with coal deposits" will be present in the cavity after the gasifier is shut down. The presence of char indicates incomplete gasification or coal pyrolysis, which also implies the presence of condensable hydrocarbons (i.e, coal tars). A recent Independent Scientific Panel report commissioned by the Queensland government found that "[t]he UCG process involves pyrolysis, combustion and gasification that will inherently produce contaminants such as benzene, toluene, ethylbenzene, xylenes (commonly referred to together as BTEX), various phenols, polycyclic aromatic hydrocarbons (PAHs) and other toxic compounds." Queensland Independent Scientific Panel for Underground Coal Gasification, *Report on Underground Coal Gasification Pilot Trials*, June 2013, available at http://mines.industry.qld.gov.au/assets/legislation-pdf/isp-final-report-cs-review.pdf, attached; *see also id.* at 34 ("During cooling there is an inherently high probability of formation of potentially contaminating chemicals."). The lighter components are highly water soluble, with the heavier, higher-boiling-point components having lower solubility and higher viscosities. Multiple water flushes may not be enough to remove these heavier hydrocarbons and eliminate subsequent exposure of the cavity to groundwater contamination.

In Australia, Linc's project is likewise still experimental in nature. The ISP report states

> Both companies have demonstrated capability to commission and operate a gasifier. Neither company has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. The ISP remains open to the possibility that the concept is feasible. However sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. Important work has been undertaken but more is yet to be done.

Id. at Executive Summary; *see also id.* at 23 ("Linc Energy manages a site that is clearly an experimental facility . . .").

Here, Linc's experimental project is particularly troubling because the company is proposing to carry out its underground coal gasification project in a major regional aquifer frequently used to supply water for homes, ranches, and municipalities. As part of its mining permit, Linc must receive an aquifer exemption under the Safe Drinking Water Act's ("SDWA") Underground Injection Control ("UIC") Program. This aquifer exemption would permanently exempt this portion of the Fort Union Formation from protection under the SDWA. According to the public notice published for this project:

> The groundwater to be affected in the production zone will be reclassified by the Water Quality Division of the Department of Environmental Quality, as Class V (Mineral Commercial) upon issuance of this license. This classification includes specified production zones for wellfield(s) included in the application. This classification process serves as the State's process to identify aquifers to be exempted under the federal underground injection control program. The aquifer exemption is being requested under the following criteria:
> a) It does not currently serve as a source of drinking water; and
> b) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

As explained below, Linc's request for aquifer reclassification and exemption should be denied because the proposed aquifer is an underground source of drinking water and cannot legally be exempted from protection under the SDWA. Additionally, Linc's proposal raises significant policy concerns about the possibility of future exemptions in the Fort Union Formation that must be resolved.

II. Linc's Proposed Aquifer Exemption Violates the SDWA

Linc's proposed aquifer exemption does not meet the requirements of the SDWA and its implementing regulations because (1) the Fort Union Formation is a regional source of drinking water and Linc cannot demonstrate that contamination will not spread beyond the exemption area; and (2) the aquifer has good quality water and is therefore a future source of drinking water that should remain protected under the SDWA.

A. The Purpose and Basic Requirements of the SDWA

The primary purpose of the SDWA and its implementing regulations is to protect underground sources of drinking water. 42 U.S.C. § 300h(b); H.R. Rep. No. 93-1185, 120 Cong. Rec. 6454, 6480 (1974); *Western Nebraska Resources Council v. EPA*, 793 F.2d 194, 195-196

(8th Cir. 1986). The Act's requirements for protecting underground sources of drinking water are found in 42 USC § 300h. Specifically, the Act provides that drinking water programs have requirements that, at a minimum, assure that no underground sources of drinking water will be endangered by any underground injection. *Id.* at 300h(b)(1), 3(C).

In passing the SDWA, Congress recognized the balance between aquifer protection and energy production but ultimately came down in favor of groundwater protection. *See, Phillips Petroleum Co. v. U.S. Environmental Protection Agency*, 803 F.2d at 560 (concluding that if a requirement on injecting activities is necessary to assure that underground sources of drinking water are not endangered, whether that requirement impedes mineral recovery is irrelevant because the "clear and overriding concern" of Congress in passing the Act was to assure the safety of "present and potential sources of drinking water").

B. The Requirements for Aquifer Exemptions Under the SDWA

An aquifer exemption removes that aquifer, or a portion of it, from protection as an underground source of drinking water under the SDWA. In order to receive an exemption, an applicant must demonstrate that the aquifer is not currently a drinking water source and is not likely to be used as a drinking water source in the future. Under the regulations implementing the SDWA, aquifer exemptions are available if the aquifer:

> a) Does not currently serve as a source of drinking water, and
> b) It cannot now and will not in the future serve as a source of drinking water *because*:
> (1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.
> (2) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;
> (3) it is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or
> (4) it is located over a Class III well mining area subject to subsidence or catastrophic collapse.

40 C.F.R. § 146.4 (emphasis added). Stated another way by David Murry, a Senior Geologist and Project Manager with the Texas Commission on Environmental Quality:

> Until the quality of the ground water is restored and the exempt status is removed, water will not be used for drinking because of its mineral or geothermal character, its depth or location, or its pre-existing contamination renders it impractical for treatment to make it fit for drinking.

David Murry, *Class III In Situ Uranium Injection Wells and Aquifer Exemptions in Texas: Multiple Levels of Permitting Protection for USDW Protection*, available at http://www.gwpc.org/sites/default/files/event-sessions/Murry_David.pdf.

In other words, EPA's regulations make it clear that the agency intended that aquifers or portions of aquifers only be exempted when they have "no real potential to be used as drinking water sources." 45 Fed. Reg. 33,290, 33,328 (May 19, 1980); *see also*, *Id.* at 33,330 (an exempted aquifer is an aquifer or portion of an aquifer that would otherwise qualify as a USDW, but has no actual potential for providing drinking water).

Aquifer exemptions must be approved by EPA because they are considered a formal revision to the state's program implementing the SDWA. *Western Nebraska Resources Council*, 793 F.2d at 197 (citing 40 C.F.R. §§ 144.7(b)(3), 145.32). The congressional directive to EPA is clear: the policy priority is to protect groundwater aquifers that are current sources of drinking water or aquifers that are capable of being future sources of drinking water.

C. Linc's Application Does Not Meet the Requirements for Aquifer Exemption

As discussed above, Linc's proposed aquifer exemption is problematic because it is proposed in a widely used regional source of drinking water – the Fort Union Formation. Because of the experimental nature of its proposed project, Linc is not able to conclusively demonstrate that contamination will not spread beyond the aquifer exemption area into portions of the Fort Union Formation that are currently used for drinking water purposes.

Second, the portion of the aquifer that Linc proposes to use for its project contains good quality water that could, with reasonable foreseeability, be used as a future source of drinking or livestock water in the near future.

Finally, even if just considering Linc's limited view of the requirements of aquifer exemptions, the company has not demonstrated it meets the requirements because it has not shown that this portion of the Fort Union Formation is capable of producing minerals in sufficient quantities and qualities to be commercial.

1. Linc's Project Will Not Prevent Contamination of Current Sources of Drinking Water Supply

In the arid Powder River Basin, ranches, homes, and local governments obtain water from the ground. There is no local surface water supply available in sufficient quantities and qualities for drinking and livestock water. *See* Wyoming State Engineer's Office, *Background: Time Limited Water Haul Permits from the Fort Union Formation in Campbell County*, April 9, 2008, available at http://tinyurl.com/longpcb ("The City of Gillette and all other water users in the vicinity of Gillette depend solely on ground water for their water needs."). As identified in numerous geological and hydrological reports, in the Powder River Basin "[g]roundwater for domestic consumption is derived predominantly from the Wasatch and Fort Union aquifers." GasTech Report at 46. Many of the Resource Council's landowner members across the Basin rely on the Fort Union Formation for drinking and livestock water.

In addition to wide use by private landowners for domestic and livestock watering purposes, the Fort Union Formation also provides significant water resources to municipalities and water districts. *See e.g.*, HKM Engineering, *Northeast Wyoming River Basins Water Plan*,

Appendix E, *available at* http://waterplan.state.wy.us/plan/newy/techmemos/muniuse.html (showing that most municipalities and water districts in Campbell County use water from Fort Union wells); *see also* Wyoming State Engineer's Office, *Background: Time Limited Water Haul Permits from the Fort Union Formation in Campbell County*, April 9, 2008 (noting that the Fort Union Formation is "a drinking water resource for both the City of Gillette and numerous subdivisions in the Gillette area."). Some of these municipal wells are in relative close proximity to Linc's project.

The Fort Union Formation is also a water source with dwindling supply, making preservation of this source even more important. Because of population and industrial growth and ongoing drought, the Wyoming State Engineer's Office determined that "[u]se of a quality, declining ground water resource for use in construction, oil and gas activities, etc. is not in the public's water interest." *Id.* As a result, the agency limits the amounts and types of water permits that can be received from the formation. *Id.*

As discussed above, there are serious questions that remain regarding Linc's ability to contain contamination in the exempted area and therefore prevent contamination from spreading to other portions of the Fort Union Formation. As discussed by the Independent Scientific Panel commissioned by Queensland:

> . . . as the UCG process continues, the uncertainties in the site geology ensures that there will be variations and deviations in temperature, pressure, groundwater flow and gas and vapour [sic] movement into and out of the UCG cavity. As a result there is a risk of contaminants leaving the cavity and entering the surrounding strata and aquifers. This has the potential to lead to underground water contamination or syngas egress towards the surface through the overburden via faults / fissures or high permeability regions.

Report on Underground Coal Gasification Pilot Trials at 21. Linc acknowledges this uncertainty inherent in its experimental project by saying that "[o]ne of the research and development objectives of the project is to refine techniques and procedures to establish hydraulic control of not only the Gasifier 6 cavity but also of the pressures within the surrounding groundwater system." Linc Application at 13.14-13.

Additionally, the presence of mineral exploration and production wells in the vicinity of Linc's project area represents risks for contamination to spread beyond the exempted aquifer. Old coalbed methane wells are present in the permit area. These wells are currently shut-in but not yet abandoned. The interaction between these wells and Linc's project must be fully explored. This is especially important given the findings of the Independent Scientific Panel in Queensland. The Panel recognized that "The government needs to determine whether approved CSG [coal seam gas] activities will jeopardise [sic] the ability of the UCG pilots to demonstrate effective decommissioning." *Report on Underground Coal Gasification Pilot Trials* at 43. Since coalbed methane development reduces groundwater pressure, the Panel concluded that "any proposed UCG must include a risk strategy to control the groundwater pressure for safe operation." *Id.* There are also deep oil wells in the area that present unknown risks. According to the report prepared for the Wyoming Business Council, "Deeper oil and gas well bores will need to be avoided by a safe distance" because of potential conflicts. Moreover, operating uranium wells and old uranium exploration wells, many of which were not properly abandoned, are also present in the local area. All of these wells present potential pathways for contamination from Linc's project to spread beyond the exempted aquifer.

EPA's guidance documents make it clear that in evaluating whether the aquifer "does not currently serve as a source of drinking water . . . [i]f the exemption pertains to only a portion of an aquifer, a demonstration must be made that the waste will remain in the exempted portion." EPA, *Guidance for Review and Approval of State Underground Injection Control (UIC) Programs and Revisions to Approved State Programs #34*, Attachment 3 at 3, available at http://www.epa.gov/ogwdw/uic/pdfs/guidance/guide-memo_guidance-34_review_state_prog.pdf. Because of the experimental nature of its project and the inherent risks and unknowns, Linc has not definitively shown that contamination will remain in the exempted portion of the aquifer.

Furthermore, even if the contamination is contained within the exempted portion of the aquifer, the aquifer should not be exempted because of the presence of livestock watering wells in the area. As identified by Linc, there are wells permitted for livestock watering purposes within the quarter mile buffer required to be evaluated by EPA. *Id.* at 2 ("the applicant should survey the proposed exempted area to identify any water supply wells which tap the proposed exempted aquifer. The area to be surveyed should cover the exempted zone and a buffer zone outside the exempted area. The buffer zone should extend a minimum of a 1/4 mile from the boundary of the exempted area.") While these wells may currently be shut-in, Linc Application at 13.14-5, they are nevertheless wells with valid permits that can be used for livestock water supply.

Both the presence of local water wells and the uncertainty of whether the contamination will remain in the exempted portion of the aquifer necessitate a denial of the aquifer exemption.

2. **Even if Not Currently Used for Drinking Water Purposes, the Aquifer Can in the Future Be Used as a Drinking Water Source**

The proposed aquifer exemption should also be denied because the aquifer can be used in the future as a source of drinking water.

Linc's own water testing data shows that this portion of the Fort Union Formation has good quality water that could be used as a water supply source. While some minor constituents (iron, manganese, and TDS)[1] slightly exceed drinking water standards, overall "WDEQ can classify the water as Class I based on the technical practicability and economic reasonableness of treating ambient water quality to meet use suitability standards." Linc Application at 13.14-6.

Linc claims that because there are commercial deposits of minerals (in this case coal) in the groundwater, it is rendered unsuitable as a future source of drinking water. However, coal does not impact water quality. While other minerals or hydrocarbons, such as oil or uranium, may render the aquifer so contaminated that it cannot be used, that is not the case with coal. Coal is more akin to sandstone or other types of rock that actually are the aquifer (because it is a permeable layer of water-bearing rock).

As discussed above, EPA's regulations provide that the aquifer can be exempted only if "it cannot now and will not in the future serve as a source of drinking water *because* . . . [it] contain[s] minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible." 40 C.F.R. § 146.4(b)(1) (emphasis added). In this case the minerals present in the aquifer do not prevent the aquifer from being a future source of drinking water. That is clear based on Linc's own water sampling data which shows that the aquifer has good water quality, and in fact has a lower TDS concentration than many other portions of the Fort Union Formation that are currently used for drinking water purposes. Additionally, the water is relatively shallow (1,100 feet deep) and is both economically and technologically practicable to produce for drinking water purposes.

[1] All three of these constituents have only secondary standards from EPA. Secondary standards apply to substances in water that can cause offensive taste, odor, color, corrosion, foaming, or staining but have no direct effect on health. As Linc acknowledges in its application, all three constituents are easily treated to come into compliance with the secondary drinking water standards.

As discussed above, the statutory intent of the SDWA is to protect sources of drinking water (both sources currently used and those that may be needed as future sources). The context and the purpose of the law inform the interpretation of EPA's regulations. In this case, words have meaning. EPA chose to use the conjunction "because" to provide that only aquifers that "cannot now and will not in the future serve as a source of drinking water" will qualify for exemption. Here, there is not the cause and effect needed to show that the presence of minerals renders the aquifer unsuitable for drinking water purposes. Instead, if anything, the presence of coal has helped to maintain the aquifer and hold drinking water quality water in reserve for future generations. While one could read the regulation the opposite way to conclude that an aquifer is not a future source of drinking water merely *because* minerals are present, that reading would frustrate the purpose of the SDWA and the implementing regulations. The purpose and intent of the SDWA is to protect aquifers that have the potential to be used for drinking water sources. It is clear that this portion of the Fort Union Formation (and the Fort Union Formation as a whole) can be used in the future for drinking water purposes. Therefore, the aquifer does not qualify for exemption under EPA's regulations.[2]

3. Linc Has Not Demonstrated Compliance with 40 C.F.R. § 146.4(b)(1) Criteria

Irrespective of the water quality of the aquifer, Linc has even failed to demonstrate compliance with the aquifer exemption criteria the company claims justify the exemption. Linc claims that the aquifer should be exempted because "minerals or hydrocarbons...are expected to be commercially producible." However, through this project, Linc does not intend to

[2] This finding would also be consistent with EPA and Wyoming's decision to regulate microbial coal projects (also known as "methane farming") pursuant to the Underground Injection Control Program's Class V permit scheme as opposed to the Class II permit scheme that would have required an aquifer exemption. At that time, EPA, WDEQ, and the Oil and Gas Commission concluded that aquifer exemptions could not be obtained for the Fort Union Formation because of the presence of drinking water wells in the formation.

commercially produce any minerals or hydrocarbons. While the company *estimates* that "approximately one million standard cubic feet per day (MMscfd) of synthesis gas or 'syngas'" will be produced during the demonstration project, Linc Application at 13.14-3, all syngas will be flared and not commercially sold. As further evidence of the trial, non-commercial, nature of this project, Linc will not pay royalties on its state lease during the research and development project. *See* Wyoming Office of State Lands and Investments, *Consideration of Royalty Valuation of Coal Extracted During Underground Coal Gasification (UCG) Production and Other Lease Terms for Linc Energy*, Dec. 6, 2012, at 2, available at http://slf-web.state.wy.us/osli/boardmatters/2012/1212/f-7.pdf. (The Board "authorize[d] Royalty Free Disposition of the coal extracted during Linc Energy's Wyoming Department of Environmental Quality (WDEQ) Research and Development (R&D) license demonstration project. Linc Energy estimates that approximately 1000 tons of coal will be extracted during the demonstration; no product will be sold.").

Furthermore, Linc has not demonstrated that an amount of one MMscfd is production in commercial quantities. In fact, one of the main purposes of the research and development scale project is to evaluate the economic viability of the process in the Powder River Basin.

The economic viability of underground coal gasification – by and of itself – has not been proven with any test projects, including Linc's own projects in Australia. While the produced syngas may become commercially economic when it is used in a downstream application, such as converting it to liquids or using it for power generation, merely producing the syngas does not appear to be economic. After over a decade of work in Australia, Linc has still not demonstrated that the technology is economically viable at a commercial scale.[3]

D. An Aquifer Exemption in the Fort Union Formation Would Set a Dangerous Precedent

Reclassification and exemption of this portion of the Fort Union Formation would set a dangerous precedent. In response to an inquiry from the Resource Council, Don Fischer, the DEQ North District Geologic Supervisor, stated "To the best of my knowledge, there are no aquifer exemptions for UIC Class I or III facilities in the Ft. Union Formation in Johnson or Campbell counties." Electronic correspondence from Don Fischer to Shannon Anderson, Oct. 11, 2013, attached. Therefore, Linc's aquifer exemption would be the first of its kind in the Fort Union Formation.

If Linc is able to obtain an aquifer exemption in this case merely because of the presence of coal, the decision opens the door for future exemptions in other portions of the Fort Union Formation, which is a coal-bearing formation across the Powder River Basin. As identified by the report prepared for the Wyoming Business Council "307 billion tons of coal, or 74% of the coals deeper than 500 feet" in the Powder River Basin are viable sources of coal for UCG projects. GasTech report at 3. If Linc is successful, the entire portion of the Fort Union Formation bearing those coals could be exempt from SDWA protection.

Additionally, the proposed reclassification of the aquifer is even more problematic, as the reclassification is not dependent on a company meeting the requirements for an aquifer exemption. Reclassifying an aquifer that has drinking water quality water (Class I water) to "Mineral Commercial" quality water (Class V water) merely because the aquifer is "closely

[3] Even the gas-to-liquids plant at the Chinchilla site is still operating at a pilot scale. *See* http://www.lincenergy.com/underground_coal_gasification.php.

associated with commercial deposits of minerals," Linc Application at 13.14-6, sets a particularly troubling precedent. Most aquifer formations in the Powder River Basin, and in fact across the state, have some "commercial deposits of minerals." The reclassification would set a bad precedent that other industries could use to their advantage to limit the protection and restoration of aquifers. For instance, under Linc's rationale, WDEQ could reclassify all of the shallow coal seams of the Fort Union Formation that are surface mined or the deeper coal seams that produce coalbed methane. That would amount to almost the entire Fort Union Formation. The Fort Union Formation would be reclassified from an aquifer that is the major source of drinking water in the Powder River Basin to an aquifer that is merely used for mineral production.

Request for Hearing

The Council hereby requests that these objections be heard before the Environmental Quality Council. To the extent that these matters are beyond WDEQ or Environmental Quality Council authority (such as the granting of the aquifer exemption), the Council requests that WDEQ and the Environmental Quality Council forward these objections to the U.S. Environmental Protection Agency's Region 8 Office for their consideration.

Dated this 18th day of October, 2013.

Shannon Anderson
Powder River Basin Resource Council
934 N. Main St.
Sheridan, WY 82801
(307) 672-5809
sanderson@powderriverbasin.org

CERTIFICATE OF SERVICE

The undersigned hereby certifies that on this 18th day of October, 2013, the foregoing OBJECTIONS AND REQUEST FOR HEARING was served on the following parties via U.S. Mail:

Thomas Coverdale
Chairman, Environmental Quality Council
122 W. 25th St.
Herschler Bldg., Rm. 1714
Cheyenne, WY 82002

Todd Parfitt
Director, Department of Environmental Quality
122 West 25th St.
Herschler Bldg., 4th Fl. West
Cheyenne, WY 82002

Nancy Nuttbrock
Administrator, Land Quality Division
Department of Environmental Quality
122 West 25th St.
Herschler Bldg., 3rd Fl. West
Cheyenne, WY 82002

Linc Energy Operations, Inc.
317 West Birch St.
Glenrock, WY 82637

Shannon Anderson

ATTACHMENT 15

RECEIVED
SEP 25 2013
LINC ENERGY OPERATIONS, INC
CASPER, WYOMING

PUBLISHER'S AFFIDAVIT

RECEIVED
SEP 30 2013

STATE OF WYOMING } ss.
County of Campbell

I, Ann Kennedy Turner do solemnly swear that I am the publisher of The News-Record, a daily newspaper of general circulation, printed and published each Sunday through Friday at Gillette, County of Campbell, State of Wyoming, that the notice hereto attached, and which is made a part of this affidavit, and a part of the proof of Linc Energy Operations, Inc. - Public Notice was printed and published in said newspaper for 4 (four) consecutive weeks, the first publication thereof having been printed and made in said newspaper on the 6th day of September, 2013, and last on the 23rd day of September, 2013; that said notice was printed and published in the regular and entire issue of said newspaper once each week during the said period and time of publication as aforesaid, and that the notice was printed and published in the newspaper proper and not in the supplement.

Ann Kennedy Turner

Publ... before me this 23rd day of September, 2013.

Crystal L. Meadows
Notary Public

Crystal L. Meadows - Notary Public
County of Campbell
State of Wyoming
My Commission Expires 7/29/2015

My Commission expires , 2015

55/128

Public Notice

Linc Energy Operations Inc. located at 317 West Birch Street, Glenrock, Wyoming 82637 has applied for an underground coal gasification research and development license from the Land Quality Division of the Department of Environmental Quality of the State of Wyoming. The research and development license area for the underground coal gasification project will be located in: Section 36, Township 44 North, Range 74 West Campbell County, Wyoming (USGS 7.5' Baker Spring and Greasewood Topographic Quadrangle Maps). The area is approximately 13 miles west of the city of Wright, Wyoming on State Highway 387 and seven (7) miles north from the intersection of State Highway 387 and the Clarkelen Road (County Road). The proposed research and development license area is accessed directly from Clarkelen Road. The proposed operation is scheduled to commence after the license approval. The project will cease upon the conclusion of the research and development/demonstration and completion of reclamation activities. The land, after mining, will be returned to wildlife, grazing and industrial uses.

The groundwater to be affected in the production zone will be reclassified by the Water Quality Division of the Department of Environmental Quality, as Class V (Mineral Commercial) upon issuance of this license. This classification includes specified production zones for wellfield(s) included in the application. This classification process serves as the State's process to identify aquifers to be exempted under the federal underground injection control program. The aquifer exemption is being requested under the following criteria:

a) It does not currently serve as a source of drinking water; and

b) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

The groundwater, after mining, will be restored to a quality of use equal to or better than and consistent with pre-mining uses.

Information regarding the proposed operation and reclamation/restoration procedures may be reviewed in the office of the Land Quality Division of the Department of Environmental Quality in Cheyenne, District 3 Sheridan Office, or the Campbell County Clerk's Office at Gillette, Wyoming. Written objections to the proposed operation and proposed reclassification of groundwater/aquifer exemption must be received by the Administrator of the Land Quality Division of the Department of Environmental Quality, Herschler Building, 122 West 25th Street, Cheyenne, WY 82002, before the close of business, October 23rd, 2013. If an objection specifically requests a public hearing before the Environmental Quality Council, a public hearing shall be held within twenty (20) days after the final date for filing objections unless a different period is stipulated

different periods stipulated to by the parties. The Environmental Quality Council or Director shall publish notice of the time, date and location of the hearing or conference in a newspaper of general circulation in the locality of the proposed operation once a week for two (2) consecutive weeks immediately prior to the hearing or conference. The hearing shall be conducted as a contested case in accordance with the Wyoming Administrative Procedure Act (W.S. §16-3-101 through 16-3-115) and the right of judicial review shall be afforded as provided in that Act. All parties as identified in W.S. §35-11-406(j) will be mailed a copy of this notice.

September 6, 13, 20, 23, 2013