The National Petroleum Council is a federal advisory committee to the Secretary of Energy.

The sole purpose of the National Petroleum Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to petroleum or the petroleum industry.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>1</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>3</td>
</tr>
<tr>
<td><strong>CHAPTER ONE: INTRODUCTION</strong></td>
<td>5</td>
</tr>
<tr>
<td>Report Objectives</td>
<td>5</td>
</tr>
<tr>
<td>Origin of Coal-Bed Gas</td>
<td>5</td>
</tr>
<tr>
<td>Chemical Composition of Coal-Bed Gas</td>
<td>5</td>
</tr>
<tr>
<td>Liberation of Coal-Bed Gas</td>
<td>7</td>
</tr>
<tr>
<td>Analysis Overview</td>
<td>8</td>
</tr>
<tr>
<td>Uncertainties</td>
<td>9</td>
</tr>
<tr>
<td><strong>CHAPTER TWO: RESOURCES</strong></td>
<td>11</td>
</tr>
<tr>
<td>Coal Resource</td>
<td>11</td>
</tr>
<tr>
<td>Gas Resource</td>
<td>13</td>
</tr>
<tr>
<td><strong>CHAPTER THREE: TECHNOLOGY</strong></td>
<td>15</td>
</tr>
<tr>
<td>Vertical Wells</td>
<td>15</td>
</tr>
<tr>
<td>Horizontal Holes From Mine Workings</td>
<td>17</td>
</tr>
<tr>
<td>Horizontal Holes From Shaft Bottoms</td>
<td>17</td>
</tr>
<tr>
<td>Slant Holes</td>
<td>17</td>
</tr>
<tr>
<td><strong>CHAPTER FOUR: PRODUCTION HISTORY AND PROJECTIONS</strong></td>
<td>19</td>
</tr>
<tr>
<td>Background</td>
<td>19</td>
</tr>
<tr>
<td>Production Data From Vertical Wells</td>
<td>19</td>
</tr>
<tr>
<td>Production Data From Long Horizontal Holes</td>
<td>22</td>
</tr>
<tr>
<td>Production Per Foot of Seam Thickness</td>
<td>22</td>
</tr>
<tr>
<td>Computation of Coal Seam Thickness</td>
<td>27</td>
</tr>
<tr>
<td><strong>CHAPTER FIVE: ECONOMIC ANALYSIS</strong></td>
<td>29</td>
</tr>
<tr>
<td>Background</td>
<td>29</td>
</tr>
<tr>
<td>Estimation of Costs</td>
<td>29</td>
</tr>
<tr>
<td>Discounted Cash Flow (DCF) Analysis</td>
<td>30</td>
</tr>
<tr>
<td>Gas Price Projections</td>
<td>31</td>
</tr>
<tr>
<td><strong>CHAPTER SIX: PROJECTION OF RESERVES AND PRODUCTION</strong></td>
<td>35</td>
</tr>
<tr>
<td>Projection of Economic Reserves</td>
<td>35</td>
</tr>
<tr>
<td>Background for Analysis of Potential Production</td>
<td>35</td>
</tr>
<tr>
<td>Projection of Rate of Development by Vertical Wells</td>
<td>36</td>
</tr>
<tr>
<td>Projection of Rate of Development by Shafts and Horizontal Drilling</td>
<td>38</td>
</tr>
</tbody>
</table>
PREFACE

By letter dated June 20, 1978, the National Petroleum Council, an industry advisory committee to the Secretary of Energy, was requested to prepare an analysis of potential natural gas recovery from coal seams, Devonian Shale, geopressured brines, and tight gas reservoirs. In requesting the study, the Secretary stated that:

...Your analysis should assess the resource base and the state-of-the-art of recovery technology. Additionally, your appraisal should include the outlook for cost and recovery of unconventional gas and should consider how government policy can improve the outlook. (See Appendix A for complete text of the Secretary's letter and a further description of the National Petroleum Council.)

To aid it in responding to this request, the National Petroleum Council established a Committee on Unconventional Gas Sources under the chairmanship of John F. Bookout, President and Chief Executive Officer, Shell Oil Company. R. Doble Langenkamp, Deputy Assistant Secretary for Resource Development & Operations, Resource Applications, U.S. Department of Energy, served as Government Cochairman of the Committee. A Coordinating Subcommittee and four task groups, by source, were formed to assist the Committee. The Coal Seams Task Group was chaired by William N. Poundstone, Consolidation Coal Company, and cochaired by Troyt York of the Department of Energy. (Rosters of the study groups responsible for this volume are included in Appendix B.)

The National Petroleum Council's report on Unconventional Gas Sources is being issued in five volumes:

- Volume I - Executive Summary
- Volume II - Coal Seams
- Volume III - Devonian Shale
- Volume IV - Geopressured Brines
- Volume V - Tight Gas Reservoirs.

The Coal Seams, Devonian Shale, and Geopressured Brines volumes are being issued in June 1980 with the Executive Summary and Tight Gas Reservoirs volumes being issued in late 1980.

For each source, reserve additions and producing rates are calculated at five gas prices, three rates of return, and at least two levels of technology. Constant January 1, 1979, dollars were used in all analyses. The report presents estimates of what could happen under certain technical and economic circumstances and is not intended to represent a forecast of what will occur.
SUMMARY

The main objective of this report is to go beyond the projection of in-place coal-bed gas resources in the United States and attempt to estimate what fraction of this resource is economically recoverable. Projections are based on the economic analysis of state-of-the-art technology and extrapolation of gas recovery rates from historical data. Since the total quantity of in-place gas is quite substantial, and since most studies done in the past have addressed only this total resource base, an impression has been created that the size of the economically recoverable reserves is also very large. This report attempts to provide a qualified and educated guess as to the quantities of coal-bed gas that could be recovered under various price scenarios.

Data on the gas content of coals in place are very sparse, being limited to about 50 coal seams out of the many hundreds that are known to exist. Besides, the bulk of data available pertain to mineable bituminous coal seams, where concern for mine safety provided the primary impetus for collection of gas-related information. Over the past few years some data have been obtained specifically for proposed gas recovery projects, but the total amount of information is still quite inadequate for proper analysis.

Theoretical models to project the flow of gas through porous media, such as coal, are in use. However, the physical prospects of coal that are relevant in such analyses are not available for a vast majority of coal seams in the country. Actual experience with gas recovery projects is also quite limited, and the results to date have shown substantial variability. In view of this paucity of information, as well as experience, the study participants could do no better than to extrapolate from the little that is known by making certain gross assumptions on costs and production. The results should, therefore, be viewed as nothing more than an order-of-magnitude projection based on current information. A concerted effort will have to be made to collect much more information and to acquire much more experience before reliable estimates could properly be projected.

Pre-drainage of significant amounts of coal-bed gas is likely to have a positive effect on the safety of eventual mining operations. However, there is risk involved in recovering gas from coal beds by hydraulic fracturing of coal seams through vertical wells. Serious concern was expressed that the fracturing technique had the potential of rendering some coal seams unmineable or, at the very least, increasing the likelihood of roof damage in mines and thereby jeopardizing the safety of mine workers and affecting the cost of mining. Since the energy content of the gas amounts to only 1 to 2 percent of the energy content of coal, some study participants felt that even a little risk in this regard was unwarranted. If the alternative approaches to gas recovery through horizontal or slant holes manifest comparable levels of gas recovery economics,
the question of hydraulic fracturing may become moot. In the meantime, the risk of damage to coal seams being mined or likely to be mined needs to be assessed carefully for each situation.

There are other constraints that will need to be addressed and which are elaborated on later in this report. The greatest constraints are the issue of legal ownership of gas and the problem of the treatment and disposal of water in accordance with applicable environmental requirements.

Keeping the above qualifications in mind, the study has projected quantities of economic reserves of coal-bed gas for the case where the raw gas, as produced, could be used on site at relatively low pressures. These projections are shown in Table 8. Also included are projections of the likely annual rates of production of this gas, under two different scenarios, up to the year 2000. In one scenario, gas is recovered by vertical wells and hydraulic stimulation, and in the other, this is done using shafts and horizontal drilling.

A separate set of economics is presented for the case where the recovered gas will need scrubbing for removal of carbon dioxide and other contaminants, high-pressure compression, and delivery to an offsite utility pipeline.
CHAPTER ONE
INTRODUCTION

REPORT OBJECTIVES

The objectives of this analysis of coal-bed gas are to:

- Identify and evaluate the resource base of the coal-bed gas
- Assess the state-of-the-art of coal gas recovery technology with projections for the future
- Project the economics of gas recovery projects and quantify the amounts of recoverable gas at various support levels
- Project rates of recovery of this reserve to the year 2000
- Analyze the constraints which may preclude recovery levels from being achieved.

ORIGIN OF COAL-BED GAS

Coal-bed gas is formed during the natural processes that lead to the formation of coal. Although much of the gas formed during the initial coalification process is lost to the atmosphere, a significant portion is retained in one of three ways:

- As free gas contained in the cracks and fractures of the coal bed
- As adsorbed gas on the internal surfaces of micropores within the structure of the coal itself
- As desorbed gas in adjacent strata which may serve as supplementary reservoirs for such gas.

CHEMICAL COMPOSITION OF COAL-BED GAS

Methane (CH₄) is the primary component of coal-bed gas, generally comprising 85 to 99 percent by volume. Other hydrocarbons account for minor quantities, not exceeding 2 percent, while contaminants such as carbon dioxide (CO₂) and nitrogen (N₂) make up the rest. Table 1 (see Appendix I, Ref. 1) shows the analysis of gas from some selected coal beds, and also the average composition of natural gas.

The presence of carbon dioxide, as evidenced by most of the gas recovered from the Pittsburgh seam, poses a potential problem because of its corrosive action in association with water and the impact that it can have on delivery lines, compressors, etc. All
<table>
<thead>
<tr>
<th></th>
<th>Pocahontas #3</th>
<th>Pittsburgh</th>
<th>Kittanning</th>
<th>Lower Hartshorne</th>
<th>Mary Lee</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$</td>
<td>96.37</td>
<td>90.75</td>
<td>97.32</td>
<td>99.22</td>
<td>96.05</td>
<td>94.40</td>
</tr>
<tr>
<td>C$_2$H$_6$</td>
<td>1.39</td>
<td>0.29</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>3.80</td>
</tr>
<tr>
<td>C$_3$H$_8$</td>
<td>0.0147</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.6</td>
</tr>
<tr>
<td>C$<em>4$H$</em>{10}$</td>
<td>0.0008</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.3</td>
</tr>
<tr>
<td>C$<em>5$H$</em>{12}$</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.2</td>
</tr>
<tr>
<td>O$_2$</td>
<td>0.17</td>
<td>0.20</td>
<td>0.24</td>
<td>0.10</td>
<td>0.15</td>
<td>--</td>
</tr>
<tr>
<td>N$_2$</td>
<td>1.7</td>
<td>0.59</td>
<td>2.3</td>
<td>0.6</td>
<td>3.5</td>
<td>0.4</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.36</td>
<td>8.25</td>
<td>0.14</td>
<td>0.06</td>
<td>0.10</td>
<td>--</td>
</tr>
<tr>
<td>H$_2$</td>
<td>0.01</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>He</td>
<td>0.03</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.27</td>
<td>--</td>
</tr>
<tr>
<td>Btu/SCF</td>
<td>1,059</td>
<td>973</td>
<td>1,039</td>
<td>1,058</td>
<td>1,024</td>
<td>1,068</td>
</tr>
</tbody>
</table>

§British thermal unit per standard cubic foot at atmospheric pressure. Note: 252 kilogram calories per Btu and 0.0283 cubic meters per cubic foot.
Utilities specify a maximum limit for carbon dioxide, and where coal-bed gas exceeds this limit, it will need to be "scrubbed" or cleaned before it can be delivered into such a utility pipeline.

The heat content of most coal-bed gas varies from about 850 Btu to about 1,050 Btu per cubic foot. For purposes of this study, an average value of 1,000 Btu per cubic foot is assumed.

Liberation of Coal-Bed Gas

Some of the gas thus entrapped in and around coal seams can be liberated either by the act of mining itself or by techniques of pre-mining degasification. The liberation of large amounts of gas in the mining of some of the more gassy coal seams, and the risk of ignition and explosion related thereto, has established a need for investigating the occurrence of coal-bed gas for many years. Thus, while the impetus for degasification has primarily come from considerations of safe mineability, it has been recognized for some years now that this gas could have value as a supplemental energy source if it could be commercially recovered and used.

Generally, three modes of gas liberation are recognized:

- Gas liberated at the mine face where coal is cut and loaded or from the ribs and pillars of coal left in place. This gas is carried away in the mine ventilation air current in an extremely diluted form, and is probably not amenable to any economic recovery, even at higher prices. Research effort is and has been, therefore, better directed at recovering as much gas as possible prior to the mining of coal.

- Gas liberated in bleeders and gob degas holes. This is the gas which gradually bleeds either from coal or other gas reservoir areas near the mine workings after the coal has been fully extracted, thus breaking the immediate roof and other superposed strata. This gas may have been contained in other porous media in proximity to the coal seam or it may be coal-bed gas that originated in the coal seam and then migrated into the porous media.

This gas is usually in a more concentrated form, but from time to time will contain large percentage amounts of air and other contaminants. While more effective pre-mining gas drainage will reduce the amount of such gas, there may be situations where it could be used locally as an energy source.

The total amount of gas available for recovery is limited by the amount of underground mining with full extraction. Since the potential for such gas is insignificant in relationship to the projected resource base, it is not considered in detail in this report.
Gas obtained by pre-mining drainage of coal seams. This gas is drained by drilling vertical or horizontal holes, and by other such techniques which are described later in this report.

ANALYSIS OVERVIEW

Since the coal gas resource is intimately connected with the resource base of the coal itself, the first step in the analysis was an evaluation of the coal resources of the country (Coal Resource section of Chapter Two). The average in-place gas content of bituminous coals was estimated for this report, based on the limited available information. Since hardly any data are available for subbituminous coals and lignites, their gas contents were extrapolated using an empirical relationship that relates gas content to the moisture content of bituminous coals (Gas Resource section of Chapter Two).

In order to relate gas production to a generalized set of project economics, it was decided to estimate an average initial gas recovery rate per well, per foot of coal seam thickness (Production Per Foot of Seam Thickness section in Chapter Four). A gas production decline of 10 percent per year was assumed, and a producing life of 12 years was used for each well. Economics were developed for a typical project, assuming a total project life of 20 years.

An analysis of the coal reserves was done to identify the total in-place coal resource for various cumulative thicknesses of reported coal seams (Computation of Coal Seam Thickness section of Chapter Four). Relating the total seam thickness to the flow of gas per well, and hence to the economics of gas recovery, it was possible to project economically recoverable gas reserves at various price levels.

Investment and operating costs were developed by the individual study participants for the types of projects they are now utilizing or would utilize (Estimation of Costs section of Chapter Five). From these, it was possible to extract average per-foot costs for vertical well projects for a base case where the recovered gas is assumed to be utilized at the project site itself without high-pressure compression, cleanup, or delivery costs. The costs for the latter items were estimated separately as add-on amounts.

The project economics were evaluated using a discounted cash flow (DCF) method of analysis (DCF Analysis section of Chapter Five). Gas prices were projected at 10, 15, and 20 percent internal rates of return (ROR's) for the two cases; i.e., (1) the base case, which assumes that the gas can be used on site without additional high-pressure compression, scrubbing, and delivery through a trunk pipeline, and (2) the case where costs for these add-on items were included. Economical gas reserves at various price levels were projected separately for the two cases mentioned.
above (Projection of Economic Reserves section of Chapter Six). Projected annual rates of gas production to the year 2000 are presented in the Projection of Rate of Development by Vertical Wells section of Chapter Six for the vertical wells case, and in the Projection of Rate of Development by Shafts and Horizontal Drilling section of Chapter Six for the case where the technique of horizontal drilling from shaft bottoms is utilized for gas recovery.

UNCERTAINTIES

- The U.S. Geological Survey coal resource data utilized for this study are less than precise. However, uncertainties about the coal resource are dwarfed by the much greater uncertainties that exist when extrapolating from the coal in place to the quantities of recoverable gas.

- Very little is known about the gas content of the vast majority of coals in the country. Out of the hundreds of coal seams that are known to exist, gas content information is available on about 50, limited primarily to mineable bituminous coal seams.

- The uncertainty regarding in-place gas content is compounded vastly by the fact that the values of physical parameters that control the flow of gas through coal beds are not available for the vast majority of coal seams in the country.

The few actual gas recovery projects have shown variable and sometimes erratic results. Hardly any consistent data on gas flow rates over an appreciable length of time are available for analysis.

- Major uncertainties also exist over the possible risks associated with hydraulic fracturing, a technique that has been used to enhance the flow of gas through coal seams, and without which many vertical well projects do not produce significant amounts of gas. There is concern that in the process of fracturing the coal seam, the roof strata may be fractured so as to render some seams more hazardous and more expensive to mine, and possibly even render some seams unmineable.

Since the energy content of the gas in a coal seam is only equivalent to 1 to 2 percent of the energy content of the coal itself, the concerns associated with hydraulic fracturing of vertical wells should be fully addressed before large-scale use of this technique is carried out in coal seams that are being mined now or are likely to be mined in the future.

- Other constraints and problems also exist, and are presented briefly in Chapter Seven. These include the issues of gas ownership, water disposal, etc.
CHAPTER TWO
RESOURCES

COAL RESOURCE

The U.S. Geological Survey reports on "mineable" coal resources in the country, based on its own definition related to the minimum seam thicknesses of various ranks and types of coal. As of 1974, it reported about 1.73 trillion tons of identified and 1.85 trillion tons of hypothetical coal resources. Another 0.39 trillion tons were reported as hypothetical resources in deeper structural basins (3,000 to 6,000 ft). A summary presentation is shown in Table 2, and a breakdown of these resources by state is presented in Table 3 (see Appendix I, Ref. 2).

A more recent computerized data base of mineable coal is also available from the U.S. Geological Survey. This data base covers only the identified reserves and shows a county-by-county listing of known coal seams by rank and by depth. This information was used in arriving at commercially recoverable gas reserves as described later in this report.

TABLE 2
Estimated Remaining Coal Resources in the United States
(January 1, 1974)

<table>
<thead>
<tr>
<th>Category</th>
<th>Billions (10^9) of Short Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identified (measured, indicated and inferred) resources:</td>
<td></td>
</tr>
<tr>
<td>A. Reserve base</td>
<td>434</td>
</tr>
<tr>
<td>B. Additional identified</td>
<td>1,297</td>
</tr>
<tr>
<td>Total Identified</td>
<td>1,731</td>
</tr>
<tr>
<td>2. Hypothetical:</td>
<td></td>
</tr>
<tr>
<td>A. 0-3,000 ft overburden</td>
<td>1,849</td>
</tr>
<tr>
<td>B. 3,000-6,000 ft overburden</td>
<td>388</td>
</tr>
<tr>
<td>Total Hypothetical</td>
<td>2,237</td>
</tr>
<tr>
<td>Grand Total -- Identified and Hypothetical</td>
<td>3,968</td>
</tr>
<tr>
<td>State</td>
<td>Remaining identified resources, Jan. 1, 1974 (from table 2)</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Remaining identified resources, Jan. 1, 1974 (from table 2)</td>
</tr>
<tr>
<td></td>
<td>Remaining identified resources, Jan. 1, 1974 (from table 2)</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Alabama</td>
<td>13,262</td>
</tr>
<tr>
<td>Abaskan</td>
<td>19,117</td>
</tr>
<tr>
<td>Arizona</td>
<td>62,234</td>
</tr>
<tr>
<td>Arkansas</td>
<td>658</td>
</tr>
<tr>
<td>Colorado</td>
<td>159,117</td>
</tr>
<tr>
<td>Georgia</td>
<td>24</td>
</tr>
<tr>
<td>Illinois</td>
<td>146,001</td>
</tr>
<tr>
<td>Indiana</td>
<td>32,868</td>
</tr>
<tr>
<td>Iowa</td>
<td>6,005</td>
</tr>
<tr>
<td>Kansas</td>
<td>18,668</td>
</tr>
<tr>
<td>Kentucky</td>
<td></td>
</tr>
<tr>
<td>Eastern</td>
<td>28,226</td>
</tr>
<tr>
<td>Western</td>
<td>36,120</td>
</tr>
<tr>
<td>Maryland</td>
<td>1,152</td>
</tr>
<tr>
<td>Michigan</td>
<td>205</td>
</tr>
<tr>
<td>Missouri</td>
<td>31,814</td>
</tr>
<tr>
<td>Montana</td>
<td>2,299</td>
</tr>
<tr>
<td>New Mexico</td>
<td>10,748</td>
</tr>
<tr>
<td>North Carolina</td>
<td>110</td>
</tr>
<tr>
<td>North Dakota</td>
<td>0</td>
</tr>
<tr>
<td>Ohio</td>
<td>41,166</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>7,117</td>
</tr>
<tr>
<td>Oregon</td>
<td>30</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>63,914</td>
</tr>
<tr>
<td>South Dakota</td>
<td>0</td>
</tr>
<tr>
<td>Tennessee</td>
<td>2,530</td>
</tr>
<tr>
<td>Texas</td>
<td>6,018</td>
</tr>
<tr>
<td>Utah</td>
<td>223,196</td>
</tr>
<tr>
<td>Virginia</td>
<td>9,216</td>
</tr>
<tr>
<td>Washington</td>
<td>1,867</td>
</tr>
<tr>
<td>West Virginia</td>
<td>100,150</td>
</tr>
<tr>
<td>Wyoming</td>
<td>12,701</td>
</tr>
<tr>
<td>Other States</td>
<td>610</td>
</tr>
<tr>
<td>Total</td>
<td>717,357</td>
</tr>
<tr>
<td></td>
<td>485,766</td>
</tr>
<tr>
<td></td>
<td>478,131</td>
</tr>
<tr>
<td></td>
<td>19,062</td>
</tr>
<tr>
<td></td>
<td>1,730,919</td>
</tr>
</tbody>
</table>

The gas content of the above coal resources cannot be estimated with any degree of confidence, since the tests to determine the in-place gas content have not been conducted on the vast majority of coal seams in the country. The limited data available, mostly from mineable bituminous coals, show considerable variability and little, if any, data are available for subbituminous coal and lignite. It is generally agreed, however, that the gas content of these lower rank coals is likely to be considerably less than that of bituminous coal on a per-ton basis.

The study participants considered published information on the gas content of coals (see Appendix I, Refs. 3, 4, 5) as well as some data produced by a few of the study participants from their ongoing programs. A listing of all such data is given in Appendix C. In making a judgment as to the average gas content of all bituminous coals, the study participants weighed two opposing considerations. First, based on mining experience, it was obvious that the majority of seams on which gas content data had been collected were the more "gassy" seams. In fact, it was concern for mine safety in gassy coal seams that had led to the collection of some of this data. The second consideration was that there was at least some indication that the gas content of coal, in general, increased with the depth of coal seams. It could, therefore, be said that deeper coal seams, especially in the western United States, may have high gas content. Weighing the two factors, the study participants decided to use a value of 200 cubic feet of gas per ton of coal for bituminous coal seams.

Later, a more comprehensive listing of gas content data was obtained from the U.S. Bureau of Mines, as presented in Appendix D. These data average about 175 cubic feet of gas per ton of coal and are generally in line with the data considered by the study participants in their deliberations.

In extrapolating the above value of 200 cubic feet per ton to subbituminous coals and lignites, it was decided to use an empirical relationship (see Appendix I, Refs. 6, 7) that relates gas content to the moisture content of coal, using a moisture content of 16 percent for subbituminous coals, and 38 percent for lignites. It was recognized that the relationship applied to bituminous coals only, but in the absence of any other information it was decided to extrapolate the equation to lower rank coals. As shown in Appendix E, such an extrapolation resulted in a value of 80 cubic feet per ton for subbituminous coals and 40 cubic feet per ton for lignites. It was also agreed that seams less than 300 feet deep probably contained no economically recoverable gas.

The above values can be used to project the gas resource base in conjunction with the coal resource data mentioned before. Since the hypothetical coal resources are not classified into different ranks, an approximate classification was used, based on the ratios between different coals in the identified category. Table 4 shows the coal-bed gas resource base that can thus be projected.
<table>
<thead>
<tr>
<th>Coal Category</th>
<th>Estimated Coal Resource (Billions of Short Tons)</th>
<th>Estimated Gas Content (Ft³/Ton)</th>
<th>Projected Gas Resource (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. 300-3,000 feet deep</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Anthracite</td>
<td>46</td>
<td>200</td>
<td>9</td>
</tr>
<tr>
<td>B. Bituminous</td>
<td>1,001</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>C. Subbituminous</td>
<td>1,137</td>
<td>80</td>
<td>91</td>
</tr>
<tr>
<td>D. Lignite</td>
<td>504</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td><strong>2. 3,000-6,000 feet deep</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>388</td>
<td>200</td>
<td>78</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>398</td>
</tr>
</tbody>
</table>
CHAPTER THREE
TECHNOLOGY

The major techniques for recovering coal-bed gas are:

- Vertical wells
- Horizontal holes from mine access
- Horizontal holes from shaft bottoms
- Slant holes.

VERTICAL WELLS

This technique of recovering coal-bed gas consists of drilling vertical holes from the surface to the coal seam. The holes are generally 9 inches (0.23 meters) in diameter or less. Experience has shown that the amount of gas that will flow to such vertical holes through the natural cleat system or from the microporous structure of the coal seam is generally quite limited unless the area is naturally highly fractured. In order to increase the gas drainage area, a technique known as hydraulic fracturing has been used.

Hydraulic fracturing is the application of a fluid pressure to a desired section of formation (in this case the coal seam) until parting or formation "breakdown" occurs. This parting or crevice is extended with further pumping under pressure, establishing a new, larger flow channel to the well bore. Higher effective average permeability is created, resulting in increased gas flow to the well bore.

The most commonly used hydraulic fracturing fluids are gelled-water and nitrogen-water foam. Propping agents such as carefully sized sand grains are carried by the fluid into the crevice, preventing it from closing or healing when the hydraulic pressure is reduced.

The extension of hydraulically created fractures into strata overlying coal seams can constitute a deterrent to the safe and efficient mining of coal. This can be especially problematic when the strata immediately above the coal are comprised of thin layers of coal and weak shale. A number of experienced coal mine operators have expressed concern over the possibility that hydraulically created fractures extending into strata overlying mineable coal seams can create additional risks to safe and efficient mining.
There have been reports of at least 10 hydraulically induced fractures that were later mined through. A synopsis of the observations made in these various reports is given below:

- The Bureau of Mines reported on two such observations, one in the Pittsburgh seam and the other in the Illinois No. 6 seam (see Appendix I, Ref. 8). While the conclusion of the report was that "no adverse effect or extension of the induced fractures into the roof or floor rock of the mine was evident," it was mentioned in the body of the report that in the Illinois No. 6 seam a "hairline crack in the roof was exposed when the continuous miner removed a small area of hard coal," and "the crack extended a few inches into the roof rock."

- The Bureau of Mines also reported two other mine-through observations in Alabama's Mary Lee seam (see Appendix I, Ref. 9). This report contained the comment "no cement was found in the southern half of the well bore; instead, prop sand and/or gel filled this annular space at both the floor and the roof." This indicates that zonal isolation of roof and floor strata from the hydraulic pressure did not exist. Other relevant comments were "cement bond to casing were generally poor," and "the lack of cement within approximately one-half of the well bore annulus in the roof also indicates poor cementing." It was further mentioned in respect to one of these mine-throughs that "although sand-filled channels were not observed at TW-1, there is sufficient evidence to indicate that partings in the coal and roof rock had been opened during drilling, cementing, and early stages of stimulation," and "the gel in the roof contained no sand and therefore must have been included in the initial fluid pad before the proppant was added."

- In a paper about another hydraulic fracture, which was later mined in the Pittsburgh seam, "fracture penetration of three strata overlying the seam" was reported (see Appendix I, Ref. 10).

- In a court testimony (Mary Cunningham vs. U.S. Steel) relating to four mine-throughs in the Mary Lee seam and three in the Pittsburgh seam, it was mentioned that two of the former and one of the latter showed penetration of the roof.

Reports of these observations clearly demonstrate that cementing and hydraulic fracturing are unpredictable at best, and that the likely impact on the safe and economic mineability of coal seams needs to be assessed carefully for each situation.

As presented in more detail later, there are situations where the technique of drilling horizontal wells from shaft bottoms is comparable in economics to the vertical well technique, and could therefore be a practical alternative to degasification by hydro-fracturing through vertical wells.
HORIZONTAL HOLES FROM MINE WORKINGS

This process consists of drilling horizontal holes into virgin coal from active working sections of an underground mine. The coal-bed gas that is thus liberated is conveyed through a piping system to the surface collecting site.

It is generally agreed that this method of recovering coal-bed gas is likely to be the most economical of all alternatives. The total potential for gas recovery from this technique, however, is limited by the number of underground mines that are under development at a given point in time. Consequently, this method is not expected to yield significant production in the foreseeable future.

HORIZONTAL HOLES FROM SHAFT BOTTOMS

In this technique, vertical shafts, ranging from 8 to 20 feet in diameter, are sunk to the bottom of the coal seam. Working within the confines of the shaft, small-diameter (approximately 4 inches) horizontal holes are drilled radially into virgin coal. The holes intersect the numerous repetitive fissures (cleats) characteristic of most coal formations and provide highly conductive vents through which the trapped gas can flow. The wellheads of the various horizontal holes are located around the perimeter of the shaft bottom and are connected through a common manifold which directs the gas to a vertical transport pipe. Once at the surface, the gas can be treated in a manner similar to that of coal-bed gas derived from vertical bore holes.

It has been reported that the rate of gas flow from horizontal holes drilled in permeable coal beds has reached up to 30 thousand cubic feet per day (MCF/D) (850 cubic meters) per 100 feet. Also, lengths of horizontal holes greater than 1,000 feet (304.8 meters) have been successfully demonstrated. This makes the concept potentially viable, even though there is a large front-end investment for shaft sinking. As pointed out earlier, in certain situations this method of gas recovery is economically comparable to a vertical well project. It could therefore be preferred, since it should have no adverse impact on the safe mineability of the coal seam.

SLANT HOLES

In this method, a small-diameter vertical hole is drilled from the surface and then intentionally and progressively deflected to penetrate the coal bed parallel to its bedding plane. The hole then continues into the coal seam as a horizontal hole.

Attempts to date to accomplish this method appear to be more costly than other techniques. In addition, it is technically difficult, and the risk involved in getting the hole properly deflected to penetrate the seam and then stay within it for long distances is quite high. Dewatering of such slant holes also poses a
problem which has not been fully resolved. Improvements in the
drilling and dewatering techniques are necessary before this method
can be considered a proven technology. Nonetheless, the approach
clearly offers an area of potential research activity, as in the
case of two reported U.S. Bureau of Mines tests, which were consid­
ered sufficiently successful to warrant further testing (see Appen­
dix I, Ref. 11).
CHAPTER FOUR
PRODUCTION HISTORY AND PROJECTIONS

BACKGROUND

Though the in-place gas content of coal is important, it is not directly related to the gas producing ability of a coal seam. There is general agreement, however, that some of the important factors that control rates of gas recovery are:

- In situ gas content of coal
- Diffusivity coefficient of coals
- Extent and permeability of the natural fracture system
- Efficiency of stimulation techniques
- Efficiency of water removal and disposal methods
- Reservoir pressure (depth of coal seam).

Quite a few efforts have been made to date to recover gas from coal beds. Although some of these have been successful, no single project has established a long-term economic viability as purely a gas recovery project, and results have been spotty and somewhat unpredictable.

PRODUCTION DATA FROM VERTICAL WELLS

A number of vertical wells, with and without hydraulic stimulation, have been drilled into coal measures, and the results from 39 such wells reported by the U.S. Bureau of Mines are presented in Table 5 (see Appendix I, Ref. 12). Of these, 23 stimulated wells averaged less than 24 MCF/D per well of gas recovery. Of the latter 23 wells, 14 were producing gas from the Pittsburgh seam, and their average production was about 30 MCF/D per well.

The U.S. Steel Corporation presented results of their gas recovery project in the Blue Creek coal seam in Jefferson County, Alabama, during the study deliberations. A rectangular pattern of vertical wells was drilled on a 21-acre spacing and hydraulically fractured. The average field production of 15 wells over the preceding four months was reported to be 65 to 70 MCF/D per well. Five of these wells had been producing for approximately one year.

Another project that has recently started producing coal-bed gas is the Waltz Mill project in Pennsylvania (see Appendix I, Ref. 5). A cumulative coal seam thickness of 27 feet, covering 12 different seams, has been tapped by a vertical well. Three of the zones containing a total of eight seams have been hydraulically
<table>
<thead>
<tr>
<th>Coal Bed and Location</th>
<th>Bore Hole Number</th>
<th>Pre-Stimulation</th>
<th>Post-Stimulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Production Rate (Ft³/D)</td>
<td>Cumulative Production (MM Ft³)</td>
</tr>
<tr>
<td>Pocahontas #3,</td>
<td>PK-1</td>
<td>5,300</td>
<td>2.3</td>
</tr>
<tr>
<td>Wyoming, WV</td>
<td>PK-2</td>
<td>830</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>PK-3</td>
<td>970</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>PK-4</td>
<td>4,680</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>PK-5</td>
<td>3,100</td>
<td>1.3</td>
</tr>
<tr>
<td>Pittsburgh,</td>
<td>PV-1</td>
<td>6,800</td>
<td>2.3</td>
</tr>
<tr>
<td>Washington, PA</td>
<td>PV-2</td>
<td>955</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>PV-3</td>
<td>5,450</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>PV-5</td>
<td>333</td>
<td>0.1</td>
</tr>
<tr>
<td>Pittsburgh,</td>
<td>PL-1</td>
<td>3,650</td>
<td>2.5</td>
</tr>
<tr>
<td>Marion, WV</td>
<td>PL-2</td>
<td>820</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>PL-3</td>
<td>350</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>PL-4</td>
<td>7,300</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>PL-5</td>
<td>1,420</td>
<td>0.5</td>
</tr>
<tr>
<td>Pittsburgh,</td>
<td>PF-1</td>
<td>540</td>
<td>0.2</td>
</tr>
<tr>
<td>Monongalia, WV</td>
<td>PF-2</td>
<td>630</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>PF-3</td>
<td>1,730</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>PF-5</td>
<td>4,060</td>
<td>1.8</td>
</tr>
<tr>
<td>Coal Bed and Location</td>
<td>Bore Hole Number</td>
<td>Average Production Rate (Ft³/D)</td>
<td>Cumulative Production (MM Ft³)</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Pittsburgh, Greene, PA</td>
<td>PE-1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-8</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PE-11</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Castlegate</td>
<td>CC-1</td>
<td>36</td>
<td>0.02</td>
</tr>
<tr>
<td>Subseam #3, Carbon, UT</td>
<td>CC-3</td>
<td>15</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>CC-4</td>
<td>68</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>CC-5</td>
<td>26</td>
<td>0.02</td>
</tr>
<tr>
<td>Hartshorne, LeFlore, OK</td>
<td>HL-1</td>
<td>6,000</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>HL-4</td>
<td>820</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>HL-5</td>
<td>1,100</td>
<td>0.2</td>
</tr>
<tr>
<td>Mary Lee, Jefferson, AL</td>
<td>ML-1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>ML-2</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>ML-3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>ML-4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>ML-9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>ML-22</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
fractured. A production rate of about 40 MCF/D has been reported (see Appendix I, Ref. 20).

PRODUCTION DATA FROM LONG HORIZONTAL HOLES

Long horizontal holes can be drilled in virgin coal either from a location in an active underground mine or from the bottom of a shaft. After such holes have been sufficiently dewatered, gas flows through them. This gas can be captured in a pipeline and taken to the surface of the mine, either for onsite use or for delivery to a gathering pipeline.

Table 6 presents available results from horizontal hole projects. It may be seen from this table that while some initial horizontal holes did not produce any gas, subsequent efforts have yielded an average of about 15 MCF/D of gas per 100-foot length of the hole.

PRODUCTION PER FOOT OF SEAM THICKNESS

In order to relate gas production on a uniformly applicable basis, it was decided to project likely gas production per foot of coal seam thickness. This would lend itself to an economic analysis based on the total thickness of coal-bearing strata at any particular location.

All available data on gas recovery rates reduced to a gas flow per foot of seam thickness, as compiled in Table 7, were considered by the study participants. The coal and gas company representatives who have been associated with many of the projects listed therein believe that their efforts to date have been conducted in seams that they consider to have the best potential for gas recovery. For projecting gas recovery rates to all other seams in the country, with the limited information available, they felt that an average of 3 MCF/D per well per foot of bituminous coal seam thickness was a value that could perhaps be attained.

Representatives of an engineering consulting company, on the other hand, felt that much of the effort to date has been limited to drilling either one well or a few wells within a project area. They believe that this approach did not enable efficient removal of water from the seams, and had an adverse effect on gas flow rates. On the basis of theoretical computer models, which, they claim, have been authenticated with performance data, they were much more optimistic about the gas recovery possible from all seams in the country. The study participants failed to reach a consensus on this issue. A majority, however, felt that projections should be based on an average of 3 MCF/D per foot, but that the final results qualified appropriately to indicate that available information was very sparse and that most of the data were related to Appalachian experience.
<table>
<thead>
<tr>
<th>Seam</th>
<th>Location</th>
<th>Total Length of Holes</th>
<th>MCF/D 100 Ft</th>
<th>Age</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>503</td>
<td>16.6</td>
<td>2 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>300</td>
<td>11.5</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>108</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>255</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>259</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>95</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>140</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>90</td>
<td>nil</td>
<td>5 days</td>
<td>1,450</td>
</tr>
<tr>
<td>Lwr. Sunnyside</td>
<td>UT</td>
<td>430</td>
<td>37.0</td>
<td>2 mos.*</td>
<td>1,100-1,200</td>
</tr>
<tr>
<td>Lwr. Sunnyside</td>
<td>UT</td>
<td>450</td>
<td>28.0</td>
<td>2 mos.*</td>
<td>1,100-1,200</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV/PA</td>
<td>--</td>
<td>25</td>
<td>5 days</td>
<td>500-900</td>
</tr>
<tr>
<td>Pocahontas #3</td>
<td>VA</td>
<td>--</td>
<td>34</td>
<td>5 days</td>
<td>1,500-1,600</td>
</tr>
<tr>
<td>Blue Creek</td>
<td>AL</td>
<td>--</td>
<td>6</td>
<td>4 mos.</td>
<td>1,100</td>
</tr>
<tr>
<td>Mary Lee</td>
<td>AL</td>
<td>--</td>
<td>20</td>
<td>5 days</td>
<td>2,100</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>4,290</td>
<td>3.7</td>
<td>2 yrs.</td>
<td>800</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>5,000</td>
<td>0.2</td>
<td>2 yrs.</td>
<td>600</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>PA</td>
<td>3,000</td>
<td>10.4</td>
<td>6 mos.</td>
<td>700</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>4,325</td>
<td>13.5</td>
<td>2 yrs.</td>
<td>600</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>4,325</td>
<td>13.1</td>
<td>4 yrs.</td>
<td>600</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>4,524</td>
<td>18.9</td>
<td>2 yrs.</td>
<td>600</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>WV</td>
<td>4,524</td>
<td>14.8</td>
<td>4 yrs.</td>
<td>600</td>
</tr>
</tbody>
</table>

---

*Declined substantially in later months.
## TABLE 7

**Coal-Bed Gas Production From Vertical Wells**

<table>
<thead>
<tr>
<th>Coal-Bed &amp; Location</th>
<th>Well</th>
<th>Estimated Seam Thickness (Ft)</th>
<th>Production Pre-Stimulation (MCF/D)</th>
<th>Production Post-Stimulation (MCF/D)</th>
<th>Production Per Foot of Seam Thickness (MCF/D Ft)</th>
<th>Referring Number In Appendix I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburgh,</td>
<td>PV-1</td>
<td>6.0</td>
<td>6.8</td>
<td>21.1</td>
<td>3.5</td>
<td>12</td>
</tr>
<tr>
<td>Washington, PA</td>
<td>PV-2</td>
<td>6.0</td>
<td>1.0</td>
<td>15.7</td>
<td>2.6</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PV-3</td>
<td>6.0</td>
<td>5.5</td>
<td>15.9</td>
<td>2.7</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PV-5</td>
<td>6.0</td>
<td>0.3</td>
<td>15.4</td>
<td>2.6</td>
<td>12</td>
</tr>
<tr>
<td>Pittsburgh,</td>
<td>PE-1</td>
<td>7.0</td>
<td>--</td>
<td>7.5</td>
<td>1.1</td>
<td>12</td>
</tr>
<tr>
<td>Greene, PA</td>
<td>PE-2</td>
<td>7.0</td>
<td>--</td>
<td>26.8</td>
<td>3.8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-3</td>
<td>7.0</td>
<td>--</td>
<td>12.3</td>
<td>1.8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-4</td>
<td>7.0</td>
<td>--</td>
<td>61.1</td>
<td>8.7</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-5</td>
<td>7.0</td>
<td>--</td>
<td>46.7</td>
<td>8.7</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-6</td>
<td>7.0</td>
<td>--</td>
<td>70.0</td>
<td>10.0</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-7</td>
<td>7.0</td>
<td>--</td>
<td>8.4</td>
<td>1.2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-8</td>
<td>7.0</td>
<td>--</td>
<td>62.2</td>
<td>8.9</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PE-11</td>
<td>7.0</td>
<td>--</td>
<td>10.0</td>
<td>1.3</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>1034</td>
<td>8.0</td>
<td>0.0</td>
<td>45.0</td>
<td>5.6</td>
<td>18</td>
</tr>
</tbody>
</table>

Pittsburgh, Monongalia, WV

<p>| PF-1 | 7.0 | 0.5 | -- | 0.1 | 12 |
| PF-2 | 7.0 | 0.6 | -- | 0.1 | 12 |
| PF-3 | 7.0 | 1.7 | -- | 0.2 | 12 |
| PF-5 | 7.0 | 4.1 | -- | 0.6 | 12 |</p>
<table>
<thead>
<tr>
<th>Coal-Bed &amp; Location</th>
<th>Well</th>
<th>Estimated Seam Thickness (Ft)</th>
<th>Gas Production Pre-Stimulation (MCF/D)</th>
<th>Gas Production Post-Stimulation (MCF/D)</th>
<th>Production Per Foot of Seam Thickness (MCF/D Ft)</th>
<th>Referring Number In Appendix I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pittsburgh, Marion, WV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL-1</td>
<td>7.0</td>
<td>3.7</td>
<td></td>
<td></td>
<td>0.5</td>
<td>12</td>
</tr>
<tr>
<td>PL-2</td>
<td>7.0</td>
<td>0.8</td>
<td></td>
<td></td>
<td>0.1</td>
<td>12</td>
</tr>
<tr>
<td>PL-3</td>
<td>7.0</td>
<td>0.4</td>
<td>16.7</td>
<td></td>
<td>2.4</td>
<td>12</td>
</tr>
<tr>
<td>PL-4</td>
<td>7.0</td>
<td>7.3</td>
<td>20.3</td>
<td></td>
<td>2.9</td>
<td>12</td>
</tr>
<tr>
<td>PL-5</td>
<td>7.0</td>
<td>1.4</td>
<td></td>
<td></td>
<td>0.2</td>
<td>12</td>
</tr>
<tr>
<td>L-5</td>
<td>8.5</td>
<td>0.0</td>
<td>8.6</td>
<td></td>
<td>1.0</td>
<td>10</td>
</tr>
<tr>
<td>L-6</td>
<td>8.5</td>
<td>0.0</td>
<td>50.4</td>
<td></td>
<td>5.9</td>
<td>10</td>
</tr>
<tr>
<td>L-7</td>
<td>8.5</td>
<td>0.2</td>
<td>15.0</td>
<td></td>
<td>1.8</td>
<td>22</td>
</tr>
<tr>
<td><strong>Pocahontas #3, Wyoming, WV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PK-1</td>
<td>6.0</td>
<td>5.3</td>
<td></td>
<td></td>
<td>0.9</td>
<td>12</td>
</tr>
<tr>
<td>PK-2</td>
<td>6.0</td>
<td>0.8</td>
<td>5.4</td>
<td></td>
<td>0.9</td>
<td>12</td>
</tr>
<tr>
<td>PK-3</td>
<td>6.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td>0.2</td>
<td>12</td>
</tr>
<tr>
<td>PK-4</td>
<td>6.0</td>
<td>4.7</td>
<td></td>
<td></td>
<td>0.8</td>
<td>12</td>
</tr>
<tr>
<td>PK-5</td>
<td>6.0</td>
<td>3.1</td>
<td></td>
<td></td>
<td>0.5</td>
<td>12</td>
</tr>
<tr>
<td><strong>Pocahontas #3, Buchanan, VA</strong></td>
<td>1</td>
<td>6.0</td>
<td>0.6</td>
<td>12.0</td>
<td>2.0</td>
<td>8</td>
</tr>
<tr>
<td><strong>Castlegate #3, Carson, UT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC-1</td>
<td>6.0</td>
<td>0.0</td>
<td></td>
<td></td>
<td>0.0</td>
<td>12</td>
</tr>
<tr>
<td>CC-3</td>
<td>6.0</td>
<td>0.0</td>
<td>0.9</td>
<td></td>
<td>0.2</td>
<td>12</td>
</tr>
<tr>
<td>CC-4</td>
<td>6.0</td>
<td>0.0</td>
<td></td>
<td></td>
<td>0.0</td>
<td>12</td>
</tr>
<tr>
<td>CC-5</td>
<td>6.0</td>
<td>0.0</td>
<td></td>
<td></td>
<td>0.0</td>
<td>12</td>
</tr>
<tr>
<td><strong>Hartshorne, LeFlore, OK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HL-1</td>
<td>5.0</td>
<td>6.0</td>
<td></td>
<td></td>
<td>1.2</td>
<td>12</td>
</tr>
<tr>
<td>HL-4</td>
<td>5.0</td>
<td>0.8</td>
<td></td>
<td></td>
<td>0.2</td>
<td>12</td>
</tr>
<tr>
<td>HL-5</td>
<td>5.0</td>
<td>1.1</td>
<td>2.2</td>
<td></td>
<td>0.4</td>
<td>12</td>
</tr>
</tbody>
</table>
TABLE 7 (continued)

<table>
<thead>
<tr>
<th>Coal-Bed &amp; Location Particulars</th>
<th>Well I.D.</th>
<th>Estimated Seam Thickness (Ft)</th>
<th>Gas Production Pre-Stimulation (MCF/D)</th>
<th>Gas Production Post-Stimulation (MCF/D)</th>
<th>Production Per Foot of Seam Thickness (MCF/D Ft)</th>
<th>Referring Number In Appendix I</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 seams in same well, Clay, IL</td>
<td>NK*</td>
<td>8.0</td>
<td>10.0</td>
<td>--</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td>Illinois #6, Jefferson, IL</td>
<td>1</td>
<td>9.0</td>
<td>0.0</td>
<td>4.3</td>
<td>0.5</td>
<td>19</td>
</tr>
<tr>
<td>5 seams in same well, Rio Blanco, CO</td>
<td>TA-1</td>
<td>7.9</td>
<td>0.0</td>
<td>--</td>
<td>0.0</td>
<td>4</td>
</tr>
<tr>
<td>12 seams in same well, Westmoreland, PA</td>
<td>1</td>
<td>23.5</td>
<td>--</td>
<td>40.0</td>
<td>1.7</td>
<td>20</td>
</tr>
<tr>
<td>6 seams in same well, Cambria, PA</td>
<td>32-13</td>
<td>23.5</td>
<td>--</td>
<td>40.0</td>
<td>1.7</td>
<td>20</td>
</tr>
<tr>
<td>Blue Creek (15 wells), Jefferson, AL</td>
<td>NK*</td>
<td>5.5</td>
<td>--</td>
<td>67.5</td>
<td>12.3</td>
<td>21</td>
</tr>
<tr>
<td>9 seams in same well, Noble, OH</td>
<td>GT-1</td>
<td>11.0</td>
<td>0.1</td>
<td>1.6</td>
<td>0.1</td>
<td>22</td>
</tr>
</tbody>
</table>

*Not known.
COMPUTATION OF COAL SEAM THICKNESS

The U.S. Geological Survey's (USGS) computerized data base contained a county-by-county listing of coal resource information by rank, depth, and thickness. For each coal-bearing county, the average coal thickness was calculated by dividing the total in-place coal reserves by the area of the county, and using the density of coal assumed in the USGS data base. Thirty percent of the reserves within each county in the depth range of 0 to 1,000 feet was assumed to lie less than 300 feet from the surface, and was subtracted first with the assumption that this coal would contain no economically recoverable gas. In certain states, the USGS report indicated additional reserves in the unassigned and unclassified category. These were allocated on a pro-rata basis to the individual coal-bearing counties in the particular state. Also included on a pro-rata basis were the additional hypothetical coal resources by state, listed in Table 3. Graphs were plotted to indicate total resource for each rank of coal against total coal thickness as depicted in Figures 1, 2, and 3.

Figure 1. Estimated Distribution of Bituminous Coal.
Figure 2. Estimated Distribution of Subbituminous Coal.

Figure 3. Estimated Distribution of Lignites.
CHAPTER FIVE
ECONOMIC ANALYSIS

BACKGROUND

It must be noted at the outset that no published data are available on the economics of coal-bed gas recovery projects. Of the few gas recovery projects that have been in operation, or are now in operation, most are primarily research oriented, with the active cooperation and assistance of the U.S. Bureau of Mines and the Department of Energy. Cost information has either not been fully developed or is not released for proprietary reasons. Economic projections cannot, therefore, be based on historical information.

Problems associated with the general lack of cost information are immeasurably compounded by the fact that gas recovery rates and volumes cannot be projected with any degree of confidence, as discussed earlier.

ESTIMATION OF COSTS

Individual study participants estimated investment costs for the type of vertical wells project they are utilizing or would utilize. The individual analyses were then compared with the objective of reconciling disparities for reasons of differing assumptions and assessments. Many of the costs are site specific in nature and these showed wide variability. Setting these items of cost aside, it was possible to synthesize average costs per foot length of a well for 3,000-foot wells, with a spacing of 3,000 feet between wells. The site-specific costs were averaged to provide a typical-case scenario.

Items of cost included water handling, wellhead compressors, all piping, etc., within the project area. High-pressure compression was not included in the base case since it was felt that in some situations the gas could be delivered directly to a low-pressure pipeline. Some of the gas is expected to need scrubbing to remove contaminants like carbon dioxide, water, etc., that may be present. These costs were estimated separately so that they could be added to the base case economics along with the cost of extending an estimated 5-mile average length of a gathering or trunk pipeline, and an estimated 10,000 feet of power transmission line, to the project site.

A "typical" hypothetical project scenario was used, comprising 20 initial wells drilled on a 5 x 4 grid to a 3,000-foot depth and a 3,000-foot spacing. It was recognized that in actual practice the spacing would be quite variable for each situation. However, the costs related to spacing between wells are a small proportion of total cost and, therefore, within the accuracy of this analysis,
the per-well costs were considered to be applicable for a wide range of well spacings.

Using a 10 percent decline rate, it was necessary to bring additional wells on line every year so as to stay with a constant yearly production. A 90 percent success ratio was assumed; i.e., of all the wells that will be drilled in a project, 10 percent will have mechanical or other drilling problems which will require that the hole be plugged, and will therefore produce no gas. A 12-year producing life was used for an individual well, and a 20-year life of the project was used for economic analysis.

It is felt that with such a hypothetical project the total field size must be consistent with that of a large commercial venture in order to properly absorb the cost of high capital investments for compression, scrubbing, trunklines, etc.

The capital costs connected with such a hypothetical project are given in Appendix F, and the operating costs are shown in Appendix G for six different levels of gas production, at 10, 25, 50, 75, 100, and 150 MCF/D per well. Costs for add-on items like scrubbing, high-pressure compression, etc., are shown separately for each case.

It may once again be emphasized that the per-well costs shown in Appendix F include not only the direct drilling and hydraulic fracturing costs, but also an apportionment of costs on items like water handling, connecting pipelines, and power transmission, as well as costs on acquiring right-of-ways, access roads, etc.

DISCOUNTED CASH FLOW (DCF) ANALYSIS

A DCF analysis was done to project gas prices under different scenarios of gas production per well, using financial guidelines established for this study. An economic case at a 10 percent ROR, using uninflated 1979 costs, was thus completed along with two other cases at 15 and 20 percent ROR's. Mid-year discount factors were used throughout.

The tangible equipment costs were depreciated by a combination of double declining balance and the sum-of-digits method of depreciation, so as to gain the fastest depreciation of assets possible. A 10 percent investment tax credit was used. All intangible costs were expensed.

A federal income tax rate of 46 percent and an average state income tax of 2 percent were used, as per the guidelines. No depletion credit was taken, and a royalty rate of one-eighth was utilized.

Gas prices were thus calculated first for the case where the produced gas will be delivered on site in a low-pressure pipeline.
The price impact of the other add-on items, like high-pressure compression, scrubbing costs, trunk gas line costs, etc., was separately assessed.

GAS PRICE PROJECTIONS

Figure 4 depicts the relationship (for the base case) between gas production per day per vertical well and the selling price of gas at 10, 15, and 20 percent ROR's. Figure 5 depicts the same relationship when costs for add-on items like high-pressure compression, scrubbing, trunk delivery line, and power transmission lines are included.

Also analyzed were economics for a project where 2,000-foot horizontal holes are drilled from the bottom of a shaft. Gas flow rate assumed in this situation was 15 MCF/D per 100-foot hole length, based on experience in the Pittsburgh seam. Assuming that the entire shaft cost was written off within the project life of 12 years, the economics were comparable to a vertical wells project where the production per well was in the 20-30 MCF/D range, which is about what the average production has been from the Pittsburgh seam.

It can, therefore, be said that in situations where production ratios between vertical and horizontal holes are comparable to what has been observed in the Pittsburgh seam, the shaft approach may provide a viable alternative to stimulated vertical wells. This approach is preferable in coal seams that may be mineable now or in the future.
Figure 4. Estimated Gas Price at Various Production Levels—Vertical Wells Project (3,000-ft Depth)—Raw Gas On Site.
Figure 5. Estimated Gas Price at Various Production Levels—Vertical Wells Project (3,000-ft Depth)—Gas Cleaned and Delivered.
CHAPTER SIX
PROJECTION OF RESERVES AND PRODUCTION

PROJECTION OF ECONOMIC RESERVES

For each gas price level, the minimum initial gas flow required per well can be determined from either Figure 4 or Figure 5, depending upon whether or not the add-on items like high-pressure compression, etc., are to be included. Using the average gas flow of 3 MCF/D per foot of bituminous coal seam thickness per well, the above minimum gas flow per well can be converted into an equivalent thickness of bituminous coal. Figure 1 can then be used to read the total bituminous coal resource in place for that particular coal thickness. A similar set of calculations can be made for subbituminous coals and lignites, with the further assumption that the gas flow per foot of seam thickness for these lower rank coals will be 40 percent and 20 percent, respectively, of that of bituminous coals, in accordance with their similarly lower estimated gas contents in place.

In extrapolating from the coal resource to the economic gas resource in place, the estimated average gas content of the different ranks of coal (200 cubic feet per ton for bituminous coals, 80 cubic feet per ton for subbituminous coals, and 40 cubic feet per ton for lignites) can be used. Recoverable gas reserves were obtained using an estimated 50 percent recovery, and further assuming that 10 percent of the recoverable gas will be inaccessible because of its location below riverbeds, recreational and wildlife areas, etc.

Table 8 shows the estimated amounts of economically recoverable reserves for the base case at different ROR's. Figure 6 shows a smoothed graph showing the same projections.

BACKGROUND FOR ANALYSIS OF POTENTIAL PRODUCTION

The rate of development of gas reserves projected above will depend on the realities of the marketplace, the federal and state regulatory climate, availability of capital, and the ability of the industry to develop the resource. A delaying factor is likely to be the issue of coal-bed gas ownership, which will have to resolve itself through the courts before a full-fledged countrywide program for coal-bed gas recovery will be established.

For purposes of this analysis it is assumed that a market will exist for coal-bed gas produced at a price based on a 10 percent ROR, and that sufficient capital will be available and can be attracted at such an ROR. It is also assumed that a favorable regulatory climate will exist for production and marketing of this gas. As far as the ownership issue is concerned, it is assumed here that it will sort itself out by the end of the year 1984. The interim period will provide sufficient time to collect additional data on
TABLE 8
Projected Economic Reserves of Coal-Bed Gas
(Raw Gas On Site With No Compression)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Price Level</th>
<th>ROR %</th>
<th>Recoverable Reserves (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.50/MCF</td>
<td>10%</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>2.0</td>
</tr>
<tr>
<td>$3.50/MCF</td>
<td>10%</td>
<td>13.1</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>7.1</td>
</tr>
<tr>
<td>$5.00/MCF</td>
<td>10%</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>16.7</td>
</tr>
<tr>
<td>$7.00/MCF</td>
<td>10%</td>
<td>33.9</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>30.7</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>24.3</td>
</tr>
<tr>
<td>$9.00/MCF</td>
<td>10%</td>
<td>44.7</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>38.4</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>33.2</td>
</tr>
</tbody>
</table>

the gas content of coals and on the physical and chemical characteristics of gas flow through coal seams, which should reduce the uncertainties that now exist.

Once the assumptions outlined above have been made, the controlling factor would be the ability of the industry to develop this resource. This will depend primarily on the availability of equipment and trained crews needed for gas recovery projects.

PROJECTION OF RATE OF DEVELOPMENT BY VERTICAL WELLS

For development of the potential gas resource by vertical well projects, the prime requirement will be the availability of sufficient drill rigs and related equipment, along with trained personnel to man the projects. It is the view of the NPC that the manufacturing industry will be able to keep pace with the production of the modest amounts of additional rigs required for this purpose, and that additional trained personnel can be put in place. With this assumption, a scenario has been developed for the drilling of the required vertical wells over a period of about 18 years, and the recovery of the resource for a total of 28 years. Such a rate of development will require the deployment of an additional 80 rigs per year for a period of eight years, assuming that each rig will be able to drill an average of 45 producing wells per year. A spare capacity already exists for the manufacturing of these additional rigs, and should therefore cause no constraint on gas production.
Figure 6. Projected Economic Reserves of Coal-Bed Gas (Raw Gas On Site Without Compression).
The projected rate at which the gas can be produced until the end of this century is shown in Figure 7. Also shown are the additional wells that will need to be drilled each year and the coal-bed gas reserves added as a consequence of such drilling. Figure 8 shows the cumulative number of wells in place, the cumulative annual production, and the remaining reserves of recoverable gas at the end of each year. It is emphasized that the graphs relate to the base case where recovered gas can be used as produced.

PROJECTION OF RATE OF DEVELOPMENT BY SHAFTS AND HORIZONTAL DRILLING

It may be deemed necessary to recover the coal-bed gas resource using alternate techniques of drilling horizontal holes from shafts if the concerns regarding hydraulic stimulation cannot be eliminated. In that case there could be a constraint, not so much in the manufacture of additional shaft-sinking equipment, but in the training of crews in this specialized field. Inquiries to this effect revealed a present capacity for sinking about 50 shafts a year, and an estimate of 20 percent additional capacity every year, if sufficient demand was at hand. Using such a timetable for the sinking of additional shafts, a 22-year shaft-sinking program will be required to recover the total projected gas resource in a period of about 35 years.

The rate at which the gas can be produced until the end of the century, using the shaft approach, is shown in Figure 9. Also shown are additional shafts per year and the additions to committed reserves. Figure 10 shows cumulative production, the cumulative number of shafts, and the resources of gas remaining every year. Once again, it is emphasized that the quantities shown relate to the base case, and that the cumulative amounts recovered will be less because of scrubbing, high-pressure compression, and delivery into a pipeline that may be required in some areas.
Figure 7. Annual Rates as a Function of Time—Vertical Wells Projects (Raw Gas on Site).
Figure 8. Cumulative Wells, Production, and Reserves as a Function of Time
Vertical Well Projects (Raw Gas on Site).
Figure 9. Annual Rates as a Function of Time
Shaits with Horizontal Holes (Raw Gas on Site).
Figure 10. Cumulative Shafts, Production, and Reserves as a Function of Time Shafts with Horizontal Holes (Raw Gas on Site).
CHAPTER SEVEN
CONSTRAINTS

BACKGROUND

The coal-bed gas resource is of a fairly impressive size and there are situations where it could be commercially exploited to reduce this country's dependence on foreign energy sources. There are, however, constraints that will have to be addressed in order to encourage the flow of sizeable capital requirements in these ventures. Some of these constraints are institutional, others are regulatory, while still others emanate from technical uncertainties due to limited availability of data.

LEGAL CONSTRAINTS

The issue of gas ownership is unresolved and will have to await a final decision from the courts of this country. Until then, to legally recover and market gas, the company must have coal as well as oil and gas rights in an area; or where two or more parties are involved in the ownership of either the coal or the oil and gas, they may join in a compromise to produce the gas. In cases where gas recovery is sought from long horizontal holes, and land ownership over the project area is divided into many small parcels, the gas ownership issue is of added significance. There is also the need to scrutinize state and other local regulations that might preclude or discourage the recovery and marketing of coal-bed gas.

ENVIRONMENTAL CONSTRAINTS

The most important environmental constraint is the disposal of coal-bed water. The composition of coal-bed water varies widely, from slightly acidic to slightly alkaline, and is often saline. Environmental requirements vary from state to state, but where large quantities of water need to be removed and treated before disposal, the costs could be substantial. Also, where availability of water is an issue, as in some western states, the drawdown of the water table due to gas recovery projects could become a significant issue.

COMMERCIAL CONSTRAINTS

Coal companies and public utilities both have limited experience in the recovery and marketing of coal-bed gas. Uncertainties involved in the rate and duration of delivery and the composition and heating value of the delivered gas is likely to complicate signing of gas purchase agreements generally sought by utility companies. Impurities in coal-bed gas, like water and carbon
dioxide, are also of concern because of their corrosive action on pipelines and other equipment. These impurities will have to be removed, if necessary at added cost. If the gas recovery project is connected to active coal mining operations, the utility will have to accept deliveries of all gas that is produced, as the concern for safety will probably leave no choice but to vent the additional gas if it is not saleable.

TECHNOLOGICAL CONSTRAINTS

Much of the technology for gas recovery is proven. The risk lies not in the equipment itself, but in the fact that gas flow rates cannot now be projected with any amount of certainty. There is a basic lack of information and a vital need, therefore, to collect baseline data on the gas content of different types of coal and on the parameters that control the flow of gas in coal beds, as well as to do research on the reservoir characteristics and gas producing ability of coal beds.

Drilling technology, especially for horizontal and slant holes, needs improvement in the drill guidance system and in continuous in-hole surveying instrumentation.
CHAPTER EIGHT
COMPARISON WITH OTHER STUDIES

COAL-BED GAS RESOURCE IN PLACE

Based on the estimates of coal resources and gas content used in this analysis, an in-place gas resource base of 398 TCF has been projected (Table 4). A comparison with other studies conducted in the past is shown in Table 9.

As can be seen from Table 9, the NPC's projection of the potential gas resource base is consistent with other recent estimates. Further, high accuracy in the resource base is not of great importance at this time, due to the myriad of other uncertainties.

TABLE 9
Comparison of Projections on In-Place Gas Resource

<table>
<thead>
<tr>
<th>Study</th>
<th>Estimate (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPC, 1979 (This Study)</td>
<td>398</td>
</tr>
<tr>
<td>FERC, 1979*</td>
<td>850</td>
</tr>
<tr>
<td>TEW, 1978†</td>
<td>72-860</td>
</tr>
<tr>
<td>Wise, 1978§</td>
<td>300-800</td>
</tr>
<tr>
<td>Deul, 1978¶</td>
<td>258-629</td>
</tr>
<tr>
<td>Natl. Acad. Sci., 1976**</td>
<td>300</td>
</tr>
</tbody>
</table>

*Appendix I, Ref. 1.
†Appendix I, Ref. 13.
§Appendix I, Ref. 14.
¶Appendix I, Ref. 12.
**Appendix I, Ref. 15.

ECONOMICALLY RECOVERABLE GAS RESERVES

Unfortunately, most studies do not go beyond projections of the coal-bed gas resource base and attempt to estimate the quantities of economically recoverable gas reserves. Since the magnitude of the resource base is large, an unfounded and unintentional impression tends to be created that the level of economically recoverable gas reserves is equally large.

This study has attempted (1) to estimate costs of recovering the resource base and (2) to develop projections of economically
recoverable quantities of gas, which are a much more relevant input for policy making. Summaries of projected economic reserves of coal-bed gas are presented in Table 8 for various price and ROR scenarios. The only other recent study which attempted to examine potential quantities of economically recoverable coal-bed gas reserves is the report by Lewin and Associates, Inc. (see Appendix I, Ref. 16).

The Lewin study was done in 1977 and is based on a 10-year payout period, while this NPC study assumes 1979 costs and is based on various internal DCF ROR's. Table 10 compares the results of the Lewin study with the projections of this study, at a 10 percent ROR.

### TABLE 10

<table>
<thead>
<tr>
<th>Gas Price ($/MCF)</th>
<th>Projected Reserves (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NPC</td>
</tr>
<tr>
<td>2.50</td>
<td>5.0</td>
</tr>
<tr>
<td>3.50</td>
<td>13.1</td>
</tr>
<tr>
<td>5.00</td>
<td>25.4</td>
</tr>
</tbody>
</table>

Note: NPC study assumes constant 1979 dollars.

The range specified in the Lewin study is a reflection of the uncertainties involved in such projections. The results of the two studies are, however, quite consistent and reinforce the conclusion that economic reserves of coal-bed gas are only a fraction of the total projected in-place resource. It is critically important that policy makers distinguish between the resource base and economic reserves.
APPENDIX A

Request Letter and Description of the National Petroleum Council
June 20, 1978

Dear Mr. Chandler:

An objective of the energy supply initiatives of the President's energy policy is to promote domestic energy production from unconventional sources as well as from conventional sources. One of the areas to be encouraged is the recovery of natural gas from unconventional sources.

In the past, the National Petroleum Council has provided the Department of the Interior with appraisals on the extent and recovery of the Nation's oil and gas resources through such studies as Future Petroleum Provinces, U. S. Energy Outlook, Ocean Petroleum Resources, and Enhanced Oil Recovery.

Therefore, the National Petroleum Council is requested to prepare, as an early and important part of its new relationship with the Department of Energy, a study on unconventional sources of natural gas to include deep geopressed zones, Devonian shale, tight gas sands, and coal seams. Your analysis should assess the resource base and the state-of-the-art of recovery technology. Additionally, your appraisal should include the outlook for costs and recovery of unconventional gas and should consider how Government policy can improve the outlook.

For the purpose of this study, I will designate the Deputy Assistant Secretary for Policy and Evaluation to represent me and to provide the necessary coordination between the Department of Energy and the National Petroleum Council.

Sincerely,

James R. Schlesinger
Secretary

Mr. Collis P. Chandler, Jr.
Chairman, National Petroleum Council
1625 K Street, N. W.
Washington, D. C. 20006
DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL

In May 1946, the President stated in a letter to the Secretary of the Interior that he had been impressed by the contribution made through government/industry cooperation to the success of the World War II petroleum program. He felt that it would be beneficial if this close relationship were to be continued and suggested that the Secretary of the Interior establish an industry organization to advise the Secretary on oil and natural gas matters.

Pursuant to this request, Interior Secretary J. A. Krug established the National Petroleum Council (NPC) on June 18, 1946. In October 1977, the Department of Energy was established and the Council's functions were transferred to the new department.

The purpose of the NPC is solely to advise, inform, and make recommendations to the Secretary of Energy on any matter, requested by him, relating to petroleum or the petroleum industry. The Council is subject to the provisions of the Federal Advisory Committee Act of 1972.

Matters which the Secretary of Energy would like to have considered by the Council are submitted as a request in the form of a letter outlining the nature and scope of the study. The request is then referred to the NPC Agenda Committee, which makes a recommendation to the Council. The Council reserves the right to decide whether or not it will consider any matter referred to it.

Examples of recent major studies undertaken by the NPC at the request of the Department of the Interior and the Department of Energy include:

- Petroleum Resources Under the Ocean Floor (1969, 1971)
  Law of the Sea (1973)
  Ocean Petroleum Resources (1974, 1975)
- Environmental Conservation -- The Oil and Gas Industries (1971, 1972)
- Petroleum Storage for National Security (1975)
- Enhanced Oil Recovery (1976)
- **Materials and Manpower Requirements (1979)**
- **Petroleum Storage & Transportation Capacities (1979).**

The NPC does not concern itself with trade practices, nor does it engage in any of the usual trade association activities.

Members of the National Petroleum Council are appointed by the Secretary of Energy and represent all segments of petroleum interests. The NPC is headed by a Chairman and a Vice Chairman who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.
NATIONAL PETROLEUM COUNCIL
MEMBERSHIP

1980

Jack H. Abernathy
Vice Chairman
Entex, Inc.

Jack M. Allen, President
Alpar Resources, Inc.

Robert O. Anderson
Chairman of the Board
Atlantic Richfield Company

R. E. Bailey
Chairman and
Chief Executive Officer
Conoco Inc.

R. F. Bauer
Chairman of the Board
Global Marine Inc.

Robert A. Belfer, President
Belco Petroleum Corporation

Harold E. Berg
Chairman of the Board and
Chief Executive Officer
Getty Oil Company

John F. Bookout
President and
Chief Executive Officer
Shell Oil Company

W. J. Bowen
Chairman of the Board
and President
Transco Companies Inc.

Howard Boyd
Chairman of the Executive Committee
The El Paso Company

I. Jon Brumley
President and
Chief Executive Officer
Southland Royalty Company

Theodore A. Burtis
Chairman, President and
Chief Executive Officer
Sun Company, Inc.

James, C. Calaway, President
Southwest Minerals, Inc.

John A. Carver, Jr.
Director of the Natural Resources Program
College of Law
University of Denver

C. Fred Chambers, President
C & K Petroleum, Inc.

Collis P. Chandler, Jr.
President
Chandler & Associates, Inc.

E. H. Clark, Jr.
Chairman of the Board
President and
Chief Executive Officer
Baker International

Edwin L. Cox
Oil and Gas Producer

Roy T. Durst
Consulting Engineer

James W. Emison, President
Western Petroleum Company

James H. Evans, Chairman
Union Pacific Corporation

John E. Faherty, President
Crown Oil and Chemical Company

Frank E. Fitzsimmons
General President
International Brotherhood of Teamsters

A-4
John S. Foster, Jr.
Vice President
Science and Technology
TRW Inc.

R. I. Galland
Chairman of the Board
American Petrofina, Incorporated

C. C. Garvin, Jr.
Chairman of the Board
Exxon Corporation

James F. Gary
Chairman and
Chief Executive Officer
Pacific Resources, Inc.

Melvin H. Gertz, President
Guam Oil & Refining Company, Inc.

Richard J. Gonzalez

Robert F. Goss, President
Oil, Chemical and Atomic Workers
International Union

F. D. Gottwald, Jr.
Chief Executive Officer,  
Chairman of the Board and  
Chairman of Executive Committee
Ethyl Corporation

David B. Graham
Deputy General Counsel
Velsicol Chemical Corporation

Maurice F. Granville
Chairman of the Board
Texaco Inc.

Frederic C. Hamilton, President
Hamilton Brothers Oil Company

Armand Hammer
Chairman of the Board and
Chief Executive Officer
Occidental Petroleum Corporation

Jake L. Hamon
Oil and Gas Producer

John P. Harbin
Chairman of the Board and
Chief Executive Officer
Halliburton Company

Fred L. Hartley
Chairman and President
Union Oil Company of California

John D. Haun, President
American Association
of Petroleum Geologists
c/o Geology Department
Colorado School of Mines

Denis Hayes
Executive Director
Solar Energy Research Institute

H. J. Haynes
Chairman of the Board
Standard Oil Company
of California

Robert A. Hefner III
Managing Partner
GHK Company

Robert R. Herring
Chairman of the Board and
Chief Executive Officer
Houston Natural Gas Corporation

Leon Hess
Chairman of the Board and
Chief Executive Officer
Amerada Hess Corporation

Ruth J. Hinerfeld, President
League of Women Voters
of the United States

H. D. Hoopman
President and
Chief Executive Officer
Marathon Oil Company

Mary Hudson, President
Hudson Oil Company

Professor Henry D. Jacoby
Director, Center for Energy
Policy Research
Massachusetts Institute
of Technology

John A. Kanerb, President
Northeast Petroleum
Industries, Inc.
James L. Ketelsen
Chairman and
Chief Executive Officer
Tenneco Inc.

Thomas L. Kimball
Executive Vice President
National Wildlife Federation

George F. Kirby
Chairman of the Board
Texas Eastern
Transmission Corporation

John T. Klinkefus, President
Berwell Energy, Inc.

Charles G. Koch
Chairman and
Chief Executive Officer
Koch Industries, Inc.

John H. Lichtblau
Executive Director
Petroleum Industry
Research Foundation, Inc.

Jerry McAfee
Chairman of the Board
Gulf Oil Corporation

Paul W. MacAvoy
The Milton Steinbach Professor of
Organization and Management
and Economics
The Yale School of Organization
and Management
Yale University

Peter MacDonald, Chairman
Council of Energy Resource Tribes

D. A. McGee, Chairman
Kerr-McGee Corporation

John G. McMillian
Chairman and
Chief Executive Officer
Northwest Alaskan
Pipeline Company

Cary M. Maguire, President
Maguire Oil Company

C. E. Marsh, II
President
Mallard Oil & Gas Company

W. F. Martin
Chairman of the Board
Phillips Petroleum Company

David C. Masselli
Energy Policy Director
Friends of the Earth

F. R. Mayer
Chairman of the Board
Exeter Company

C. John Miller, Partner
Miller Brothers

James R. Moffett, President
McMoRan Exploration Company

Kenneth E. Montague
Immediate Past Chairman
of the Board
GCO Minerals Company

Jeff Montgomery
Chairman of the Board
Kirby Exploration Company

R. J. Moran, President
Moran Bros., Inc.

Robert Mosbacher

C. H. Murphy, Jr.
Chairman of the Board
Murphy Oil Corporation

John H. Murrell
Chief Executive Officer and
Chairman of Executive Committee
DeGolyer and MacNaughton

Ira S. Nordlicht
Holtzmann, Wise & Shepard

R. L. O'Shields
Chairman and
Chief Executive Officer
Panhandle Eastern
Pipe Line Company
John G. Phillips  
Chairman of the Board and  
Chief Executive Officer  
The Louisiana Land  
& Exploration Company

T. Boone Pickens, Jr.  
President  
Mesa Petroleum Company

L. Frank Pitts, Owner  
Pitts Oil Company

Rosemary S. Pooler  
Chairwoman and  
Executive Director  
New York State  
Consumer Protection Board

Donald B. Rice, President  
Rand Corporation

Corbin J. Robertson  
Chairman of the Board  
Quintana Petroleum Corporation

James C. Rosapepe, President  
Rosapepe, Fuchs & Associates

Henry A. Rosenberg, Jr.  
Chairman of the Board and  
Chief Executive Officer  
Crown Central Petroleum  
Corporation

Ned C. Russo  
Consultant of Public Relations  
Stabil-Drill Specialties, Inc.

Robert V. Sellers  
Chairman of the Board  
Cities Service Company

Robert E. Seymour  
Chairman of the Board  
Consolidated Natural Gas Company

J. J. Simmons, Jr.  
President  
Simmons Royalty Company

Theodore Snyder, Jr.  
President  
Sierra Club

Charles E. Spahr  
John E. Swearingen  
Chairman of the Board  
Standard Oil Company (Indiana)

Robert E. Thomas  
Chairman of the Board  
MAPCO Inc.

H. A. True, Jr.  
Partner  
True Oil Company

Martin Ward, President  
United Association of Journeymen  
and Apprentices of the  
Plumbing and Pipe Fitting  
Industry of the United States  
and Canada

Rawleigh Warner, Jr.  
Chairman of the Board  
Mobil Corporation

J. N. Warren  
Chairman of the Board  
Goldrus Drilling Co.

Lee C. White  
Founding President  
Consumer Energy Council  
of America

Alton W. Whitehouse, Jr.  
Chairman of the Board and  
Chief Executive Officer  
The Standard Oil Company (Ohio)

Joseph H. Williams  
Chairman of the Board and  
Chief Executive Officer  
The Williams Companies

Robert E. Yancey, President  
Ashland Oil, Inc.
NATIONAL PETROLEUM COUNCIL

COAL SEAMS TASK GROUP
OF THE
COMMITTEE ON
UNCONVENTIONAL GAS SOURCES

CHAIRMAN

William N. Poundstone
Executive Vice President - Engineering
Consolidation Coal Company

ASSISTANT TO THE CHAIRMAN

Kenneth E. Novak, Economist
Coordinating and Planning Department
Conoco Inc.

Alvin Abrams, President
Geosearch, Inc.

Maurice Deul
Research Supervisor
U.S. Bureau of Mines

Dr. Ab Flowers, Director
Gas Supply Research
Gas Research Institute

Amzi G. Gossard
General Manager
Underground Operations
Kerr-McGee Corporation

Dr. James V. Mahoney*
Senior Research Engineer
Coal Mining Processing Division
United States Steel Corporation

GOVERNMENT COCHAIRMAN

Troyt York
Office of Oil and Natural Gas Supply and Development
U.S. Department of Energy

SECRETARY

Peter J. Cover, Consultant
National Petroleum Council

Richard M. Orr, Manager
Resources and Materials
CNG Energy Company

Harvey S. Price
Senior Vice President
Intercomp Resource Development & Engineering, Inc.

Arie M. Verrips
Executive Director
American Public Gas Association

Dr. Hilmar A. von Schonfeldt
Manager
Coal Mining Research
Occidental Research Corporation

SPECIAL ASSISTANTS

Ben H. Daud, Manager
Consolidation Coal of Australia

Raymond R. Golli
Assistant Manager of Resources & Material
CNG Energy Company

*Replaced John A. Wallace
Raymond L. Mazza
Senior Staff Engineer
Conoco Inc.

John C. Sharer
Assistant Director
Unconventional Natural Gas
Gas Research Institute

Edward R. Talon
Director of Gas Development
Intercomp Resources Development & Engineering, Inc.
NATIONAL PETROLEUM COUNCIL

COMMITTEE ON
UNCONVENTIONAL GAS SOURCES

CHAIRMAN

John F. Bookout, President
and Chief Executive Officer
Shell Oil Company

GOVERNMENT COCHAIRMAN

R. Dobie Langenkamp
Deputy Assistant Secretary
Resource Development and
Operations
Resource Applications
U.S. Department of Energy

EX OFFICIO

C. H. Murphy, Jr.
Chairman
National Petroleum Council

EX OFFICIO

H. J. Haynes
Vice Chairman
National Petroleum Council

SECRETARY

Marshall W. Nichols
Executive Director
National Petroleum Council

R. E. Bailey
Chairman and
Chief Executive Officer
Conoco Inc.

Edward W. Erickson
Professor of Economics and
Business
North Carolina State University

Robert A. Belfer, President
Belco Petroleum Corporation

John S. Foster, Jr.
Vice President
Science and Technology
TRW Inc.

Howard Boyd
Chairman of the Executive
Committee
The El Paso Company

Frederic C. Hamilton, President
Hamilton Brothers Oil Company

John A. Carver, Jr.
Director of the Natural
Resources Program
College of Law
University of Denver

John D. Haun, President
American Association of Petroleum
Geologists
c/o Geology Department
Colorado School of Mines

Collis P. Chandler, Jr.
President
Chandler & Associates, Inc.

Denis Hayes
Executive Director
Solar Energy Research Institute

Robert A. Hefner III
Managing Partner
GHK Company
Robert R. Herring  
Chairman of the Board and  
Chief Executive Officer  
Houston Natural Gas Corporation

H. D. Hoopman  
President and  
Chief Executive Officer  
Marathon Oil Company

George F. Kirby  
Chairman of the Board  
Texas Eastern Transmission Corp.

Floyd W. Lewis  
Chairman and  
Chief Executive Officer  
Middle South Utilities, Inc.

Paul W. MacAvoy  
The Milton Steinbach Professor of  
Organization and Management  
and Economics  
The Yale School of Organization  
and Management  
Yale University

W. C. McCord  
Chairman and President  
Enserch Corporation

C. E. Marsh, II  
President  
Mallard Oil & Gas Company

W. F. Martin  
Chairman of the Board  
Phillips Petroleum Company

John G. Phillips  
Chairman of the Board and  
Chief Executive Officer  
The Louisiana Land & Exploration Company

Robert E. Seymour  
Chairman of the Executive Committee  
Consolidated Natural Gas Company

Elvis J. Stahr  
Senior Counselor  
National Audubon Society

W. A. Strauss  
Chairman of the Board and  
Chief Policy Officer  
InterNorth, Inc.

Stephen A. Wakefield  
Baker & Botts

Lee C. White  
Founding President  
Consumer Energy Council of America
NATIONAL PETROLEUM COUNCIL
COORDINATING SUBCOMMITTEE
OF THE
COMMITTEE ON
UNCONVENTIONAL GAS SOURCES

CHAIRMAN
Richard F. Nelson
General Manager Natural Gas
Shell Oil Company

ASSISTANT TO CHAIRMAN
Charles S. Matthews
Consulting Petroleum Engineer
Shell Oil Company

C. Ovid Baker, Manager
E & P Research Planning
Mobil Research & Development
Corporation

John L. Moore
Chief Production Engineer
Consolidated Natural Gas Service
Company

GOVERNMENT COCHAIRMAN
Lucio D'Andrea
Director of Natural Gas
Division
Office of Oil & Natural Gas
Supply Development
U.S. Department of Energy

SECRETARY
John H. Guy, IV
Director, Committee Operations
National Petroleum Council

William N. Poundstone
Executive Vice President –
Engineering
Consolidation Coal Company

Thomas W. Stoy, Jr.
Vice President
Oil and Gas Division
Union Oil Company of California
APPENDIX C

Gas Content Data on Bituminous Coals (Considered in this Report)
<table>
<thead>
<tr>
<th>Coal Bed/Location</th>
<th>Depth (ft)</th>
<th>Gas Content cm³/g</th>
<th>Gas Content ft³/ton</th>
<th>Reference in Appendix I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beckley</td>
<td>991</td>
<td>13.0</td>
<td>416</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>876</td>
<td>14.0</td>
<td>448</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>830</td>
<td>15.0</td>
<td>480</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>742</td>
<td>14.0</td>
<td>448</td>
<td>3</td>
</tr>
<tr>
<td>Hartshorne</td>
<td>1,480</td>
<td>16.0</td>
<td>512</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,295</td>
<td>18.0</td>
<td>576</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>571</td>
<td>12.0</td>
<td>384</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>553</td>
<td>13.0</td>
<td>416</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>488</td>
<td>11.0</td>
<td>352</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>252</td>
<td>5.0</td>
<td>160</td>
<td>3</td>
</tr>
<tr>
<td>New Castle</td>
<td>2,137</td>
<td>17.0</td>
<td>544</td>
<td>3</td>
</tr>
<tr>
<td>Pocahontas No. 3</td>
<td>2,110</td>
<td>14.0</td>
<td>448</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2,038</td>
<td>17.0</td>
<td>544</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,736</td>
<td>11.0</td>
<td>352</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,621</td>
<td>12.0</td>
<td>384</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,588</td>
<td>16.0</td>
<td>512</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,529</td>
<td>15.0</td>
<td>480</td>
<td>3</td>
</tr>
<tr>
<td>Pratt</td>
<td>1,365</td>
<td>15.0</td>
<td>480</td>
<td>3</td>
</tr>
<tr>
<td>Mary Lee</td>
<td>2,185</td>
<td>16.0</td>
<td>512</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,706</td>
<td>12.0</td>
<td>384</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,703</td>
<td>14.0</td>
<td>448</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,700</td>
<td>13.0</td>
<td>416</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1,099</td>
<td>14.0</td>
<td>448</td>
<td>3</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>850</td>
<td>7.0</td>
<td>224</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>771</td>
<td>6.0</td>
<td>192</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>676</td>
<td>5.0</td>
<td>160</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>427</td>
<td>3.0</td>
<td>96</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>312</td>
<td>2.0</td>
<td>64</td>
<td>3</td>
</tr>
<tr>
<td>Redstone</td>
<td>747</td>
<td>4.0</td>
<td>128</td>
<td>3</td>
</tr>
<tr>
<td>Sewell</td>
<td>679</td>
<td>9.0</td>
<td>288</td>
<td>3</td>
</tr>
<tr>
<td>Sewickley</td>
<td>675</td>
<td>5.0</td>
<td>160</td>
<td>3</td>
</tr>
<tr>
<td>Waynesburg</td>
<td>402</td>
<td>3.0</td>
<td>96</td>
<td>3</td>
</tr>
<tr>
<td>Sublette Cty., WY</td>
<td>3,480</td>
<td>10.5</td>
<td>336</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3,500</td>
<td>13.0</td>
<td>416</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3,512</td>
<td>11.9</td>
<td>381</td>
<td>4</td>
</tr>
<tr>
<td>Mesa Verde Cty., CO</td>
<td>3,930</td>
<td>1.6</td>
<td>51</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4,660</td>
<td>7.2</td>
<td>230</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4,720</td>
<td>8.7</td>
<td>278</td>
<td>4</td>
</tr>
<tr>
<td>Pittsburgh Cty., OK</td>
<td>1,903</td>
<td>4.1</td>
<td>130</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2,129</td>
<td>6.6</td>
<td>211</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2,725</td>
<td>2.3</td>
<td>73</td>
<td>4</td>
</tr>
<tr>
<td>Rio Blanco Cty., CO</td>
<td>685</td>
<td>1.0</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>698</td>
<td>.6</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>759</td>
<td>.8</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>791</td>
<td>.4</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>774</td>
<td>.8</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>802</td>
<td>.7</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>Coal Bed/Location</td>
<td>Depth (ft)</td>
<td>Gas Content</td>
<td>Reference in Appendix I</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td>Rio Blanco Cty., CO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>805</td>
<td>.6</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>827</td>
<td>.9</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,585</td>
<td>.6</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,603</td>
<td>.5</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Clay Cty., IL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>993</td>
<td>.9</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>994</td>
<td>.9</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>994</td>
<td>.5</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,034</td>
<td>.6</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,035</td>
<td>.2</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,075</td>
<td>.4</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,090</td>
<td>.8</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1,352</td>
<td>1.2</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>Westmoreland Cty., PA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>188</td>
<td>.4</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>240</td>
<td>.7</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>325</td>
<td>.8</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>385</td>
<td>1.7</td>
<td>53</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>435</td>
<td>.7</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>460</td>
<td>.9</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>480</td>
<td>2.0</td>
<td>63</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>520</td>
<td>1.0</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>1.5</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>590</td>
<td>1.4</td>
<td>46</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>620</td>
<td>1.8</td>
<td>59</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>630</td>
<td>3.2</td>
<td>104</td>
<td>5</td>
</tr>
</tbody>
</table>
APPENDIX D

Gas Content Data on Bituminous Coals
(Additional Data Obtained from the U.S. Bureau of Mines)
# TABLE D-1

Gas Content Data Obtained from the U.S. Bureau of Mines

<table>
<thead>
<tr>
<th>Coal Bed</th>
<th>County and State</th>
<th>Sample Depth (ft)</th>
<th>Total Gas Content (cm³/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alma</td>
<td>Mingo, West Virginia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>753</td>
<td>.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>819</td>
<td>1.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>855</td>
<td>1.2</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>869</td>
<td>.4</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>934</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>963</td>
<td>.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>996</td>
<td>.8</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,029</td>
<td>1.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,059</td>
<td>3.4</td>
</tr>
<tr>
<td>A Seam</td>
<td>Emery, Utah</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bald Knoll</td>
<td>Garfield, Utah</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bear Canyon</td>
<td>Emery, Utah</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beckley</td>
<td>Raleigh, West Virginia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>558</td>
<td>.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>588</td>
<td>4.8</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>653</td>
<td>5.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>655</td>
<td>11.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>740</td>
<td>13.7</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>830</td>
<td>15.4</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>850</td>
<td>9.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>852</td>
<td>12.4</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>875</td>
<td>14.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>990</td>
<td>12.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,198</td>
<td>10.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,200</td>
<td>11.6</td>
</tr>
<tr>
<td>Brookville</td>
<td>Allegheny, Pennsylvania</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castlegate</td>
<td>Emery, Utah</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon, Utah</td>
<td></td>
<td>1,016</td>
<td>4.7</td>
</tr>
<tr>
<td>Emery, Utah</td>
<td></td>
<td>1,248</td>
<td>.7</td>
</tr>
<tr>
<td>Carbon, Utah</td>
<td></td>
<td>1,430</td>
<td>1.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,645</td>
<td>.2</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,952</td>
<td>.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>2,170</td>
<td>7.8</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>2,186</td>
<td>2.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>2,221</td>
<td>.4</td>
</tr>
<tr>
<td>Cedar Grove(Lower)Mingo, West Virginia</td>
<td>682</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>704</td>
<td>.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>819</td>
<td>1.0</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>833</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>842</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>851</td>
<td>.2</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>878</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>936</td>
<td>.2</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>943</td>
<td>.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>993</td>
<td>1.0</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,037</td>
<td>3.5</td>
</tr>
</tbody>
</table>
TABLE D-1 (Continued)

<table>
<thead>
<tr>
<th>Coal Bed</th>
<th>County and State</th>
<th>Sample Depth (ft)</th>
<th>Total Gas Content (cm³/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarion</td>
<td>Barbour, West Virginia</td>
<td>818</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>821</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Allegheny, Pennsylvania</td>
<td>966</td>
<td>2.5</td>
</tr>
<tr>
<td>Coalburg</td>
<td>Mingo, West Virginia</td>
<td>506</td>
<td>.1</td>
</tr>
<tr>
<td>Emery</td>
<td>Garfield, Utah</td>
<td>273</td>
<td>.4</td>
</tr>
<tr>
<td>Elkorn</td>
<td>Pike, Kentucky</td>
<td>400</td>
<td>2.0</td>
</tr>
<tr>
<td>Flat Canyon</td>
<td>Emery, Utah</td>
<td>1,367</td>
<td>.3</td>
</tr>
<tr>
<td>Freeport (Upper)</td>
<td>Westmoreland, Pennsylvania</td>
<td>598</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Allegheny, Pennsylvania</td>
<td>603</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Greene, Pennsylvania</td>
<td>704</td>
<td>.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>706</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>892</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>936</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,058</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,071</td>
<td>3.4</td>
</tr>
<tr>
<td>Fruitland</td>
<td>San Juan, New Mexico</td>
<td>1,475</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,485</td>
<td>3.9</td>
</tr>
<tr>
<td>Gibson</td>
<td>Emery, Utah</td>
<td>2,339</td>
<td>1.3</td>
</tr>
<tr>
<td>Hartshorne(Lower)</td>
<td>LeFlore, Oklahoma</td>
<td>175</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>252</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>313</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>356</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>488</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>489</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>516</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>553</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>556</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>561</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>571</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>892</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td>Haskell, Oklahoma</td>
<td>1,295</td>
<td>17.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,439</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,440</td>
<td>15.4</td>
</tr>
<tr>
<td>Hartshorne(Upper)</td>
<td></td>
<td>822</td>
<td>15.1</td>
</tr>
<tr>
<td>Hiawatha</td>
<td>Emery, Utah</td>
<td>356</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>448</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>616</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>872</td>
<td>.1</td>
</tr>
<tr>
<td>Illinois No. 5</td>
<td>Jefferson, Illinois</td>
<td>793</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Wayne, Illinois</td>
<td>1,010</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,066</td>
<td>2.7</td>
</tr>
<tr>
<td>Illinois No. 6</td>
<td>Jefferson, Illinois</td>
<td>733</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Wayne, Illinois</td>
<td>900</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>969</td>
<td>3.4</td>
</tr>
<tr>
<td>Indiana No. 3</td>
<td></td>
<td>1,287</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,290</td>
<td>3.1</td>
</tr>
<tr>
<td>Indiana No. 6</td>
<td>Knox, Indiana</td>
<td>340</td>
<td>2.8</td>
</tr>
<tr>
<td>Indiana No. 7</td>
<td></td>
<td>360</td>
<td>1.7</td>
</tr>
</tbody>
</table>
**TABLE D-1 (Continued)**

<table>
<thead>
<tr>
<th>Coal Bed</th>
<th>County and State</th>
<th>Sample Depth (ft)</th>
<th>Total Gas Content (cm³/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivie (Upper)</td>
<td>Emery, Utah</td>
<td>81</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>275</td>
<td>.1</td>
</tr>
<tr>
<td>Kenilworth</td>
<td></td>
<td>245</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,448</td>
<td>11.1</td>
</tr>
<tr>
<td>Kittanning (Upper)</td>
<td>Barbour, West Virginia</td>
<td>706</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Allegheny, Pennsylvania</td>
<td>834</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Buckhannon, West Virginia</td>
<td>838</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>(Middle)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upshur, West Virginia</td>
<td>908</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>909</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>911</td>
<td>2.3</td>
</tr>
<tr>
<td>Kittanning (Lower)</td>
<td>Armstrong, Pennsylvania</td>
<td>323</td>
<td>.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>324</td>
<td>.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>325</td>
<td>.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>326</td>
<td>.6</td>
</tr>
<tr>
<td></td>
<td>Indiana, Pennsylvania</td>
<td>621</td>
<td>.8</td>
</tr>
<tr>
<td></td>
<td>Barbour, West Virginia</td>
<td>801</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Westmoreland, Pennsylvania</td>
<td>1,057</td>
<td>11.2</td>
</tr>
<tr>
<td>Mary Lee (UB)</td>
<td>Walker, Alabama</td>
<td>639</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>721</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Jefferson, Alabama</td>
<td>1,084</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Tuscaloosa, Alabama</td>
<td>1,700</td>
<td>12.2</td>
</tr>
<tr>
<td>Mary Lee (LB)</td>
<td>Jefferson, Alabama</td>
<td>1,086</td>
<td>23.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,099</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>Tuscaloosa, Alabama</td>
<td>1,704</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,705</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,706</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,910</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,929</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,185</td>
<td>17.4</td>
</tr>
<tr>
<td>Menefee</td>
<td>LaPlata, Colorado</td>
<td>295</td>
<td>.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>310</td>
<td>.3</td>
</tr>
<tr>
<td>Mercer</td>
<td>Allegheny, Pennsylvania</td>
<td>1,103</td>
<td>1.1</td>
</tr>
<tr>
<td>New Castle</td>
<td>Tuscaloosa, Alabama</td>
<td>2,137</td>
<td>17.5</td>
</tr>
<tr>
<td>Peach Mountain</td>
<td>Schuylkill, Pennsylvania</td>
<td>684</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>686</td>
<td>7.4</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>Greene, Pennsylvania</td>
<td>313</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Washington, Pennsylvania</td>
<td>427</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Greene, Pennsylvania</td>
<td>675</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>680</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>770</td>
<td>5.9</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>Marion, West Virginia</td>
<td>848</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>850</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>850</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Wetzel, West Virginia</td>
<td>1,147</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,260</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,267</td>
<td>-</td>
</tr>
<tr>
<td>Coal Bed</td>
<td>County and State</td>
<td>Sample Depth (ft)</td>
<td>Total Gas Content (cm³/g)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------</td>
<td>------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>Greene, Pennsylvania</td>
<td>1,273</td>
<td>6.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,276</td>
<td>6.9</td>
</tr>
<tr>
<td>Pittsburgh(Rider)</td>
<td>Marion, West Virginia</td>
<td>839</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;</td>
<td>Wetzel, West Virginia</td>
<td>1,131</td>
<td>1.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Greene, Pennsylvania</td>
<td>1,272</td>
<td>6.8</td>
</tr>
<tr>
<td>Pocahontas No. 3</td>
<td>Wyoming, West Virginia</td>
<td>778</td>
<td>8.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>Buchanan, Virginia</td>
<td>930</td>
<td>10.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,316</td>
<td>12.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,430</td>
<td>13.6</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,518</td>
<td>14.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,528</td>
<td>14.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,551</td>
<td>17.3</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,554</td>
<td>16.6</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,589</td>
<td>16.3</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,621</td>
<td>11.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,621</td>
<td>12.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,737</td>
<td>11.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,764</td>
<td>17.8</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,845</td>
<td>10.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,999</td>
<td>15.8</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2,022</td>
<td>16.4</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2,036</td>
<td>17.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2,108</td>
<td>13.8</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2,143</td>
<td>10.4</td>
</tr>
<tr>
<td>Pond Creek</td>
<td>Pike, Kentucky</td>
<td>125</td>
<td>2.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>Martin, Kentucky</td>
<td>400</td>
<td>2.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>Pike, Kentucky</td>
<td>500</td>
<td>1.2</td>
</tr>
<tr>
<td>Pratt</td>
<td>Tuscaloosa, Alabama</td>
<td>1,365</td>
<td>15.1</td>
</tr>
<tr>
<td>Redstone</td>
<td>Monongalia, West Virginia</td>
<td>736</td>
<td>3.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>744</td>
<td>4.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Marion, West Virginia</td>
<td>836</td>
<td>2.4</td>
</tr>
<tr>
<td>&quot;</td>
<td>Wetzel, West Virginia</td>
<td>1,099</td>
<td>.8</td>
</tr>
<tr>
<td>Rock Canyon(Upper)</td>
<td>Emery, Utah</td>
<td>2,339</td>
<td>2.7</td>
</tr>
<tr>
<td>Rock Canyon(Lower)</td>
<td>&quot;</td>
<td>2,352</td>
<td>5.4</td>
</tr>
<tr>
<td>Sewell</td>
<td>Raleigh, West Virginia</td>
<td>680</td>
<td>9.3</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>700</td>
<td>4.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Braxton, West Virginia</td>
<td>981</td>
<td>2.7</td>
</tr>
<tr>
<td>Sewickley</td>
<td>Monongalia, West Virginia</td>
<td>60</td>
<td>.7</td>
</tr>
<tr>
<td>&quot;</td>
<td>Washington, Pennsylvania</td>
<td>449</td>
<td>1.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>Greene, Pennsylvania</td>
<td>669</td>
<td>2.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Monongalia, West Virginia</td>
<td>670</td>
<td>4.6</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>675</td>
<td>4.7</td>
</tr>
<tr>
<td>&quot;</td>
<td>Marion, West Virginia</td>
<td>740</td>
<td>1.6</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>740</td>
<td>2.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Monongalia, West Virginia</td>
<td>823</td>
<td>1.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>Wetzel, West Virginia</td>
<td>1,039</td>
<td>1.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Monongalia, West Virginia</td>
<td>1,145</td>
<td>1.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>Greene, Pennsylvania</td>
<td>1,176</td>
<td>4.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1,182</td>
<td>2.4</td>
</tr>
<tr>
<td>Coal Bed</td>
<td>County and State</td>
<td>Sample Depth (ft)</td>
<td>Total Gas Content (cm³/g)</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Sewickley</td>
<td>Greene, Pennsylvania</td>
<td>1,591</td>
<td>4.2</td>
</tr>
<tr>
<td>Smirl</td>
<td>Garfield, Utah</td>
<td>442</td>
<td>.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>Kane, Utah</td>
<td>752</td>
<td>.1</td>
</tr>
<tr>
<td>Sunnyside(Lower)</td>
<td>Emery, Utah</td>
<td>1,798</td>
<td>4.6</td>
</tr>
<tr>
<td>Tunnel</td>
<td>Schuylkill, Pennsylvania</td>
<td>602</td>
<td>14.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>604</td>
<td>12.6</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>606</td>
<td>18.5</td>
</tr>
<tr>
<td>Vermejo</td>
<td>Huerfano, Colorado</td>
<td>111</td>
<td>.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>155</td>
<td>.2</td>
</tr>
<tr>
<td>Wadge</td>
<td>Routt, Colorado</td>
<td>335</td>
<td>.3</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,284</td>
<td>0</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,393</td>
<td>.1</td>
</tr>
<tr>
<td>Waynesburg</td>
<td>Monongalia, West Virginia</td>
<td>400</td>
<td>2.8</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>402</td>
<td>2.7</td>
</tr>
<tr>
<td>&quot;</td>
<td>Greene, Pennsylvania</td>
<td>458</td>
<td>3.8</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>971</td>
<td>3.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>973</td>
<td>4.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,231</td>
<td>3.5</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,553</td>
<td>4.1</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,667</td>
<td>2.7</td>
</tr>
<tr>
<td>Wolf Creek</td>
<td>Routt, Colorado</td>
<td>488</td>
<td>0</td>
</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>1,123</td>
<td>.2</td>
</tr>
</tbody>
</table>
APPENDIX E

Gas Content of Non-Bituminous Coals
GAS CONTENT OF NON-BITUMINOUS COALS

It has been shown that the methane content of bituminous coals is a function of moisture content.¹

\[ \frac{V_d}{V_w} = C_0 m + 1 \]

where \( V_d \) & \( V_w \) are the volumes (cm\(^3\) (STP)/gm) of methane adsorbed in dry and moist coal, respectively; \( C_0 \) = empirically determined constant = 0.31 for bituminous coals; and \( m \) = moisture content of the coal in wt %. Thus, for bituminous coals, the equation becomes

\[ \frac{V_w}{V_d} = \frac{1}{1 + 0.31m} \]

A recent (June 1979) scan of existing USGS data² indicated the following mean moisture contents for various ranks of coals:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Mean Moisture Content (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous</td>
<td>4.53</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>16.01</td>
</tr>
<tr>
<td>Lignite</td>
<td>37.64</td>
</tr>
</tbody>
</table>

The gas content of dry bituminous coal would then become 2.4 times the quantity contained at a moisture content of 4.53 percent. It is recognized that although this empirical relationship is for bituminous coals, the extension of its application to non-bituminous coals probably represents the most logical approach to determining their gas content. The resulting gas content of subbituminous coal and lignite then becomes 16.8 and 7.9 percent, respectively, of that for dry bituminous coals.


In summary, if the gas content of wet bituminous coals is 200 ft$^3$/ton (6.25 cm$^3$/gm), as agreed upon by the study participants, the subbituminous coal and lignite would contain 80 and 40 cubic feet per ton, respectively.

Discussion of these volumes, along with the general agreement with a single value for lesser rank coals supplied by an independent consulting firm, resulted in agreement on the gas content of coal for the purpose of this study as follows:

<table>
<thead>
<tr>
<th>Rank</th>
<th>ft$^3$/ton</th>
<th>(cm$^3$/gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous</td>
<td>200</td>
<td>6.25</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>80</td>
<td>2.50</td>
</tr>
<tr>
<td>Lignite</td>
<td>40</td>
<td>1.25</td>
</tr>
</tbody>
</table>
APPENDIX F

Capital Costs
### TABLE F-1

**Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 10 MCF/D Well (Base Case)**

*(Constant 1979 Dollars)*

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lease, R.O.W. Location</td>
<td>13.8</td>
<td>13.8</td>
</tr>
<tr>
<td>2 Drill, Case, Cement</td>
<td>13.7</td>
<td>54.6</td>
</tr>
<tr>
<td>3 Frac (1500 BBL)</td>
<td>-</td>
<td>27.8</td>
</tr>
<tr>
<td>4 Well Head Compr.</td>
<td>7.9</td>
<td>4.5</td>
</tr>
<tr>
<td>5 Water Disposal</td>
<td>4.0</td>
<td>16.4</td>
</tr>
<tr>
<td>6 Water Lines, Pumps</td>
<td>21.6</td>
<td>2.2</td>
</tr>
<tr>
<td>7 Gas Lines (Internal)</td>
<td>7.5</td>
<td>17.5</td>
</tr>
<tr>
<td>8 Power Lines (Internal)</td>
<td>4.3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>59.0</strong></td>
<td><strong>139.3</strong></td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Contingency (10%)</td>
<td>5.9</td>
<td>13.9</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>21.8</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total (Base Case)</strong></td>
<td><strong>64.9</strong></td>
<td><strong>175.0</strong></td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.*
**TABLE F-2**

Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 25 MCF/D Well

(Base Case)

(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lease, R.O.W. Location</td>
<td>13.8</td>
<td>13.8</td>
</tr>
<tr>
<td>2 Drill, Case, Cement</td>
<td>13.7</td>
<td>54.6</td>
</tr>
<tr>
<td>3 Frac (1500 BBL)</td>
<td>-</td>
<td>27.8</td>
</tr>
<tr>
<td>4 Well Head Compr.</td>
<td>12.4</td>
<td>4.5</td>
</tr>
<tr>
<td>5 Water Disposal</td>
<td>4.0</td>
<td>16.4</td>
</tr>
<tr>
<td>6 Water Lines, Pumps</td>
<td>21.6</td>
<td>2.2</td>
</tr>
<tr>
<td>7 Gas Lines (Internal)</td>
<td>8.8</td>
<td>20.6</td>
</tr>
<tr>
<td>8 Power Lines (Internal)</td>
<td>8.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>68.7</td>
<td>142.9</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>6.9</td>
<td>14.3</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>23.3</td>
</tr>
<tr>
<td>Total (Base Case)</td>
<td>75.6</td>
<td>180.5</td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-3

Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 50 MCF/D Well
(Base Case)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Lease, R.O.W. Location</td>
<td>13.8</td>
<td>13.8</td>
</tr>
<tr>
<td>2  Drill, Case, Cement</td>
<td>13.7</td>
<td>54.6</td>
</tr>
<tr>
<td>3  Frac (1500 BBL)</td>
<td>-</td>
<td>27.8</td>
</tr>
<tr>
<td>4  Well Head Compr.</td>
<td>17.6</td>
<td>4.5</td>
</tr>
<tr>
<td>5  Water Disposal</td>
<td>4.0</td>
<td>16.4</td>
</tr>
<tr>
<td>6  Water Lines, Pumps</td>
<td>21.6</td>
<td>2.2</td>
</tr>
<tr>
<td>7  Gas Lines (Internal)</td>
<td>10.0</td>
<td>23.4</td>
</tr>
<tr>
<td>8  Power Lines (Internal)</td>
<td>13.9</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Subtotal                   | 80.8     | 146.2      |

Contingency (10%)           | 8.1      | 14.6       |
Overhead (10%)*             |          | 25.0       |

Total (Base Case)           | 88.9     | 185.8      |

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-4

Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 75 MCF/D Well (Base Case) (Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lease, R.O.W. Location</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>2 Drill, Case, Cement</td>
<td>13.7</td>
<td>54.6</td>
</tr>
<tr>
<td>3 Frac (1500 BBL)</td>
<td></td>
<td>27.8</td>
</tr>
<tr>
<td>4 Well Head Compr.</td>
<td>21.5</td>
<td>4.5</td>
</tr>
<tr>
<td>5 Water Disposal</td>
<td>4.0</td>
<td>16.4</td>
</tr>
<tr>
<td>6 Water Lines, Pumps</td>
<td>21.6</td>
<td>2.2</td>
</tr>
<tr>
<td>7 Gas Lines (Internal)</td>
<td>10.8</td>
<td>25.1</td>
</tr>
<tr>
<td>8 Power Lines (Internal)</td>
<td>19.1</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td><strong>148.3</strong></td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>9.1</td>
<td>14.8</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td><strong>Total (Base Case)</strong></td>
<td><strong>189.4</strong></td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
### TABLE F-5

**Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 100 MCF/D Well**  
(Base Case)  
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Per-Well Costs (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangible</td>
</tr>
<tr>
<td>1 Lease, R.O.W. Location</td>
<td></td>
</tr>
<tr>
<td>2 Drill, Case, Cement</td>
<td>13.7</td>
</tr>
<tr>
<td>3 Frac (1500 BBL)</td>
<td></td>
</tr>
<tr>
<td>4 Well Head Compr.</td>
<td>24.9</td>
</tr>
<tr>
<td>5 Water Disposal</td>
<td>4.0</td>
</tr>
<tr>
<td>6 Water Lines, Pumps</td>
<td>21.6</td>
</tr>
<tr>
<td>7 Gas Lines (Internal)</td>
<td>11.4</td>
</tr>
<tr>
<td>8 Power Lines (Internal)</td>
<td>24.1</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal</td>
<td>99.7</td>
<td>150.1</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (Base Case)</td>
<td>109.7</td>
<td>192.6</td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-6

Vertical Wells Project -- Estimated Capital Investment for a 3,000-Foot, 150 MCF/D Well (Base Case) (Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Per-Well Costs (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangible</td>
</tr>
<tr>
<td>1 Lease, R.O.W. Location</td>
<td>-</td>
</tr>
<tr>
<td>2 Drill, Case, Cement</td>
<td>13.7</td>
</tr>
<tr>
<td>3 Frac (1500 BBL)</td>
<td>-</td>
</tr>
<tr>
<td>4 Well Head Compr.</td>
<td>30.5</td>
</tr>
<tr>
<td>5 Water Disposal</td>
<td>4.0</td>
</tr>
<tr>
<td>6 Water Lines, Pumps</td>
<td>21.6</td>
</tr>
<tr>
<td>7 Gas Lines (Internal)</td>
<td>12.2</td>
</tr>
<tr>
<td>8 Power Lines (Internal)</td>
<td>33.7</td>
</tr>
</tbody>
</table>

Subtotal                                      115.7  152.8

Contingency (10%)                              11.6   15.3

Overhead (10%)*                                -      29.5

Total (Base Case)                              127.3  197.6

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-7
Vertical Wells Project -- Estimated Capital Investment for a 10 MCF/D Well Project (Add-on Items) (Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Compressor (Central)</td>
<td>87.7</td>
<td>5.0</td>
</tr>
<tr>
<td>2 Scrubber</td>
<td>130.0</td>
<td>125.0</td>
</tr>
<tr>
<td>3 Trunk Line (5 Miles)</td>
<td>66.0</td>
<td>150.2</td>
</tr>
<tr>
<td>4 Primary Power (10,000 ft.)</td>
<td>60.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>343.7</td>
<td>300.2</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>34.4</td>
<td>30.0</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>70.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>378.1</strong></td>
<td><strong>401.0</strong></td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
### TABLE F-8

Vertical Wells Project -- Estimated Capital Investment for a 25 MCF/D Well Project
(Add-on Items)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Per-Project Costs (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangible</td>
</tr>
<tr>
<td>1 Compressor (Central)</td>
<td>115.0</td>
</tr>
<tr>
<td>2 Scrubber</td>
<td>219.5</td>
</tr>
<tr>
<td>3 Trunk Line (5 Miles)</td>
<td>85.8</td>
</tr>
<tr>
<td>4 Primary Power (10,000 ft.)</td>
<td>60.0</td>
</tr>
</tbody>
</table>

Subtotal               | 480.3         | 319.6      |
Contingency (10%)       | 48.0          | 32.0       |
Overhead (10%)*         |               | 88.0       |
Total                   | 528.3         | 439.6      |

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-9

Vertical Wells Project -- Estimated Capital
Investment for a 50 MCF/D Well Project
(Add-on Items)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Per-Project Costs (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangible</td>
</tr>
<tr>
<td>Compressor (Central)</td>
<td>154.0</td>
</tr>
<tr>
<td>Scrubber</td>
<td>340.0</td>
</tr>
<tr>
<td>Trunk Line (5 Miles)</td>
<td>85.8</td>
</tr>
<tr>
<td>Primary Power (10,000 ft.)</td>
<td>60.0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>639.8</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>64.0</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>703.8</td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
**TABLE F-10**

`Vertical Wells Project -- Estimated Capital Investment for a 75 MCF/D Well Project (Add-on Items)` *(Constant 1979 Dollars)*

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> Compressor (Central)</td>
<td>177.2</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>2</strong> Scrubber</td>
<td>400.0</td>
<td>190.0</td>
</tr>
<tr>
<td><strong>3</strong> Trunk Line (5 Miles)</td>
<td>85.8</td>
<td>152.6</td>
</tr>
<tr>
<td><strong>4</strong> Primary Power (10,000 ft.)</td>
<td>60.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

**Subtotal**

<table>
<thead>
<tr>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>723.0</td>
<td>367.6</td>
</tr>
</tbody>
</table>

**Contingency (10%)**

<table>
<thead>
<tr>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.3</td>
<td>36.8</td>
</tr>
</tbody>
</table>

**Overhead (10%)**

<table>
<thead>
<tr>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120.0</td>
</tr>
</tbody>
</table>

**Total**

<table>
<thead>
<tr>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>795.3</td>
<td>524.4</td>
</tr>
</tbody>
</table>

---

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.*
Table F-11

Vertical Wells Project -- Estimated Capital Investment for a 100 MCF/D Well Project (Add-on Items) (Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Tangible</th>
<th>Intangible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Compressor (Central)</td>
<td>196.3</td>
<td>5.0</td>
</tr>
<tr>
<td>2  Scrubber</td>
<td>527.9</td>
<td>180.3</td>
</tr>
<tr>
<td>3  Trunk Line (5 Miles)</td>
<td>105.6</td>
<td>184.8</td>
</tr>
<tr>
<td>4  Primary Power (10,000 ft.)</td>
<td>60.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>889.8</td>
<td>390.1</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>89.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Overhead (10%)*</td>
<td></td>
<td>140.8</td>
</tr>
<tr>
<td>Total</td>
<td>978.8</td>
<td>569.9</td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
TABLE F-12

Vertical Wells Project -- Estimated Capital Investment for a 150 MCF/D Well Project
(Add-on Items)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Per-Project Costs (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangible</td>
</tr>
<tr>
<td><strong>Compressor (Central)</strong></td>
<td>227.0</td>
</tr>
<tr>
<td><strong>Scrubber</strong></td>
<td>620.0</td>
</tr>
<tr>
<td><strong>Trunk Line</strong></td>
<td>105.6</td>
</tr>
<tr>
<td>(5 Miles)</td>
<td></td>
</tr>
<tr>
<td><strong>Primary Power</strong></td>
<td>60.0</td>
</tr>
<tr>
<td>(10,000 ft.)</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>1012.6</td>
</tr>
<tr>
<td><strong>Contingency (10%)</strong></td>
<td>101.3</td>
</tr>
<tr>
<td><strong>Overhead (10%)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1113.9</td>
</tr>
</tbody>
</table>

*Overhead calculated as 10% of the summation of tangible costs, intangible costs, and their respective contingency costs.
APPENDIX G

Operating Costs
### TABLE G-1

**Vertical Wells Project -- Estimated Operating Costs for a 3,000-Foot, 10 MCF/D Well**
*(Constant 1979 Dollars)*

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>1043.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>1400.0</td>
</tr>
<tr>
<td><strong>Overhead (20%)</strong></td>
<td>488.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2931.6</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor -</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day;</td>
<td></td>
</tr>
<tr>
<td>30¢/mile;</td>
<td></td>
</tr>
<tr>
<td>350 days/year = $10,500</td>
<td></td>
</tr>
<tr>
<td><strong>Leasing costs - 2 Trucks</strong></td>
<td>4000</td>
</tr>
<tr>
<td><strong>Miscellaneous Tools</strong></td>
<td>750</td>
</tr>
<tr>
<td><strong>Road Maintenance</strong></td>
<td>3000</td>
</tr>
<tr>
<td><strong>Overhead (20%)</strong></td>
<td>9850.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>59100.0</td>
</tr>
<tr>
<td><strong>B ADD-ONS:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Central Compressor Maintenance</td>
<td>9650.0</td>
</tr>
<tr>
<td>2. Scrubber - Maintenance</td>
<td>14300.0</td>
</tr>
<tr>
<td>3. Scrubber - Glycol</td>
<td>1168.0</td>
</tr>
<tr>
<td><strong>Overhead (20%)</strong></td>
<td>5023.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30141.6</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.*
### TABLE G-2

**Vertical Wells Project -- Estimated Operating Costs for a 3,000-Foot, 25 MCF/D Well**

*(Constant 1979 Dollars)*

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>1391.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>1900.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>658.2</td>
</tr>
<tr>
<td>Total</td>
<td>3949.2</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor -</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day; 30¢/mile; 350 days/year = $10,500</td>
<td></td>
</tr>
<tr>
<td>Leasing costs - 2 Trucks = 4,000</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Tools = 750</td>
<td></td>
</tr>
<tr>
<td>Road Maintenance = 3,000</td>
<td>18250.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>9850.0</td>
</tr>
<tr>
<td>Total</td>
<td>59100.0</td>
</tr>
<tr>
<td><strong>B ADD-ONS:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Central Compressor Maintenance</td>
<td>12650.0</td>
</tr>
<tr>
<td>2. Scrubber - Maintenance</td>
<td>24145.0</td>
</tr>
<tr>
<td>3. Scrubber - Glycol</td>
<td>2920.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>7943.0</td>
</tr>
<tr>
<td>Total</td>
<td>47658.0</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.*
### TABLE G-3

**Vertical Wells Project -- Estimated Operating Costs for a 3,000-Foot, 50 MCF/D Well**  
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A  BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>1739.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>2500.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>847.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5086.8</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor -</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day; 30¢/mile; 350 days/year = $10,500</td>
<td></td>
</tr>
<tr>
<td>Leasing costs - 2 Trucks =</td>
<td>4,000</td>
</tr>
<tr>
<td>Miscellaneous Tools =</td>
<td>750</td>
</tr>
<tr>
<td>Road Maintenance =</td>
<td>18250.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>9850.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>59100.0</td>
</tr>
</tbody>
</table>

| **B  ADD-ONS:** |                 |
| 1. Central Compressor Maintenance | 16940.0 |
| 2. Scrubber - Maintenance | 37400.0 |
| 3. Scrubber - Glycol | 5840.0 |
| Overhead (20%) | 12036.0 |
| **Total** | 72216.0 |

*See Estimation of Costs and DCF Analysis sections of Chapter Five.*
# TABLE G-4

**Vertical Wells Project -- Estimated Operating Costs for a 3,000-Foot, 75 MCF/D Well**

(Co[nstant 1979 Dollars)

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>2087.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>2900.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>997.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5984.4</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor -</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day;</td>
<td></td>
</tr>
<tr>
<td>30¢/mile;</td>
<td></td>
</tr>
<tr>
<td>350 days/year = $10,500</td>
<td></td>
</tr>
<tr>
<td>Leasing costs - 2 Trucks = 4,000</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Tools = 750</td>
<td></td>
</tr>
<tr>
<td>Road Maintenance = 3,000</td>
<td>18250.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>9850.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>59100.0</td>
</tr>
<tr>
<td><strong>B ADD-ONS:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Central Compressor Maintenance</td>
<td>19492.0</td>
</tr>
<tr>
<td>2. Scrubber - Maintenance</td>
<td>44000.0</td>
</tr>
<tr>
<td>3. Scrubber - Glycol</td>
<td>8760.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>14450.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>86702.4</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
### TABLE G-5

Vertical Wells Project -- Estimated Operating Costs for a 3,000-Foot, 100 MCF/D Well (Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>2609.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>3300.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>1181.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7090.8</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor -</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day;</td>
<td></td>
</tr>
<tr>
<td>30¢/mile; 350 days/year</td>
<td>$10,500</td>
</tr>
<tr>
<td>Leasing costs - 2 Trucks</td>
<td>4,000</td>
</tr>
<tr>
<td>Miscellaneous Tools</td>
<td>750</td>
</tr>
<tr>
<td>Road Maintenance</td>
<td>3,000</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>9850.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>59100.0</td>
</tr>
<tr>
<td><strong>B ADD-ONS:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Central Compressor Maintenance</td>
<td>21593.0</td>
</tr>
<tr>
<td>2. Scrubber - Maintenance</td>
<td>58069.0</td>
</tr>
<tr>
<td>3. Scrubber - Glycol</td>
<td>11680.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>18268.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>109610.4</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Dollars Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A BASE CASE:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Per Well Costs:</td>
<td></td>
</tr>
<tr>
<td>(i) Power</td>
<td>3479.0</td>
</tr>
<tr>
<td>(ii) Maintenance</td>
<td>3900.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>1475.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8854.8</td>
</tr>
<tr>
<td>2. Per Project Costs:*</td>
<td></td>
</tr>
<tr>
<td>(i) Labor</td>
<td></td>
</tr>
<tr>
<td>240 days @ $80/day</td>
<td></td>
</tr>
<tr>
<td>50 days @ $120/day</td>
<td></td>
</tr>
<tr>
<td>36 days @ $160/day</td>
<td>31000.0</td>
</tr>
<tr>
<td>(ii) Other Costs -</td>
<td></td>
</tr>
<tr>
<td>2 Trucks - 50 miles/day;</td>
<td></td>
</tr>
<tr>
<td>30¢/mile;</td>
<td></td>
</tr>
<tr>
<td>350 days/year = $10,500</td>
<td></td>
</tr>
<tr>
<td>Leasing costs - 2 Trucks = 4,000</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Tools = 750</td>
<td></td>
</tr>
<tr>
<td>Road Maintenance = 3,000</td>
<td></td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>59100.0</td>
</tr>
<tr>
<td><strong>B ADD-ONS:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Central Compressor Maintenance</td>
<td>24970.0</td>
</tr>
<tr>
<td>2. Scrubber - Maintenance</td>
<td>68200.0</td>
</tr>
<tr>
<td>3. Scrubber - Glycol</td>
<td>17520.0</td>
</tr>
<tr>
<td>Overhead (20%)</td>
<td>22138.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>132828.0</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
APPENDIX H
Yearly Capital and Operating Costs
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>778.8</td>
<td>2100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>649.0</td>
<td>1750.0</td>
<td>1.70</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>129.8</td>
<td>350.0</td>
<td>1.78</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>129.8</td>
<td>350.0</td>
<td>1.87</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>129.8</td>
<td>350.0</td>
<td>1.95</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>129.8</td>
<td>350.0</td>
<td>2.04</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>129.8</td>
<td>350.0</td>
<td>2.12</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>129.8</td>
<td>350.0</td>
<td>2.21</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>129.8</td>
<td>350.0</td>
<td>2.29</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>129.8</td>
<td>350.0</td>
<td>2.38</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>129.8</td>
<td>350.0</td>
<td>2.46</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>129.8</td>
<td>350.0</td>
<td>2.55</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>129.8</td>
<td>350.0</td>
<td>2.63</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>519.2</td>
<td>1640.0</td>
<td>2.12</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>129.8</td>
<td>374.0</td>
<td>2.12</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>194.7</td>
<td>549.0</td>
<td>2.17</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>129.8</td>
<td>374.0</td>
<td>2.17</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>194.7</td>
<td>549.0</td>
<td>2.21</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>129.8</td>
<td>374.0</td>
<td>2.21</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>194.7</td>
<td>549.0</td>
<td>2.25</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>129.8</td>
<td>374.0</td>
<td>2.25</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.*
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>20</td>
<td>907.2</td>
<td>2166.0</td>
<td>0.80</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>756.0</td>
<td>1805.0</td>
<td>0.84</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>151.2</td>
<td>361.0</td>
<td>0.89</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>151.2</td>
<td>361.0</td>
<td>0.93</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>151.2</td>
<td>361.0</td>
<td>0.98</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>151.2</td>
<td>361.0</td>
<td>1.02</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>151.2</td>
<td>361.0</td>
<td>1.07</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>151.2</td>
<td>361.0</td>
<td>1.11</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>151.2</td>
<td>361.0</td>
<td>1.16</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>151.2</td>
<td>361.0</td>
<td>1.20</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>151.2</td>
<td>361.0</td>
<td>1.25</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>151.2</td>
<td>361.0</td>
<td>1.29</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>151.2</td>
<td>361.0</td>
<td>1.32</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>604.8</td>
<td>1684.0</td>
<td>1.02</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>151.2</td>
<td>385.0</td>
<td>1.02</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>226.8</td>
<td>565.5</td>
<td>1.05</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>151.2</td>
<td>385.0</td>
<td>1.05</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>226.8</td>
<td>565.5</td>
<td>1.07</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>151.2</td>
<td>385.0</td>
<td>1.07</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>226.8</td>
<td>565.5</td>
<td>1.09</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>151.2</td>
<td>385.0</td>
<td>1.09</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
TABLE H-3
Vertical Wells Project*
3,000-Foot, 50 MCF/D Well
(Raw Gas On Site)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Tangible Total Active Wells Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>1066.8</td>
<td>2229.6</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>889.9</td>
<td>1858.0</td>
<td>0.46</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.49</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.52</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.55</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.58</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.61</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.64</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.67</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.79</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.73</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.76</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>177.8</td>
<td>371.6</td>
<td>0.79</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>711.2</td>
<td>1726.4</td>
<td>0.61</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>177.8</td>
<td>395.6</td>
<td>0.61</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>266.7</td>
<td>581.4</td>
<td>0.63</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>177.8</td>
<td>395.6</td>
<td>0.63</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>266.7</td>
<td>581.4</td>
<td>0.64</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>177.8</td>
<td>395.6</td>
<td>0.64</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>266.7</td>
<td>581.4</td>
<td>0.65</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>177.8</td>
<td>395.6</td>
<td>0.65</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
### TABLE H-4

**Vertical Wells Project***

3,000-Foot, 75 MCF/D Well

(Raw Gas On Site)

(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1197.6</td>
<td>2272.8</td>
<td>0.34</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>998.0</td>
<td>1894.0</td>
<td>0.34</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>199.6</td>
<td>378.8</td>
<td>0.37</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>199.6</td>
<td>378.8</td>
<td>0.39</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>199.6</td>
<td>378.8</td>
<td>0.42</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>199.6</td>
<td>378.8</td>
<td>0.44</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>199.6</td>
<td>378.8</td>
<td>0.47</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>199.6</td>
<td>378.8</td>
<td>0.49</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>199.6</td>
<td>378.8</td>
<td>0.52</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>199.6</td>
<td>378.8</td>
<td>0.54</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>199.6</td>
<td>378.8</td>
<td>0.57</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>199.6</td>
<td>378.8</td>
<td>0.59</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>199.6</td>
<td>378.8</td>
<td>0.62</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>798.4</td>
<td>1755.2</td>
<td>0.47</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>199.6</td>
<td>402.8</td>
<td>0.47</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>299.4</td>
<td>592.2</td>
<td>0.48</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>199.6</td>
<td>402.8</td>
<td>0.48</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>299.4</td>
<td>592.2</td>
<td>0.49</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>199.6</td>
<td>402.8</td>
<td>0.49</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>299.4</td>
<td>592.2</td>
<td>0.51</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>199.6</td>
<td>402.8</td>
<td>0.51</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>–</td>
<td>396.0</td>
<td>–</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>316.4</td>
<td>2311.2</td>
<td></td>
<td>0.29</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1097.0</td>
<td>1926.0</td>
<td>0.29</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>219.4</td>
<td>385.2</td>
<td>0.31</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>219.4</td>
<td>385.2</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>219.4</td>
<td>385.2</td>
<td>0.35</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>219.4</td>
<td>385.2</td>
<td>0.37</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>219.4</td>
<td>385.2</td>
<td>0.39</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>219.4</td>
<td>385.2</td>
<td>0.41</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>219.4</td>
<td>385.2</td>
<td>0.43</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>219.4</td>
<td>385.2</td>
<td>0.45</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>219.4</td>
<td>385.2</td>
<td>0.47</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>219.4</td>
<td>385.2</td>
<td>0.49</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>219.4</td>
<td>385.2</td>
<td>0.51</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>877.6</td>
<td>1780.8</td>
<td>0.39</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>219.4</td>
<td>409.2</td>
<td>0.39</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>329.1</td>
<td>601.8</td>
<td>0.40</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>219.4</td>
<td>409.2</td>
<td>0.40</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>329.1</td>
<td>601.8</td>
<td>0.41</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>219.4</td>
<td>409.2</td>
<td>0.41</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>329.1</td>
<td>601.8</td>
<td>0.42</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>219.4</td>
<td>409.2</td>
<td>0.42</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>–</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
**TABLE H-6**

Vertical Wells Project*  
3,000-Foot, 150 MCF/D Well  
(Raw Gas On Site)  
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>20</td>
<td>1527.6</td>
<td>2371.2</td>
<td>0.23</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1273.0</td>
<td>1976.0</td>
<td>0.23</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>254.6</td>
<td>395.2</td>
<td>0.24</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>254.6</td>
<td>395.2</td>
<td>0.26</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>254.6</td>
<td>395.2</td>
<td>0.27</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>254.6</td>
<td>395.2</td>
<td>0.29</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>254.6</td>
<td>395.2</td>
<td>0.30</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>254.6</td>
<td>395.2</td>
<td>0.32</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>254.6</td>
<td>395.2</td>
<td>0.33</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>254.6</td>
<td>395.2</td>
<td>0.35</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>254.6</td>
<td>395.2</td>
<td>0.36</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>254.6</td>
<td>395.2</td>
<td>0.38</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>254.6</td>
<td>395.2</td>
<td>0.39</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>1018.4</td>
<td>1820.8</td>
<td>0.30</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>254.6</td>
<td>419.2</td>
<td>0.30</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>381.9</td>
<td>616.8</td>
<td>0.31</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>254.6</td>
<td>419.2</td>
<td>0.31</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>381.9</td>
<td>616.8</td>
<td>0.32</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>254.6</td>
<td>419.2</td>
<td>0.32</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>381.9</td>
<td>616.8</td>
<td>0.33</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>254.6</td>
<td>419.2</td>
<td>0.33</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td>967.8</td>
<td>2300.5</td>
<td>2.32</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>868.0</td>
<td>1950.5</td>
<td>2.32</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>129.8</td>
<td>350.0</td>
<td>2.41</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>129.8</td>
<td>350.0</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>129.8</td>
<td>350.0</td>
<td>2.58</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>129.8</td>
<td>350.0</td>
<td>2.67</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>129.8</td>
<td>350.0</td>
<td>2.75</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>129.8</td>
<td>350.0</td>
<td>2.84</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>129.8</td>
<td>350.0</td>
<td>2.92</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>129.8</td>
<td>350.0</td>
<td>3.01</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>129.8</td>
<td>350.0</td>
<td>3.09</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>129.8</td>
<td>350.0</td>
<td>3.18</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>129.8</td>
<td>350.0</td>
<td>3.26</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>519.2</td>
<td>1640.0</td>
<td>2.75</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>129.8</td>
<td>374.0</td>
<td>2.75</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>194.7</td>
<td>549.0</td>
<td>2.80</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>129.8</td>
<td>374.0</td>
<td>2.80</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>194.7</td>
<td>549.0</td>
<td>2.84</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>129.8</td>
<td>374.0</td>
<td>2.84</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>194.7</td>
<td>549.0</td>
<td>2.88</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>129.8</td>
<td>374.0</td>
<td>2.88</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1171.3</td>
<td>2385.8</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1020.2</td>
<td>2024.8</td>
<td>1.16</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>151.2</td>
<td>361.0</td>
<td>1.21</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>151.2</td>
<td>361.0</td>
<td>1.26</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>151.2</td>
<td>361.0</td>
<td>1.31</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>151.2</td>
<td>361.0</td>
<td>1.36</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>151.2</td>
<td>361.0</td>
<td>1.41</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>151.2</td>
<td>361.0</td>
<td>1.46</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>151.2</td>
<td>361.0</td>
<td>1.51</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>151.2</td>
<td>361.0</td>
<td>1.56</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>151.2</td>
<td>361.0</td>
<td>1.61</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>151.2</td>
<td>361.0</td>
<td>1.66</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>151.2</td>
<td>361.0</td>
<td>1.71</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>604.8</td>
<td>1684.0</td>
<td>1.41</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>30</td>
<td>151.2</td>
<td>385.0</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>226.8</td>
<td>565.5</td>
<td>1.44</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>3</td>
<td>31</td>
<td>151.2</td>
<td>385.0</td>
<td>1.44</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>226.8</td>
<td>565.5</td>
<td>1.46</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>3</td>
<td>32</td>
<td>151.2</td>
<td>385.7</td>
<td>1.46</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>3</td>
<td>33</td>
<td>226.8</td>
<td>565.5</td>
<td>1.48</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>3</td>
<td>33</td>
<td>151.2</td>
<td>385.0</td>
<td>1.48</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>20</td>
<td>1418.7</td>
<td>2469.0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1240.9</td>
<td>2097.5</td>
<td>0.67</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>177.8</td>
<td>371.6</td>
<td>0.70</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>177.8</td>
<td>371.6</td>
<td>0.73</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>177.8</td>
<td>371.6</td>
<td>0.76</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>177.8</td>
<td>371.6</td>
<td>0.79</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>177.8</td>
<td>371.6</td>
<td>0.82</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>177.8</td>
<td>371.6</td>
<td>0.85</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>177.8</td>
<td>371.6</td>
<td>0.88</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>177.8</td>
<td>371.6</td>
<td>0.91</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>177.8</td>
<td>371.6</td>
<td>0.94</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>177.8</td>
<td>371.6</td>
<td>0.97</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>177.8</td>
<td>371.6</td>
<td>1.00</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>711.2</td>
<td>1726.4</td>
<td>0.82</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>177.8</td>
<td>395.6</td>
<td>0.82</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>266.7</td>
<td>581.4</td>
<td>0.83</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>177.8</td>
<td>395.6</td>
<td>0.83</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>266.7</td>
<td>581.4</td>
<td>0.85</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>177.8</td>
<td>395.6</td>
<td>0.85</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>266.7</td>
<td>581.4</td>
<td>0.86</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>177.8</td>
<td>395.6</td>
<td>0.86</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
TABLE H-10

Vertical Wells Project*
3,000-Foot, 75 MCF/D Well
(Gas Cleaned and Delivered)
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1596.2</td>
<td>2535.0</td>
<td>0.55</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1395.7</td>
<td>2152.2</td>
<td>0.55</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>199.6</td>
<td>378.8</td>
<td>0.58</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>199.6</td>
<td>378.8</td>
<td>0.60</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>199.6</td>
<td>378.8</td>
<td>0.63</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>199.6</td>
<td>378.8</td>
<td>0.65</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>199.6</td>
<td>378.8</td>
<td>0.68</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>199.6</td>
<td>378.8</td>
<td>0.70</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>199.6</td>
<td>378.8</td>
<td>0.73</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>199.6</td>
<td>378.8</td>
<td>0.75</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>199.6</td>
<td>378.8</td>
<td>0.78</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>199.6</td>
<td>378.8</td>
<td>0.80</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>199.6</td>
<td>378.8</td>
<td>0.83</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>798.4</td>
<td>1755.2</td>
<td>0.68</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>199.6</td>
<td>402.8</td>
<td>0.68</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>299.4</td>
<td>592.2</td>
<td>0.69</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>199.6</td>
<td>402.8</td>
<td>0.69</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>299.4</td>
<td>592.2</td>
<td>0.70</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>199.6</td>
<td>402.8</td>
<td>0.70</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>299.4</td>
<td>592.2</td>
<td>0.72</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>199.6</td>
<td>402.8</td>
<td>0.72</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>20</td>
<td>1805.8</td>
<td>2596.2</td>
<td>0.49</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1586.4</td>
<td>2210.9</td>
<td>0.49</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>219.4</td>
<td>385.2</td>
<td>0.51</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>219.4</td>
<td>385.2</td>
<td>0.53</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>219.4</td>
<td>385.2</td>
<td>0.55</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>219.4</td>
<td>385.2</td>
<td>0.57</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>219.4</td>
<td>385.2</td>
<td>0.59</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>219.4</td>
<td>385.2</td>
<td>0.61</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>219.4</td>
<td>385.2</td>
<td>0.63</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>219.4</td>
<td>385.2</td>
<td>0.65</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>219.4</td>
<td>385.2</td>
<td>0.67</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>219.4</td>
<td>385.2</td>
<td>0.69</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>219.4</td>
<td>385.2</td>
<td>0.71</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>877.6</td>
<td>1780.8</td>
<td>0.59</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>219.4</td>
<td>409.2</td>
<td>0.59</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>329.1</td>
<td>601.8</td>
<td>0.60</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>219.4</td>
<td>409.2</td>
<td>0.60</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>329.1</td>
<td>601.8</td>
<td>0.61</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>219.4</td>
<td>409.2</td>
<td>0.61</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>329.1</td>
<td>601.8</td>
<td>0.62</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>219.4</td>
<td>409.2</td>
<td>0.62</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>-</td>
<td>396.0</td>
<td></td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
**TABLE H-12**

Vertical Wells Project*  
3,000-Foot, 150 MCF/D Well  
(Gas Cleaned and Delivered)  
(Constant 1979 Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Wells Drilled</th>
<th>No. Wells Plugged</th>
<th>Total Active Wells</th>
<th>Tangible Investment (Thousands of Dollars)</th>
<th>Intangible Investment (Thousands of Dollars)</th>
<th>Operating Costs ($/MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
<td>20</td>
<td>2084.6</td>
<td>2683.3</td>
<td>0.39</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>1829.9</td>
<td>2288.2</td>
<td>0.39</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>22</td>
<td>254.6</td>
<td>395.2</td>
<td>0.40</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>24</td>
<td>254.6</td>
<td>395.2</td>
<td>0.42</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>26</td>
<td>254.6</td>
<td>395.2</td>
<td>0.43</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>254.6</td>
<td>395.2</td>
<td>0.45</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>254.6</td>
<td>395.2</td>
<td>0.46</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>254.6</td>
<td>395.2</td>
<td>0.48</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>34</td>
<td>254.6</td>
<td>395.2</td>
<td>0.49</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0</td>
<td>36</td>
<td>254.6</td>
<td>395.2</td>
<td>0.51</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0</td>
<td>38</td>
<td>254.6</td>
<td>395.2</td>
<td>0.52</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>254.6</td>
<td>395.2</td>
<td>0.54</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0</td>
<td>42</td>
<td>1018.4</td>
<td>1820.8</td>
<td>0.46</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>20</td>
<td>30</td>
<td>254.6</td>
<td>419.2</td>
<td>0.46</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>381.9</td>
<td>616.8</td>
<td>0.47</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>31</td>
<td>254.6</td>
<td>419.2</td>
<td>0.47</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>381.9</td>
<td>616.8</td>
<td>0.48</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>254.6</td>
<td>419.2</td>
<td>0.48</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>2</td>
<td>32</td>
<td>381.9</td>
<td>616.8</td>
<td>0.49</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>254.6</td>
<td>419.2</td>
<td>0.49</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>-</td>
<td>396.0</td>
<td>0.49</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
<td>33</td>
<td>33</td>
<td>-</td>
<td>396.0</td>
<td>0.49</td>
</tr>
</tbody>
</table>

*See Estimation of Costs and DCF Analysis sections of Chapter Five.
APPENDIX I

References
REFERENCES


