Local Lessons for a Global Landscape Challenge: Design and Planning Responses to Unconventional Shale Gas Development

Timothy MURTHA[1] and Brian ORLAND[1]
[1]Penn State University, Pennsylvania/USA · tmurtha@psu.edu

Abstract

Deep shale natural gas deposits made accessible by new technologies are quickly becoming a demonstrative share of North America's energy portfolio. The pace and scale of recent extraction overwhelms local and state planning and regulatory bodies and is exempted from national regulation. Extraction is dispersed and the full extent of cultural and environmental impact is equally dispersed and varies considerably. Additionally, extraction activities fluctuate and respond to global market considerations. Unlike traditional energy deposits and extraction footprints, shale gas offers dispersed and complex landscape challenges. These challenges are both cultural and environmental; and they are experienced individually, locally and regionally, despite being influenced by the global energy market. Our paper describes the local and regional challenges experienced by communities in the Marcellus Shale region of the eastern United States. We report on the ways, using a geodesign approach, in which we are working with communities to develop tools for comprehensive landscape planning and informed decision making. In this paper, we emphasize our research focused on visual and cultural resources.

1 Introduction

This paper does not condone the headlong exploitation of fossil hydrocarbon resources and acknowledges the impact such hydrocarbon use has on global climate and a host of other critically important environmental impacts. Instead it responds to an unfortunate political and economic reality that governments are willing to accept environmental and social risks in order to feed the demand for cheap energy to fuel economic expansion. We view our obligation as designers and planners to offer responses to those risks that minimize the negative impacts for the longer-term future when this current cheap energy boom is exhausted.

Natural gas extraction from deep shale deposits using horizontal drilling and hydraulic fracturing is sweeping across the planet offering unique energy potential and with it equally unique and complex challenges to communities, landscapes and regions. Known shale deposits are broadly distributed throughout North / South America, Europe, Africa, Australia and Asia. Spanning six continents, the resources are located beneath a diverse expanse of ecological and cultural settings, indiscriminately underlying forested, agrarian, urban and rural landscapes. Specialized networks of infrastructure combined with dispersed gas well

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locations initiate incremental and dispersed landscape transformations that are often difficult to observe and fully interpret the scale of change. Experience in the United State indicates that the pace and scale of extraction quickly overwhelms local decision making and infrastructure, permanently and irrevocably transforming households, communities and regions. Planning for the future of landscapes facing shale gas exploitation requires complex spatial information about natural and cultural resources and important evaluations and assessments of their visual and cultural attributes.

For the past five years, we have been studying shale gas extraction issues in the eastern United States using an interdisciplinary geodesign approach. We have examined broad landscape based approaches to decision making in the context of this unique resource and, recently, we sharpened our focus studying potential impacts to visual and cultural resources. Our projects emphasize interdisciplinary perspectives within a geodesign framework, combining traditional techniques for studying landscapes in anthropology and landscape architecture. In this paper we argue that our approach in the rural context of shale gas extraction in Pennsylvania may offer potential for the varied cultural and ecological contexts in other global settings.

In this paper, we will:

1. Introduce shale gas resources and their worldwide distribution.
2. More specifically describe the specific context of our multi-year research project (i.e., Marcellus Shale in the Eastern United States) and how we have been studying these issues
3. Report and discuss our results as they are related to visual and cultural resources analyzed using an interdisciplinary geodesign framework.
4. Describe how similar approaches may be used to investigate the future potential impacts of shale gas extraction beyond North America.

The pace, scale and distribution of unconventional natural gas extraction globally demands a concerted landscape ecological planning response (ORLAND & MURTHA 2013). From our experiences in the eastern United States, this imperative is clear in Pennsylvania, New York, Ohio, West Virginia and Maryland as communities attempt to manage the feverish pace of development associated with the Marcellus Shale natural gas deposit. The successful and profitable applications of new technology to extract shale gas from the wide distribution of shale deposits, driven by national ideologies of oil independence and job creation, suggest that we have only witnessed the early days of what is sure to be a dominant, albeit short-lived, activity on the global landscape. Simply, while much of the rhetoric associated with this resource revolves around global issues, the decisions and plans to be made are very local. Our research and community engagement potentially offers new perspectives about ways to manage this resource boom locally and regionally as it quickly expands globally. Simply, the potential for energy development is high but the opportunity costs of not planning for future development far outweigh the net present value of the recoverable resources.

2 Global Shale Gas

There are four primary types of unconventional gas: shale gas, coalbed methane, 'tight gas' and methane hydrates. Exploitation of shale gas is sweeping the planet and dominating headlines, even though it isn't technically a new resource (WORLD ENERGY COUNCIL 2013: 65). The first commercial gas well drilled was a shale gas well and ironically drilled in New York State, which currently has a moratorium on shale gas drilling. The transformation of this resource is primarily due to market conditions and technological developments. Most of what we know about shale gas comes from extraction efforts in the US where development has accelerated in the past decade but shale gas is a global phenomenon.

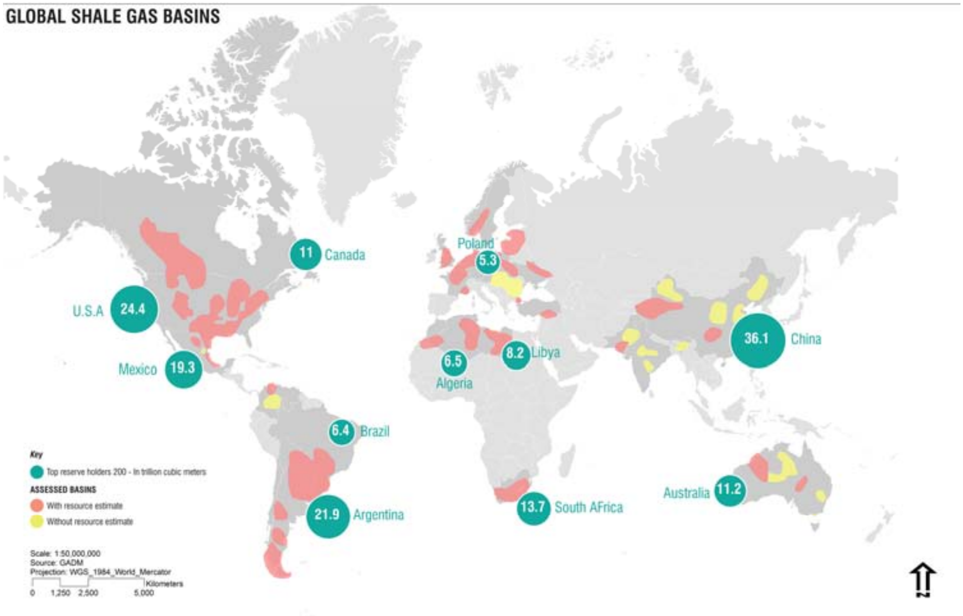

Fig. 1: Global 'Risked' Recoverable Shale Gas Estimates in trillion cubic meters after THOMSON REUTERS 2012 (see also WEC 2013: 65)

Globally, there are an estimated 700 basins with an estimated shale gas reserve of more than 6,000 trillion cubic feet (tcf) of recoverable natural gas (WEC 2013). Annual use of natural gas in the US is currently 22 tcf/year. Most credible estimates calculate over 16,000 tcf (456 tcm) of gas are embedded in global shales, 40% of which is recoverable using current technologies. Capital costs of developing the resource in the absence of infrastructure are considerable, but the economic prospects of shale gas seem to outweigh those potential costs. Nearly 30% of the recoverable gas is estimated to be found in North America, while only 7% is projected to be developed in Europe (624 tcf). Given existing infrastructure and market demands in Europe, there is incentive for development. Exxon and Marathon have initiated shale operations in Poland, France, Germany Sweden and Austria (WEC 2013: 65). Estimates for shale gas are changing rapidly but outside of the US there is less detailed information available on a national basis. No national estimates have been calculated for Europe. Based on past experiences in the US, it is likely that current estimates are conservative. China, for example, is estimated to have 1,275 tcf, but so little is known about China's shale gas potential, it's difficult to assess whether this estimate under or over represents China's shale gas potential. One resource we have come to know quite well in the US is the Marcellus Shale gas.

3 Marcellus Shale in the United States

The Marcellus shale is an organic rich shale underlying much of Pennsylvania and parts of New York, Ohio West Virginia and Maryland (Figure 2a). Named for a surface outcrop in Marcellus, New York, the formation dips to nearly 9,000 feet deep in southern Pennsylvania. Ranging up to 900 feet thick, the deposit varies between 1% and 11% organic content. While occurring as oil and "wet" gas (including higher order hydrocarbons such as ethane and butane suitable for plastics) in the west, the more thermally mature parts of the formation to the east yield primarily methane gas. The existence of the gas has been known for many years, but attempts to access the resource by conventional drilling were proven inefficient. The development of horizontal drilling and application of a technique called slick-water hydraulic fracturing (now widely known as "fracking") elsewhere showed that development of shale gases could be made economically viable. Estimates for how much extractable shale gas there is in the Marcellus deposit vary widely. In 2002 the USGS estimated the Marcellus contained 1.9 trillion cubic feet (TCF) and more recently Terry Engelder revised that estimate to 363 TCF, still enough to supply the entire US energy demand for fourteen years. Range Resources, a Texas company, drilled the first unconventional Marcellus well in 2007.

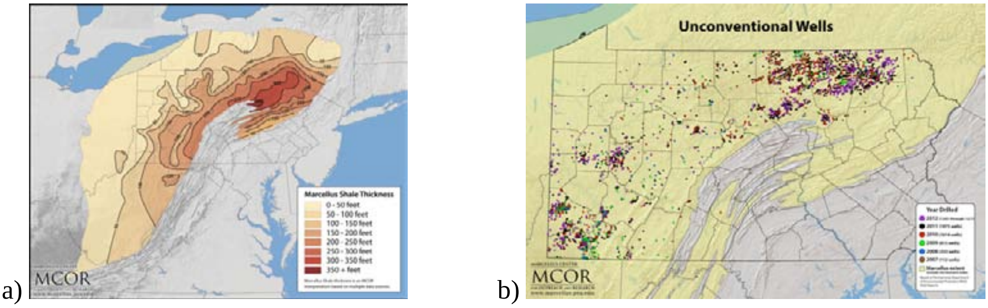

Fig. 2: (a) Extent of Marcellus shale. (b) Unconventional wells as of December 1, 2012 (see MCOR 2012).

The economic benefits of development of the Marcellus are considerable, Engelder's numbers equating to $1.25 trillion at a market price of $4.00 per thousand cubic feet. At typical royalty rates of 15-18% landowners estimate $250 billion in gas royalty checks. The contribution to national energy security has also been used to argue for the imperative for immediate Marcellus extraction. This combined with other energy development in the US contribute to projections of the US reaching energy self-sufficiency in the imminent future. Evidence of the boom in fossil energy availability, of which natural gas is one facet, is seen in the plunge in natural gas prices that occurred between 2009 and 2013. This is a complex resource with an equally complex future. Drilling must respond to market demand and profit margins, so active drilling has currently shifted to those areas in Ohio and western Pennsylvania seeking the higher-value oil and "wet" gas. Moreover, Utica black shale underlies the Marcellus and includes oil resources as well as natural gas.

Framing the energy benefits there are a range of known and unknown environmental impacts, some much publicized but localized such as instances of groundwater contamination, others perhaps less evident but potentially of much broader and long-term impact. The latter are the subject of this paper. In 1859 the Drake oil well in Titusville, Pennsylvania, was the birthplace of the oil industry in the USA. Since then, more than 350,000 oil and gas wells have been drilled in Pennsylvania. As of December 2012, 6012 of those are unconventional wells targeting gas in the Marcellus and Utica formations (Figure 2b). However, by comparison with the "footprint" of a conventional well, unconventional gas development is more dispersed and each site exerts a significantly higher toll in terms of land clearing, site compaction, infrastructure development and fresh water usage.

To date development has been most vigorous in the northeast and southwest parts of Pennsylvania. The resources have proven to be highly productive in these areas. Major infrastructure is in place regionally, but new pipelines are needed to bring the gas to market. For example, a new interstate pipeline, the MARC-1, was completed in 2013 running SW-NE. The studies reported below take that new infrastructure into account. Despite the potential risks, natural gas development is exempted from (US) federal regulations regulations normally applied to major development projects. Exemptions include portions of the National Environmental Policy Act (1969), Clean Air Act (1970), Clean Water Act (1972), and Safe Drinking Water Act (1974). The burden of regulation falls on individual states. In Pennsylvania, the major controlling law is the Pennsylvania Public Utility Commission Act 13 (2012), which enacts environmental standards such as setback requirements for unconventional gas development. While the federal laws regulated by the state require a range of important environmental protections, they affect a relatively small proportion of Pennsylvania's landscape. PA Act 13 does essentially exclude drilling from small communities through set-backs to buildings and water bodies. However, currently major elements of PA Act 13 have been set aside by the state Supreme Court leaving even those setback provisions in doubt. Visual and cultural resources, while essential elements in decision making are not formally protected by any state or local legal code.

Fig. 3:
Visible drilling rig adjacent to small family cemetery with headstones dating to the 19th century.

Set against these very basic protections is the primacy of land ownership and of mineral rights over surface rights in land use determinations. Pennsylvania, because of a historic past of coal mining is a state in the US wherein surface rights (i.e., the ability to build and farm) can be severed from mineral (or subsurface) rights. In places where surface and mineral rights are severed, oil and gas law requires that landowners provide access for the development of mineral resources, which may include the construction of drilling pads, access roads, water impoundments and pipeline access corridors. The optimal location of gas wells is driven by underlying geology so that the location of well pads will follow paths of preferential access to drilling units that are established by the mineral rights owners or lessees and may ignore landscape features. Unless specific information is included in leases, mineral rights owners have little influence over decision making about the placement of wells and infrastructure (see figure 3).

4 Our Approach

4.1 Goals and Objectives

Previously we characterized planning for Marcellus development as a "wicked problem" in that it is a unique situation; not informed by any precedent; and there is no identifiable set of solutions (BALASSIANO 2011; RITTEL & WEBBER 1973). Rather than attempt to address the entire scope of Marcellus-related issues, we designed our research around a series of interrelated problems. We started with four critical analyses, emerging from the single issue of pipeline placement in order to understand and interpret how one network of relationships has implications across a complex system of resource extraction-driven landscape changes (ORLAND & MURTHA 2013). Recently, we shifted our efforts to investigate specifically aesthetic / visual resources and cultural resources. We recognize the many other important health and environmental considerations associated with shale gas development, but focused our efforts on the visual and cultural resources with a hope to break through the often-polarizing rhetoric surrounding shale gas. This work was conducted by the authors and their students while working with an advanced landscape design studio. Overall, it contributes to the development of a tool set intended to help inform the public about the role of land-use design and planning in this complex, fast-moving and un-planned energy boom (i.e., http://marcellusbydesign.psu.edu).

4.2 Methods

Our approach generally follows the Geodesign framework described by STEINITZ (2012). We conducted initial scoping exercises to identify salient land planning issues in the northern tier of Pennsylvania and specifically focused this year on Sullivan County, PA. The county is the second smallest, by population, in the state, encompassing 450 square miles split 60:40 between forest cover and rural farmland. Our first analysis studies the critical impacts of land cover conversion associated with gas pads and pipeline development. We used a projection of Marcellus gas activity provided by THE NATURE CONSERVANCY (2010) to estimate the location of proposed well pads under the Conservancy's fully developed scenario.

While individual impacts might be viewed as contained or in some cases hidden, the repetition of impacts in numerous drilling locations and the linear extent of pipelines in a densely connected network accumulate to significant acreages of land conversion. In this analysis, we developed a model of landscape visual quality as a surrogate for the range of cultural landscape issues that would need to be considered in comprehensive planning. The model, based on existing landscape conditions, is used to evaluate the impact of the fully developed projection of Marcellus gas activity provided by the Nature Conservancy vs the current conditions in the Endless Mountains of eastern Pennsylvania.

We also developed a Cultural Resources geospatial planning tool, called the Cultural Landscape Assessment and Resource Information System (figure 4). The tool will help leaders identify important watershed sub-basins (those with substantial quantity of cultural resources or potential for significant resources), while overlaying the permit and drilling activity to provide leaders to also document a list of high priority sub-basins (where important sub-basins will be potentially impacted by new or existing drilling activity). In developing the tool, we were able to identify some key infrastructure and database challenges facing communities as related to shale gas development.

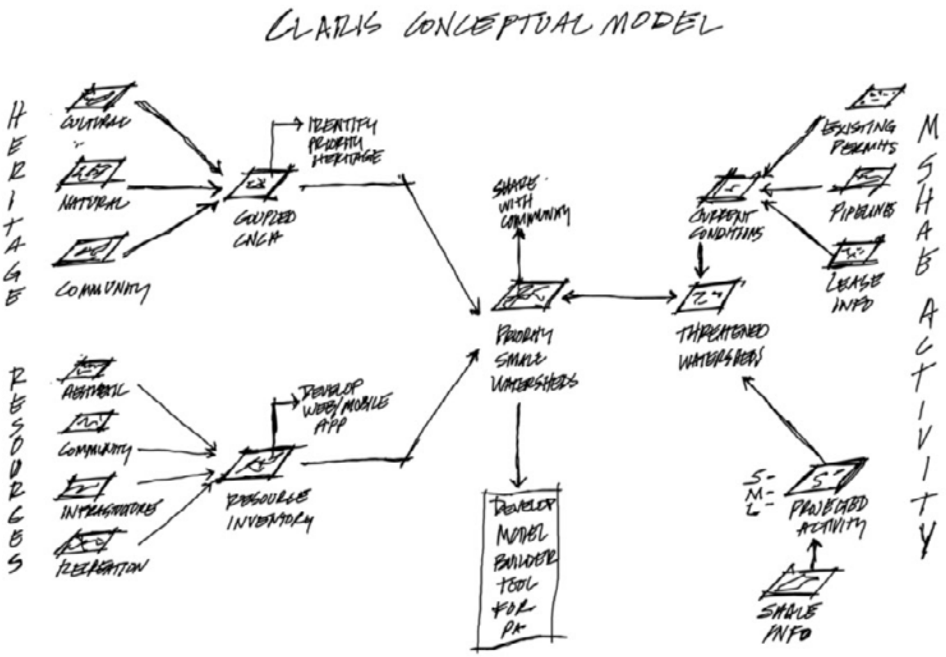

Fig. 4: CLARIS Conceptual Model

4.3 Results

All of the following results take a single set of assumptions for future well-pad location. The Nature Conservancy has projected probable well locations using three intensity models, low, moderate and high. We used high estimates for all of our analyses (see THE NATURE CONSERVANCY 2010). Future efforts should include a more sophisticated approach for predictively modeling well and pad location.

Pipeline land use change

Gas wells are of little use unless the gas can be transported and sold and pipelines are the most economical means of conveyance. "Gathering lines" connect to the well head and transport gas to larger interstate pipeline systems that connect with major gas markets. While pipeline systems themselves are complex with compressor stations and other infrastructure, for this analysis we considered only the impact of the pipeline and its surface right of way. Using the projected well-pad locations and taking into account a new interstate pipeline running N-S through Sullivan County, three pipeline location scenarios were developed:

1. Shortest-distance from well-head to interstate pipeline
2. Industry-preferred – minimizing property lines crossed
3. Conservation – minimizing habitat fragmentation, especially forest areas

These three alternatives are simplified, but they address important design issues. In scenario 1 the only formal controls on placement are the needs to protect wetlands and water bodies. Otherwise, the requirement of oil and gas laws to allow access to the resource means that landowners have limited influence on location, which may cut through forests and across agricultural fields. Scenario 2 uses property lines as a surrogate for the challenges a pipeline company may face in minimizing land leasing costs, i.e., the more owners, the higher the cost. Scenario 3 ignores property boundary issues but is designed to avoid areas of high habitat value, in most cases, minimizing divisions of continuous blocks of forest, a major habitat, tourism and timber resource in Sullivan County.

Table 1: Impacts of alternative pipeline scenarios

Shortest-distance	**Market-preferred**	**Conservation**
158 Stream crossings	184 Stream crossings	124 Stream crossings
18 Homes displaced	3 Homes displaced	10 Homes displaced
84 Wetlands impacted	49 Wetlands impacted	19 wetlands impacted
1,648 Properties impacted	1,248 Properties impacted	2,198 Properties impacted
0.56 Miles per well	0.63 Miles per well	0.66 Miles per well

Each existing well in Sullivan County requires, on average, 1.06 miles of pipeline. The right-of-way for protecting pipelines varies from 75 to 100 feet. Use of the right of way is restricted to annual crops once constructed, and much of the land impacted in unsuitable for agriculture due to various landscape factors. One mile of pipeline (100 feet wide) changes the land use of 13 acres of land for at least a sixty-year window while gas development continues. Our analyses above indicate the important role of design in minimizing quality and quantity of landscape change, but the land use change can become a driver for down the line impacts, including increased stormwater run-off and impacts on scenic beauty, among others. If planned appropriately infrastructure needs might provide opportunities for new land uses, which we investigate in the next three analyses.

Visual quality changes

Our visual quality analysis was completed in several phases. First, photos from sampled sites throughout Sullivan County were scored for perceived visual quality by various groups. Second, photos were analyzed for their composite elements in order to test correlation between coverage in the photo and visual quality. Here, photos were coded by key land use categories visible in the photo, such as forested, recreation and industrial and compared to the visual quality scores in phase one, using the approach of SHAFER & BRUSH (1976). Third, photo locations were georeferenced and photo scores were compared to the existing land cover, taken from the 2006 NLCD. Using this analysis, we then projected potential future changes to visual quality for Sullivan County, based on changes in land use relying on the high impact estimates from the Nature Conservancy, including pipeline development. What we developed was essentially a visual resource map that we have since extrapolated beyond Sullivan County. While the tool may not communicate the nuanced and important details of visual quality, we conclude that an approach like this is useful for identifying key spatial zones wherein substantial changes to land use (for infrastructure) can result in changes to the way in which these places are perceived. Efforts like this need to be coupled with human scale approaches to assess visual quality, so in 2013, we presented some design ideas to local leaders in Sullivan county, including: pipeline land use and planting and ridgeline protection strategies.

CLARIS

Our final analysis investigated Cultural Resources through the development of the Cultural Landscape Assessment and Resource Information System. Through this process we determined that cultural resources were not only key resources not afforded any state or federal protection from the extraction process, but also that cultural resources could be an effective leverage point for benefitting the planning process. State or federal review of archaeological or historic sites is not required unless drilling will occurs on state or federal lands. Through a recent Gas and Preservation Project (GAPP), gas and private cultural resource management firms have combined to offer voluntary guidance for review. But this partnership is absent governmental representation and is overwhelming the state agency’s ability to review reports. Perhaps, most important, we identified two key issues:

1. Direct impacts are real and known archaeological sites have been destroyed, but the indirect impacts are far more substantial.
   - > 80% of roads and bridges will be substantially repaired or rebuilt. Could be the greatest challenge to cultural resources in the next 50 years.
   - Water extraction + transportation pressures present immediate and important challenges:
     - Direct impact to known historic and archaeological resources.
     - Unknown resources are impacted at a greater rate in areas of PA with lower population densities.
     - Direct impact to recreation resources (boat slips + campsites).
     - Aesthetic + Scenic Context needs to be more aggressively addressed. Simply, a historic site stripped of its context isn’t preserved.
2. Impact to non-listed or locally recognized buildings and places is far greater, because they often are not as visible (e.g., local historic cemeteries); and local heritage groups and regional organizations are the most important 'hub' for communities, state agencies and corporations. They need better and more comprehensive information from both the PHMC and developers.

5 Conclusion and Outlook

From our work locally we have concluded that while much public attention has addressed fracking technologies and issues associated with well pad construction, the potential landscape impacts from changes in transportation infrastructure and the development of required pipelines will be substantially greater, transforming landscapes associated with shale gas development. These down the line impacts are experienced locally and regionally and not offered protection from not only national regulations, but national databases (e.g., the national registry of historic places). These clustered down the line impacts are irrevocably impacting wildlife habitat and fisheries as well as cultural and aesthetic resources. We also conclude that we need to develop a new set of planning tools that not only meets the unique challenges of shale gas development, that also leverages mobile geospatial tools, so that the tools can be place based and widely distributed. Moreover, these tools need to address broad water systems, aesthetic and cultural elements of the landscape, and provide a broader context for resource use.

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