North Carolina

REASONABLY FORESEEABLE DEVELOPMENT SCENARIO FOR FLUID MINERALS

Prepared for:

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
EASTERN STATES
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The Bureau of Land Management is responsible for the stewardship of our public lands. It is committed to manage, protect, and improve these lands in a manner to serve the needs of the American people for all times. Management is based on the principles of multiple use and sustained yield of our nation's resources within a framework of environmental responsibility and scientific technology. These resources include air, fish and wildlife, minerals, paleontological relics, recreation, rangelands, scenic scientific and cultural values, timber; water, and wilderness.

BLM/ES/PL-08/XXX

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ACRONYMS

ACEC	Area of Critical Environmental Concern
APD	Application for Permit to Drill
AU	Assessment Units
BCF	billion cubic feet
BLM	Bureau of Land Management
BOPD	barrels of oil per day
CBNG	Coal Bed Natural Gas
EIS	Environmental Impact Statement
EOR	Enhanced Oil Recovery
ESA	Endangered Species Act
EIS	Environmental Impact Statement
JFO	Jackson Field Office
MMBO	million barrels of oil
RFDS	Reasonable Foreseeable Development Scenario
ROD	Record of Decision
RMP	Resource Management Plan
SMA	Surface Management Agency
TCF	trillion cubic feet
TPS	Total Petroleum Systems
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey

Summary

1.0 INTRODUCTION

The Bureau of Land Management's Jackson Field Office is located in Jackson, Mississippi, and is responsible for 11 southern states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. The Jackson Field Office manages approximately 34.25 million acres of federal mineral estate in the eastern portion of the United State. Of this approximately 2.24 million mineral estate acres are located in North Carolina, however there is current no oil or gas production on federal minerals.

The Reasonable Foreseeable Development Scenario (RFDS) forecasts fluid mineral exploration, development, and production for the planning area for the next 10 years. The RFDS assumes a baseline scenario in which no new policies are introduced and all areas not currently closed to leasing and development are opened for oil and gas activity.

Interagency Reference Guide - Reasonably Foreseeable Development Scenarios and Cumulative Effects Analysis for Oil and Gas Activities on Federal Lands in the Greater Rocky Mountain Region" (USDI 2002), "Policy for Reasonably Foreseeable Development Scenario (RFD) for Oil and Gas (BLM WO IM No. 2004-089) and Planning for Fluid Minerals Supplemental Program Guidance (BLM Handbook H-1624-1) guided the criteria and analyses methods used in this RFD.

1.1 Discussion of Determining Oil and Gas Resource Potential

Potential accumulations of oil and gas are described in Section 2. Non-BLM land within the state may be included in this section when it provides a better understanding of resource potential on BLM property. These determinations were made using the geologic criteria provided by reference in Section 2. Also contained in Section 2 are descriptions of stratigraphy, structure, historic oil and gas activities, as well as relevant studies done in the area. Potential reservoir rocks, source rocks, and existing stratigraphic and structural traps are discussed in detail.

1.2 Methodology for Predicting Future Oil and Gas Exploration and Development Activity

Section 7 predicts the type and intensity of future oil and gas exploration and development activities. These forecasts are determined by an area's geology, and historical and present activity, as well as factors such as economics, technological advances, access to oil and gas areas, transportation, and access to processing facilities. Economics, technology, and other factors may be hard to predict because of their complex nature and rapid rate of change. Projections of oil and gas activities are based upon present knowledge. Future changes in global oil and gas markets, infrastructure and transportation, or technological advancements, may affect future oil and gas exploration and development activities within the state.

1.3 Relating the Potential for Resource Occurrence to Potential for Activity

Predicted oil and gas activity does not necessarily correlate with geologic potential for the presence of hydrocarbons. Although the geology of an area may suggest the possibility of oil and gas resources, actual exploration and development may be restricted by high exploration costs, low oil and gas prices, or difficulty accessing the area due to lease stipulations. Thus a small area may have a high resource potential, yet have a low exploration and development potential due to severe restrictions on access. Conversely, technological advancements or an increase in oil and gas prices could result in oil and gas activities in areas regarded as having low potential for occurrence.

2.0 DESCRIPTION OF THE GEOLOGY OF NORTH CAROLINA

The state of North Carolina spans three distinct geologic regions; from northwest to southeast, those three regions are the Blue Ridge, the Piedmont, and the Coastal Plain as shown in Figure 1. All of these geologic regions extend into the surrounding states.

2.1 The Blue Ridge

The Blue Ridge is a region of severely folded and faulted, low- to high-grade metamorphic rocks. Many of the rocks within the region appear to be metamorphosed Proterozoic or Paleozoic sedimentary rocks. Others are metamorphosed igneous rocks. This Blue Ridge is characterized by mountainous area of steep ridges, intermountain basins and valleys that intersect at angles, giving the area a rugged appearance. The steep slope that separates the mountains and Piedmont is the Blue Ridge escarpment.

2.2 The Piedmont

The Piedmont is a region of moderate-to-high-grade metamorphic rocks and igneous rocks like granite. Topographically, the Piedmont consists of generally rolling, well-rounded hills and ridges with a few hundred feet of elevation difference between the hills and valleys. Isolated granitic plutons rise above the Piedmont as prominent features. Elevations range from 300 to 600 feet above sea level near its border with the Coastal Plain to 1,500 feet at the foot of the Blue Ridge. Resistant hills and knobs, called monadnocks, occur in the Piedmont, some noteworthy ones include the Saurtown, South and Uwharrie Mountains.

2.2.1 The Fall Line

The Fall Line of North Carolina marks the contact of the Piedmont with the Atlantic Coastal Plain. The Fall Line is a boundary of bedrock geology between the metamorphics of the Blue Ridge and Piedmont with the largely unconsolidated sediments of the coastal plain, but it can also be recognized from stream geomorphology. Rivers crossing the Fall Line show falls or rapids and below the line they develop much broader flood plains.

2.3 The Coastal Plain

The Coastal Plain Region, covering approximately one-half of North Carolina, consists of a wedge of Cretaceous and Tertiary sedimentary strata thickening toward the coast as well as dipping toward the southeast, and so the outcropping starta are younger nearer the coast. The sedimentary rocks of the Coastal Plain partly consist of sediment eroded from the Piedmont and Valley and Ridge and partly of limestones generated by marine organisms and processes. Several small Mesozoic basins, including the Dan River Basin at the northern edge of the state and the Deep River Basin extends across most of the state from the border with South Carolina almost to the Virginia border (Olsen and Huber, 1998).

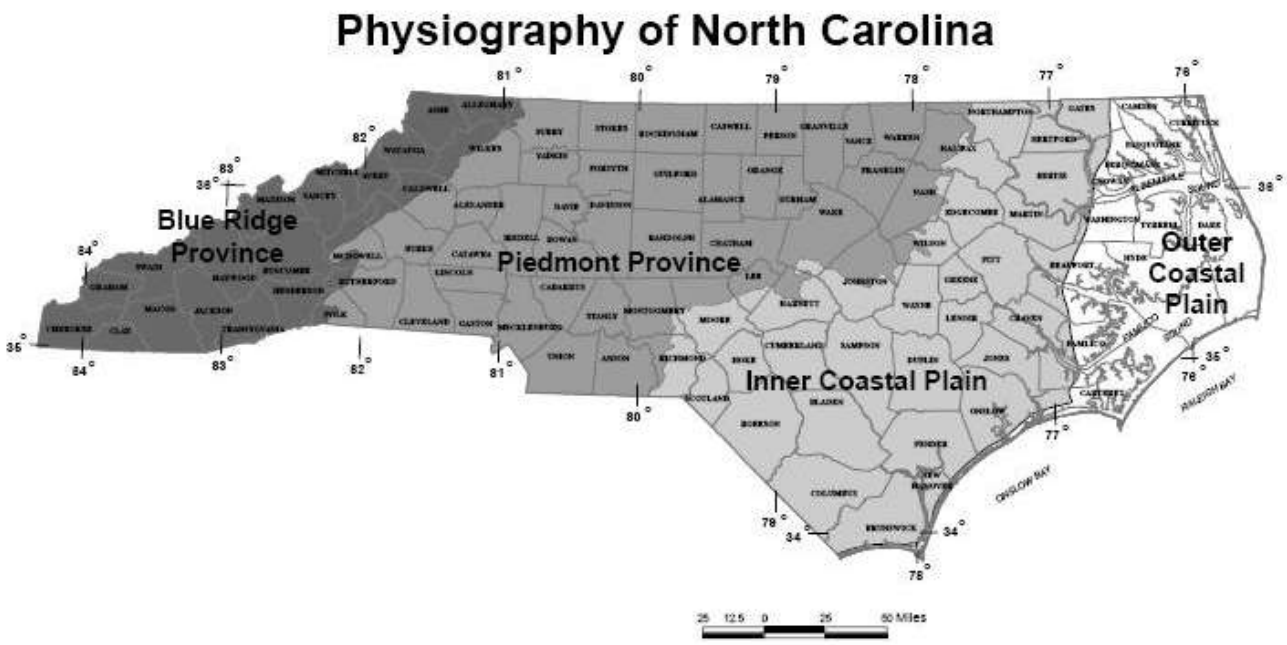
2.4 Subsurface Stratigraphy and Structure

North Carolina has a long and complex geologic history and is best described in terms of geological belts; that is, areas with similar rock types and geologic history.

The following discusses geologic belts as shown in on Figure 2.

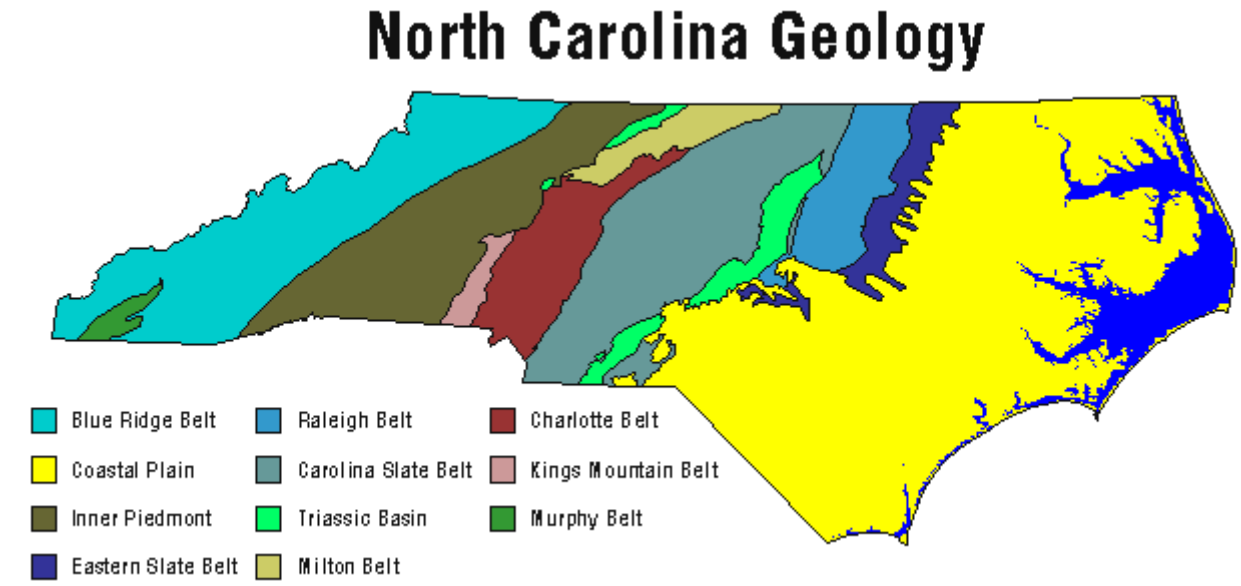
Blue Ridge Belt - This region is mountainous and made up of rocks from over one billion to about one-half billion years old. The Blue Ridge belt is known for its minerals deposits including feldspar, mica, and quartz-basic materials. Olivine is also found in this region and commonly mined for use as a refectory material and foundry molding sand.

Figure 1: Generalized Physiology of North Carolina



Source: North Carolina Geological Survey, 2004

Figure 2: Geological Map of North Carolina



Source: North Carolina Geological Survey, 1998

Inner Piedmont Belt - The Inner Piedmont Belt is intensely deformed and metamorphosed. The metamorphic rocks are from 500 to 750 million years in age. They include gneiss and schist that have been intruded by younger granitic rocks. The northeast-trending Brevard fault zone forms almost the entire boundary between the Inner Piedmont and Blue Ridge belts. This zone of strongly deformed rocks is one of the major structural features in the southern Appalachians however its origin is inadequately known. Crushed stone for road aggregate and building construction is the principal commodity produced.

Kings Mountain Belt - This belt is made up of moderately deformed and metamorphosed volcanic and sedimentary rocks. The rocks are about 400-500 million years old. Lithium deposits are found here and provide raw materials for chemical compounds, ceramics, glass, greases, batteries and television glass.

Milton Belt - This belt consists of schist, gneisses, and metamorphosed intrusive rocks. The principal mineral resource is crushed stone for road aggregate and buildings.

Charlotte Belt -This belt consists mainly of igneous rocks such as diorite, gabbro, and granite. These are 300-500 million years old. The principal mineral resource is igneous rocks which are good sources of dimension stone for building.

Carolina Slate Belt - This belt consists of heated and deformed volcanic and sedimentary rocks. It was the site of a series of oceanic volcanic islands about 550-650 million years ago. The belt is known for its numerous abandoned gold mines and prospects. In recent decades, only insignificant gold mining has taken place, but mining companies continue to show interest in the area. Mineral production consists of pyrophyllite for refectories, ceramics, filler, paint and insecticide carriers as well as crushed stone for road aggregate.

Triassic basins - This basins are comprised of sedimentary rocks that formed nearly 190-200 million years ago. Streams carried mud, silt, sand and gravel down from adjacent highlands in rift valleys similar to those of Africa today. The mudstones are mined and processed to make brick, sewer pipe, structural tile and drain pipe.

Raleigh belt - The Raleigh belt contains gneiss, granite, and schist. In the 19th century there were a number of small building stone quarries in this region, but today the main mineral product is crushed stone for construction and road aggregate.

Eastern Slate Belt - This belt contains slightly metamorphosed volcanic and sedimentary rocks similar to those of the Carolina slate belt. The rocks are poorly exposed and partially covered by the Coastal Plain sediments.The metamorphic rocks, 500-600 million years old, are intruded by younger, approximately 300 million-year-old, granitic bodies. Gold was once mined in the belt, and small occurrances of molybdenite, and ore of molybdenum, have been prospected here. Crushed stone, clay, sand and gravel are currently mined in this belt.

Coastal Plain – This belt is the largest in the state covering 45 percent of the land area. The most common sediment types are sand and clay, although a significant amount of limestone occurs in the southern portion. In the Coastal Plain, numerous wells have been drilled that add to the study of geology for this belt. The state's most important mineral resource comes from this area, phosphate and is mined near Aurora in Beaufort County. Industrial sand for making container and flat glass and ferrosilicon are mined in the Sandhills area.

The stratigraphic section in North Carolina includes rock and sediment units from Pre-Cambrian to Holocene in age and includes igneous, metamorphic and sedimentary rock types as well as loose sediments. Figure 3 exhibits a generalized stratigraphic column for the State.

Figure 3: Generalized Stratigraphic Column for the Sedimentary Section of North Carolina

Age	Era	System	Group	Formation	Members
Cenozoic	Quaternary	Pleistocene			
	Tertiary	Pliocene		Waccamaw Formation	
				Pinehurst Formation	
		Miocene		Bellgrade Frm.	
		Oligocene			
				River Bend Formation	
		Eocene		Castle Hayne Formation	Comfort Member
					New Haven Member
		Paleocene		Beaufort Formation	
Mesozoic	Cretaceous			Peedee Formation	
				Black Creek Frm.	
				Middendorf Frm.	
				Cape Fear Frm.	
	Triassic		Dan River Group	Stonevile Frm.	
				Pine Hall Frm.	
			Chatham Group	Sanford Formation	
				Cumnock Frm.	
				Pekin Formation	

After NC Geological Survey, Generalized Geologic Map, 1991

3.0 SUMMARY OF USGS PLAY DESCRIPTIONS FOR THE STATE OF NORTH CAROLINA

The most recent oil and gas assessments for the three geologic provinces that are within North Carolina were completed in 1995; The Blue Ridge Thrust Belt (068), piedmont (069) and the Atlantic Coastal Plain (070). In each of these province assessments a number of conventional and unconventional oil and gas plays were assessed however none indicate the presences of oil and gas in North Carolina.

The East Coast Mesozoic Basins also extend into parts of North Carolina however only hypothetical plays exist and no oil or gas has been found.

The primary source materials for this summary presentation are the geologic reports for each of the province assessments as published by the USGS and are available at the USGS National Oil and Gas Assessment website (http://energy.cr.usgs.gov/oilgas/noga/).

A copy of the USGS province report is available for review in Appendix A.

4.0 PAST AND PRESENT OIL AND GAS EXPLORATION ACTIVITY

4.1 Geophysical and Geochemical Surveys

Several areas in North Carolina are considered to have potential to produce oil and gas. The main area is the outer Coastal Plain. It contains a relatively thick pile of sedimentary rocks including some excellent reservoir rocks, but source rocks may not be present. Seismic surveys in the Blue Ridge suggest that sedimentary rocks may be present deep beneath the crystalline rocks. These may be similar to oil- and gas-bearing strata in the Valley and Ridge Province of Virginia and West Virginia. Detailed studies have not been conducted to verify the seismic surveys (Tayor, 2008).

4.2 Exploratory Drilling and Success Rates

The first exploratory oil well in North Carolina was drilled in 1925, near Havelock in Craven County. Since then, exploration conducted in 23 counties has brought the total number of wells drilled in North Carolina to 125 as of 1998 when the last well was drilled (Taylor, 2008). Most exploration wells have been drilled in the outer Coastal Plain although exploration has been conducted as far inland as Lee County. Traces of oil and gas have been detected in a few of these wells but no producing wells nor commercial oil or gas has ever been established. The deepest well to date was drilled at Cape Hatteras in Dare County and reached a depth of 10,044 feet.

4.3 New Field and Reservoirs

The USGS recognizes no future oil and gas plays in the state (USGS, 1995). No new fields or reservoirs have been discovered.

5.0 OIL AND GAS ACTIVITY IN NORTH CAROLINA

This section deals with the current status of oil and gas activity in North Carolina based on information provided by both public and private sources. Information includes; leasing activity, well spacing requirements, drilling permits by county, drilling practices, production statistics, oil and gas characteristics, oil and gas prices, operational costs (drilling and completion), conflicts with other mineral development, and gas storage fields.

5.1 Leasing Activity

There has been no leasing activity nor applications for permit to drill submitted in recent years (Taylor, 2008).

5.2 Regulations

The North Carolina Oil and Gas Conservation Act is regulated by the Department of Natural and Economic Resources. The DNER has the jurisdiction to administer and enforce all aspects of the development of oil and gas in the state including permitting, spacing, completion and reporting.

5.3 Drilling and Completion Statistics

5.3.1 Drilling Practices

The vast majority of drilling operations in North Carolina are standard vertical tests drilled with air rotary equipment that vary in depth from 800 feet to 10,000 feet. This range of is based on the drill site's elevation and general position on regional structural features with the average well depth in the order of 2,000 feet (Steele, 1986). The deepest vertical test drilled to date reached a depth of approximately 11,470 feet.

5.3.2 Drilling and Completion Costs

Information regarding drilling costs and well completion costs was not available for the exploration wells drilled in North Carolina.

5.4 Production Statistics

5.4.1 Crude Oil

There has been no crude oil produced in North Carolina.

5.4.2 Natural Gas

There has been no natural gas produced in North Carolina.

5.5 Conflicts with Other Mineral Development

North Carolina has many mineral deposits several which are important in fact North Carolina annually leads the Nation in the production of feldspar, lithium minerals, olivine, pyrophyllite and scrap mica. The state ranks second in phosphate rock extraction and fifth in clay and crushed granite production. North Carolina does not generate major quantities of metallic minerals. North Carolina also has a significant precious and semi-precious gem stone mining industry that includes garnet, moonstone, ruby, sapphire, emerald, aquamarine, amethyst, hiddenite, rutile, and quartz.

In 2005, nonfuel raw mineral production was valued at $792 million, minus the proprietary information for phosphate rock based upon annual U.S. Geological Survey (USGS) data. North Carolina continues to be the only State that produced pyrophyllite. Mineral development in North Carolina is not in conflict with the exploration for oil and gas.

5.6 Gas Storage Fields

EIA gas storage data for 2006 indicates that there are no gas storage fields operating in the State of North Carolina (EIA website, Natural Gas Storage, Form EIA-191 Data, 2007).

6.0 OIL AND GAS OCCURRENCE POTENTIAL

6.1 Coal and Coal Bed Methane

Only one area in North Carolina is known to contain coal beds of potential commercial importance (NCGS, 2008). This is the Deep River coal field which lies along the Deep River in Chatham, Moore, and Lee counties. The coal field is in the Deep River Triassic Basin and occupies a zone of about 35 miles long and 5 to 10 miles wide. Its center lies about 10 miles northwest of Sanford, North Carolina. The medium volatile bituminous coal occurs in beds in the Cumnock Formation. The Cumnock and the Carolina coal mines produced coal from this seam intermittently from 1854 to 1953. However, because the coal seam is deeply buried and badly broken by numerous dissecting faults, production in the Deep River area ceased in 1953. It is estimated that 110,337,000 tons of steam and coking coal exists. However, because of faulting in the area, less than half of this coal might be mined. In order to recover a large quantity of coal from this area, much subsurface structural geologic mapping and drilling must be done to determine the locations of faulted coal seams.

The Cumnock and Gulf coal beds have been studied for possible in-situ methane gas generation. At least one Coal Bed Methane (CBM) well has been drilled within the Deep River Triassic Basin coal field (Hoffman and Buetel, 1991) to test the gas potential of Triassic coals. This well contained methane within coals and black shales and appeared to be capable of producing small amounts of natural gas. The well was plugged. The narrow Dan River Triassic Basin on the northern edge of the state extends into Virginia as the Danville Basin (Cornet, 1993); the lacustrine sediments do not appear to be favorable for generating hydrocarbons.

The Triassic basins have received sporadic attention from oil and gas exploration companies during recent years. Good source rocks are present, but the sandstones have poor permeability. The Deep River Mesozoic Basin may have some potential for hydrocarbons because of the mineable bituminous coal seams and associated bituminous shales (USGS, 1995).

6.2 Oil Shales

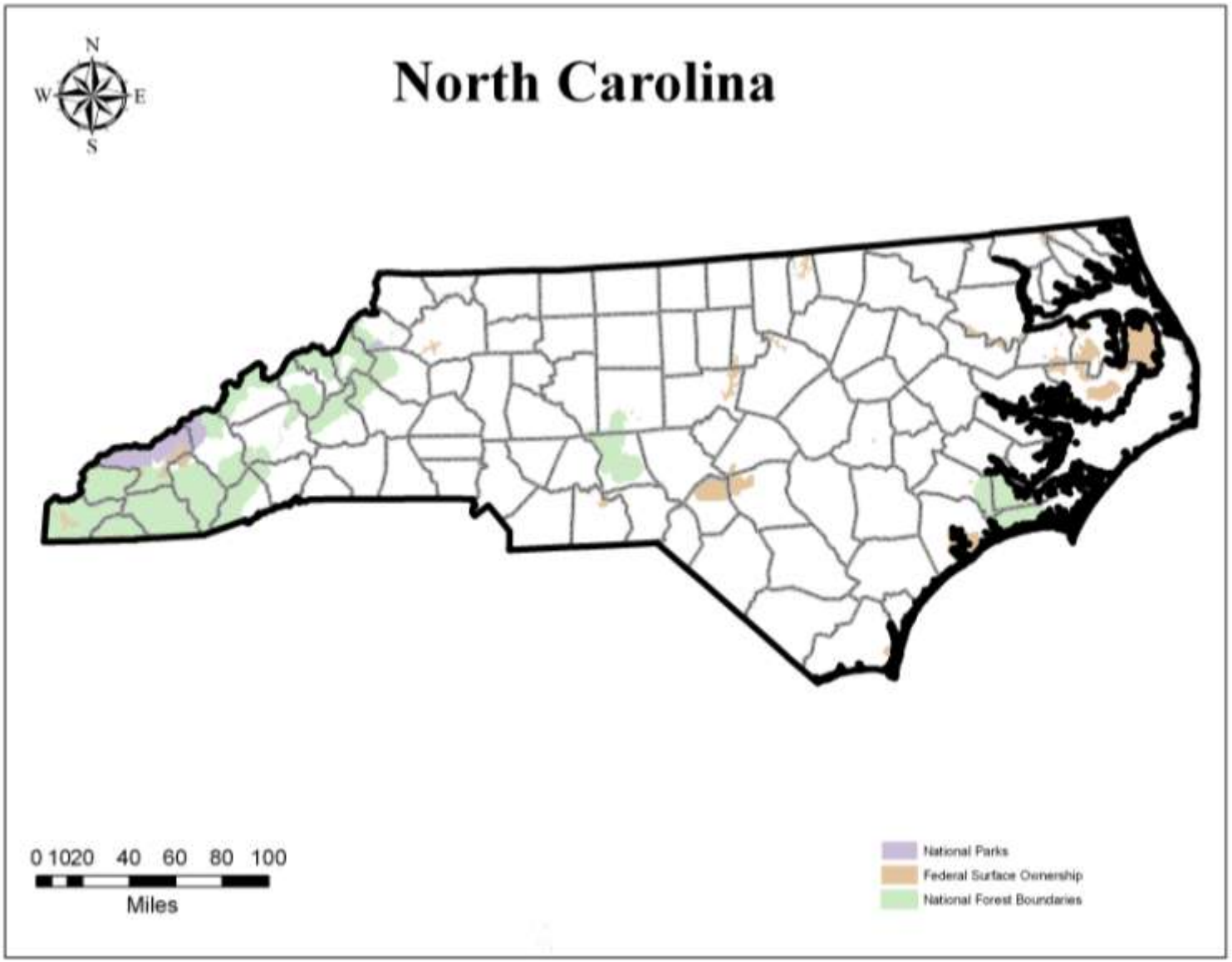
Oil shales have been documented from the Deep River Mesozoic Basin (Vilbrandt, 1927) where these shales outcrop. The shales contain organic matter as kerogen – “the naturally occurring, solid, insoluble organic matter that occurs in source rocks and can yield oil upon heating. Typical organic constituents of kerogen are algae and woody plant material.” (Schlumberger, 2008) Triassic oil shales contain up to 35% carbon, mostly as kerogen and bitumen (soluble organic matter including crude oil). Oil shales need to be heated to convert the kerogen and bitumen to crude oil. This has not been done on a large scale in North Carolina but lab analyses suggest that as much as 27 billion gals (642 million bbls) of crude oil could be extracted from the shales in the Deep River basin (Vilbrandt, 1927). This resource has not been exploited within the state although a CBM test drilled in 1981 did drill through some of the oil shale and did encounter shows of oil (Hoffman and Buetel, 1991).

Shale oil extraction will depend upon price of crude oil (currently in the range of $110 to $125/bbl) and extraction costs, including capital costs, operating costs, and environmental costs. At the present time all of these costs are relatively unknown although field tests are being advanced in the Piceance Basin of Colorado that will have a bearing on the Deep River oil shales (O’Connor, 2008).

7.0 OIL AND GAS DEVELOPMENT POTENTIAL

No oil and gas wells are forecast to be drilled in North Carolina in the next ten years. This is consistent with the fact that the US Bureau of Land Management has never issued an oil and gas drilling permit for the State of North Carolina. Federal lands are shown in Figure 4.

Figure 4: Federal Administered Lands in North Carolina



8.0 REASONABLE FORESEEABLE DEVELOPMENT BASELINE SCENARIO ASSUMPTIONS AND DISCUSSION

This RFD scenario assumes that all potentially productive areas are open under the standard lease terms and conditions except those areas designated as closed to leasing by law, regulation, or executive order. The areas closed to leasing typically include Areas of Critical Environmental Concern (ACECs), Wilderness Study Areas (WSAs) and USFWS Wildlife Refuges. The RFD scenario contains projections for the number or wells and acres disturbed for these counties. This in no way is intended to imply that the BLM are making decisions about the Forest Service lands or the USFWS lands. The predictions are intended to provide the information necessary so that all potential cumulative impacts can be analyzed. The disturbance for each well is based on the typical depth of wells for an area; generally, shallow gas wells disturb fewer acres than deeper oil wells. The assumptions for conventional oil and gas are as follows:

The number of wells was calculated based on historical statistics and data trends as follows:

- Wells drilled to date were taken from the North Carolina Department of Natural Resources, Information Circulars.
- The number of wells drilled to date was statistically analyzed to calculate a median per year wells drilled per county.
- The data trends associated with the last 6 years (2001-2006) represents a more accurate estimate of future development trends than historical data, thus, it is weighted more heavily.
- The data trends from 1979 to 1984 data set are a more accurate estimate of future trends than the complete historical record and were weighted more heavily than the historical record.
- The data trends for the complete historical record (1903 – 1979) represent the least accurate estimate of future development trends and, thus, it was weighted the lightest.
- For each geographic/geologic boundary region and sub region, the calculated estimates for future development were summed to obtain a per year well count.
- Wellhead oil and gas prices are a driving force for well drilling and completion; current prices are historically high and have resulted in increased activity throughout the state. An estimate of activity for the future well development to into consideration this influence. The forecast assumes wellhead oil and gas prices will remain high and development over the next 10 years will continue at an elevated rate.
- Estimates of well counts for the different mineral ownership entities are based on spatial analysis of the percent of mineral ownership within each county times the total number of producing wells anticipated to be developed in that boundary area.
- The average acreage figure (acres per well) for the resource area was used to estimate federal disturbed acres.
- The RFD projections have a 10-year life.
- The number of dry holes was determined based on historic analysis of dry holes in the geologic boundary areas.

The assumptions were used to calculate the number of wells to be drilled, the number of in-field compressors, and the number of sales compressors required.

9.0 SURFACE DISTURBANCE DUE TO OIL AND GAS ACTIVITY ON ALL LANDS

9.1 Surface Disturbances

There are no estimates of the surface disturbances associated with the development of oil and gas on federal minerals within the State of North Carolina because no new wells are predicted to occur over the next ten years.

10.0 REFERENCES

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Appendix A

USGS Play Descriptions