Brunswick County North Carolina: Construction & Demolition Landfill Expansion Analysis

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ENST Capstone Class Fall 2011
Currently Brunswick County, North Carolina has a functioning Construction and Demolition landfill that serves as the collection point for all C&D waste in the county. The county has proposed to expand the size of the current landfill five-fold from 54 acres to 257 acres, and provide C&D waste services to surrounding counties. The Royal Oak community, affiliated as the Royal Oak Concerned Citizens Association, is located directly next to the landfill and has issued a complaint for relief and injunction of the landfill expansion. They are focusing their case on the county’s violation of the zoning for the proposed landfill site, the North Carolina Fair Housing Act, and the Equal Protection Clause. The Royal Oak community already bears many of the county’s undesirable land-use burdens, including an animal shelter, hog farm, and various mines. The community does not have access to sewer or water lines and must rely on wells. The Royal Oak community fears the landfill expansion will contaminate their drinking water or cause other unknown environmental and health effects.
PROJECT OVERVIEW

The project described in this report took on the challenge of assessing all aspects of the landfill expansion and its potential environmental effects on the surrounding areas. Of particular interest was the Royal Oak community and other neighborhoods that are home to primarily low-income, minority populations. We evaluated the existing environmental and health burdens Royal Oak currently bears, including the existing landfill, mines, animal shelter, and other Locally Unwanted Land Uses (LULUs). We enumerated and described these burdens, and analyzed the potential effects on the community and the county as a whole. We investigated the proposed landfill expansion’s prospective environmental effects on local wildlife, nearby wetlands, geology, and hydrology. We investigated potential means of improving the landfill’s efficiency and reducing C&D waste, including examining case studies of landfill expansions that managed to mitigate negative effects or to benefit multiple parties. Additionally, we analyzed the possible benefits of the expansion, such as new job opportunities or increased flow of resources into the community.
MAJOR FINDINGS

The proposed landfill expansion is adjacent to a community that is already burdened with land uses that raise questions about environmental justice. Royal Oak is a low-income, high percent minority community, which makes it a community highly vulnerable to environmental injustice.

Publically available information regarding the physical characteristics of the landfill site is currently scarce and access to that information is through the preliminary report of a contractor commissioned by the county. Based on the amount information currently available, it is difficult for a non-expert to form a conclusive assessment of the suitability of the proposed site for landfill activities.

A list of potentially present sensitive species for Brunswick County was constructed. Given that this analysis is not being performed physically in Brunswick Country, it wasn’t possible to determine which species were present at the proposed tracts. However, due to the dense level of biodiversity present within most wetlands, it is likely that there will be an issue with at least one of the potentially present sensitive species. Further investigation is necessary to directly determine the specific toxins related to the expansion site that severely threaten the residents of the Royal Oak community.

In efforts to minimize the already prevalent hazardous effects of the landfill there are ample opportunities that can be utilized to reduce waste. The first step towards a more sustainable C&D landfill is the construction of an efficient recycling program, which would allow citizens to swap
and share unwanted goods and would provide an opportunity for the materials to serve a different use. The process of recycling would significantly reduce waste while providing jobs for citizens and a sense of stewardship and involvement for the community.

Whether or not the landfill expansion should progress as planned is outside the scope of this report. However, based on our findings, it is important for Brunswick County to look at the potential negative effects, such as possible contaminated drinking water and endangered species habitat destruction, and ensure mitigation of these effects such that Royal Oak community member receive the minimum possible harm and maximum potential benefit that may flow from this expansion.
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Figure I. Existing and proposed landfill locations in Brunswick County, North Carolina. (Dewberry 2008)
I. DEMOGRAPHICS OF THE ROYAL OAK COMMUNITY

The landfill is located in the rural Royal Oak Community, a predominantly low-income and minority community. The geographical region of the community is as follows:

Taken from the formal Complaint for Relief filed by the UNC Center for Civil Rights, for The Royal Oak Concerned Citizens Association, the Royal Oak community lies within the following bounds:

Beginning at the intersection of N.C. Highway 2ll and Big Macedonia Road; west on Big Macedonia Road (houses on both sides of road) to Makatoka Rd; north on Makatoka Road to Little Macedonia Road (including Hankins Way off to the west); east on Little Macedonia Road; across N.C. Hwy. 211 Little Macedonia Road becomes Middle River Road and extending along Middle River Road to its termination; southeast in a straight line to the intersection of Galloway and Landfill road; and southwest in a straight line to the beginning point at the intersection of Big Macedonia Road and N.C. Hwy. 2111' including all the side streets contained within these boundaries: Running Brook Trail, Skyview Lane, Smith Rd, Zane Way, Pearl Way, Grant Way, Foxtrot Way, and Deerview way.
Figure 2: Royal Oak and Randolphville, two low-income communities in Brunswick County

The proposed expansion will encroach even farther into this community. Because of the large scale of the expansion project, it is necessary to determine whether this project will place disproportional burdens onto the Royal Oak Community. To evaluate environmental justice vulnerability, we collected and analyzed data on income, race, and population density.

TAX DATA

Using the boundaries described above, tax data were collected to determine the property values for the residents of the community. The data derived from the tax data is shown in Appendix 1. Using the property tax values, we were able to find the median house value and property value, which can be seen in Appendix 2.
TABLE 1. Royal Oak Community tax data

<table>
<thead>
<tr>
<th>Taxable Value as of 2010</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Value</td>
<td>$147,730.00</td>
<td>$68,890.00</td>
</tr>
<tr>
<td>Building Value *</td>
<td>$90,922.00</td>
<td>$63,005.00</td>
</tr>
<tr>
<td>Total Value</td>
<td>$537,175.00</td>
<td>$109,450.00</td>
</tr>
</tbody>
</table>

* Taken only from parcels with buildings

The mean and median values for property and building value differ greatly. This is because there are three parcels, owned by Brunswick County, which are worth a significantly larger amount than the surrounding parcels. These high-value parcels are the where the landfill is and where the proposed expansion will be. Given that these three parcels pull the mean to a higher average, the median is a more accurate representation of the community’s property value. Additionally, according to research by Reichert, Small and Mohanty (1992), property values close to a landfill may be expected to experience three to four percent depreciation.

ENVIRONMENTAL JUSTICE VULNERABILITY ANALYSIS

Two methods of environmental justice vulnerability analysis were used to develop an Environmental Justice Vulnerability Index for Brunswick County. These methods were developed by the Department of Transportation for the purposes of recognizing potential problems with social equity. The DOT uses these methods to recognize vulnerable areas before starting major transportation projects (Forenbrock et al. 2004). While this project is not a transportation project, the Environmental Justice Vulnerability Index and spatial interpolation can be applied to projects that deal with potential environmental justice violations. The Environmental Justice Vulnerability Index is used by government agencies and developers to evaluate vulnerable populations and to
recognize whether or not there are disproportionate risks to vulnerable communities, based on population density, percent of minority population and percent of low-income population. Spatial interpolation compiles the concentration of minority or low-income households living within a certain distance from the proposed project. These percentages are compared to the average percent minority or low-income households within the entire county. This test shows whether or not the project is at a higher risk of environmental justice vulnerability.

We have collected data on the block group level and county level in the following areas:

- Housing (Appendix 3)
- Income (Appendices 4 and 5)
- Race (Appendix 6)

The block groups that Royal Oak is a part of are Census Tract 206 and Block Groups 2 and 4, which are shown in bold. The landfill is located in Block Group 4 within two miles of Block Group 2 and within one mile of Block Group 3. Block Group 3 is not part of the Royal Oak Community, but is still in close proximity to the landfill.

An Environmental Justice Vulnerability Index was performed to assess the vulnerability of each block group. This index is based on the Department of Transportation’s Effective Methods for Environmental Justice Vulnerability Assessment (Forenbrock et al. 2004). The analysis was based on population density, percent of minority households, and percent of households below the poverty line. The scale goes from 1 to 12, with higher numbers indicating higher vulnerability.
These demographic data were taken at the block group and state level and put into the following formula for the Environment Justice Index (EJI):

\[
EJI = DVPOP \times DVMAV \times DVECO
\]

Where

DVPOP = degree of vulnerability based on population density

DVMAV = degree of vulnerability based on presence of minority population

DVECO = degree of vulnerability based on presence of low-income population

Factors were computed as follows:

**TABLE 2: DVPOP**

<table>
<thead>
<tr>
<th>Population per square mile</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt;0 and &lt;200</td>
<td>1</td>
</tr>
<tr>
<td>&gt;200 and &lt;1,000</td>
<td>2</td>
</tr>
<tr>
<td>&gt;1,000 and &lt;5,000</td>
<td>3</td>
</tr>
<tr>
<td>&gt;5,000</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE 3: DVMAV and DVECO**

<table>
<thead>
<tr>
<th>Percent minority or percent low-income</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; State Average</td>
<td>1</td>
</tr>
<tr>
<td>&gt; State Average and &lt; 1.33 times the state average</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 1.33 times and &lt; 1.66 times</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 1.66 times and &lt; 2 times</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 2 times state average</td>
<td>5</td>
</tr>
</tbody>
</table>

Following, in Figure 3, are the results of the vulnerability of each block group in Brunswick County.
<table>
<thead>
<tr>
<th>Block Group</th>
<th>Total EJVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Group 5, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 3, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 5, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 6, Census Tract 202, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 203.01, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 203.01, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 3, Census Tract 203.01, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 3, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 5, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 6, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 3, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 5, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 6, Census Tract 201, Brunswick County, North Carolina</td>
<td>1</td>
</tr>
<tr>
<td>Block Group 7, Census Tract 201, Brunswick County, North Carolina</td>
<td>4</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 203.02, Brunswick County, North Carolina</td>
<td>4</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 204.02, Brunswick County, North Carolina</td>
<td>4</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 206, Brunswick County, North Carolina</td>
<td>4</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 205.01, Brunswick County, North Carolina</td>
<td>5</td>
</tr>
<tr>
<td>Block Group 3, Census Tract 201, Brunswick County, North Carolina</td>
<td>6</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 201, Brunswick County, North Carolina</td>
<td>6</td>
</tr>
<tr>
<td>Block Group 1, Census Tract 205.01, Brunswick County, North Carolina</td>
<td>6</td>
</tr>
<tr>
<td>Block Group 5, Census Tract 203.01, Brunswick County, North Carolina</td>
<td>8</td>
</tr>
<tr>
<td>Block Group 4, Census Tract 206, Brunswick County, North Carolina</td>
<td>3</td>
</tr>
<tr>
<td>Block Group 2, Census Tract 206, Brunswick County, North Carolina</td>
<td>8</td>
</tr>
</tbody>
</table>

**Figure 3. Environmental Justice Vulnerability Index by block group; full data in Appendix 7**
The two block groups that the Royal Oak Community lies within are highly vulnerable to environmental injustice. The most vulnerable block group, Block Group 3 Census Tract 206, is adjacent to the landfill and the Royal Oak Community. It has similar percent minority and low-income percentages as are in Block Groups 2 and 4, but it is more densely populated, making it more vulnerable. The location of the landfill is centrally located between two of the most vulnerable tracts in the county. Figure 4 depicts the Environmental Justice Index visually.

Figure 4. Map of Environmental Justice Vulnerability Index

A high degree of vulnerability surrounding the landfill expansion was determined; however, this was only at the block group level. Spatial interpolation was used to determine percent minority
within a smaller area closer to the landfill. This is population that would be most affected by the expansion. Spatial Interpolation using small-area data was also used to determine the percent minority within ½ mile, 1 mile, 1 ½ miles, and 2 miles of the landfill. This method of analysis also was taken from the Department of Transportation’s *Effective Methods for Environmental Justice Vulnerability Assessment* (Forenbrock et al. 2004). Data was collected on the block level to ensure the most accurate measure. The data was then compared to the percent minority within the entire county.

**TABLE 4. Spatial interpolation**

<table>
<thead>
<tr>
<th>Distance from existing landfill</th>
<th>Total # households</th>
<th># minority households</th>
<th>% minority households</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ mile Blocks: 4182; 4169; 4179; 4168</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 mile Blocks: 4167; 4161; 4188</td>
<td>29</td>
<td>28</td>
<td>96.5%</td>
</tr>
<tr>
<td>1 ½ miles Blocks 4187; 4186; 2267; 4184; 4165; 4164; 4183; 4166</td>
<td>76</td>
<td>59</td>
<td>77.6%</td>
</tr>
<tr>
<td>2 miles Blocks: 2265; 2269; 2122</td>
<td>132</td>
<td>112</td>
<td>84.8%</td>
</tr>
<tr>
<td>County</td>
<td>46,297</td>
<td>7,021</td>
<td>15%</td>
</tr>
</tbody>
</table>

Using spatial interpolation, we see that there is a higher percentage of minority households within close proximity to the landfill than the average percentage of minority households for the county.

**GROWTH OF CONSTRUCTION IN BRUNSWICK COUNTY**

Construction is an indicator of economic growth within a community. The level of economic growth and vibrancy, while not factored into the Environmental Justice Vulnerability Index, can
indicate another dimension of vulnerability (William 1969). For this section of the report, data was taken from non-municipality affiliated areas, which are primarily rural areas. This does not include the major islands off the coast of Brunswick County or the major towns and cities within the county. The area of the landfill falls within a non-municipality affiliated area, with regards to permitting. Beyond this distinction, there is no further public data to specify building permits in Royal Oak.

![Building permits in Brunswick County](image)

**Figure 5. Building permits in Brunswick County**

Data is available only back to January 2007. According to the National Association for Home Builders, North Carolina has a construction trend of negative six percent. As seen above, the rural areas of Brunswick County has a construction trend closer to negative thirty-five percent. Construction is slowing in rural areas of Brunswick County at a much higher rate than the rest of the state.
II. GEOLOGY AND HYDROLOGY ANALYSIS

An understanding of the physical characteristics of the proposed landfill expansion site is necessary in order to predict the effects of such construction upon the site itself and the surrounding areas, as well as to contextualize and inform certain design considerations for any facility to be built upon the site. In particular, the topography, ecology, geology, and hydrology of the site play a large role in determining the manner and likelihood of soil and water contamination and any ensuing environmental and human health effects that might arise from the operation of a construction and demolition landfill at this site.

ASSESSMENT OF LAND

An assessment of the hydrological and geological characteristics of the proposed expansion site is limited by the available data specific to the site. Though general characteristics of the geological formations in the area are widely available, the data concerning local ground water flow, soil composition, and water table height—all factors important when considering the risk for contamination and human health impacts that may be posed by a landfill on the spot—are dependent upon the reports of professionals commissioned to survey and advise the stake holders upon the characteristics and suitability of the site. Without proper training, it is difficult for an interested non-expert to assess the quality of the report and to determine whether the samples are representative or if certain data types or important qualities were left unaddressed. The concerned citizen finds herself in a difficult position, wherein attempting basic research into the topic is unlikely to yield any direction regarding points on which to challenge the assessments of the physical qualities of the site. This is not to call into question the integrity and quality of the work
presented by the consultants, but rather to bring attention to the challenges faced by an engaged public in being sufficiently informed to advocate for its own needs and interests.

The United States Department of Agriculture (USDA) Rural Development provides a Solid Waste Management Grant to qualified non-profit organizations and educational institutions to help assess solid waste issues in low income and at-risk communities. However, the grant description states that it is limited to assessing the risk of water contamination by landfills currently operating, implying that a grant would not be administered until the proposed landfill is built. Additionally, the grant applicants must have the technical expertise to perform such an assessment, meaning a university, local government, or experienced nonprofit with the necessary skills would have to apply for the grant on the behalf of the Royal Oaks Community (USDA 2011).

The Royal Oaks Concerned Citizens’ Association has contracted with several organizations to address various concerns over the landfill expansion, some of which are capable of offering third-party expert advice in the fields of geology and hydrology. The association has also received grant money to support litigation on the basis of zoning and the Fair Housing act (Reichert et al. 1992), though it is unclear whether any grants have been awarded on their behalf for technical evaluation of the site. It also remains to be seen whether a third-party expert analysis of the siting report and other publically available data would be sufficient to properly assess the site’s physical characteristics and risk of environmental damages from the construction of the proposed landfill, or whether additional direct survey work at the site and on neighboring locations (such as the nearby swamps and residential areas) would be required. If the latter is the case, considerable expenditures would be required to collect and process the data, and difficulties concerning access to the locations.
in question would likely arise. For comparison purposes, Brunswick County allocated $318,100 for the siting study and report for this landfill expansion proposal. It would be difficult for a small community to raise similar funds should it be determined that additional direct evaluation is necessary to adequately assess the risk of expanding the landfill (Brunswick County Board of Commissioners 2011).

The difficulties in assessing the quality of available data notwithstanding, it is possible and beneficial for the concerned non-expert to develop a sense of the current understanding regarding the physical characteristics of the site. Such a sense allows the interested individual to make qualitative comparisons between the site of interest and other existing landfill projects that may or may not have resulted in environmental and human health damages. To this end, the available information is summarized below, accompanied by explanations and analysis where possible.

DATA AVAILABLE

The site-specific data currently available are only from the preliminary-phase site analysis, and as such may be lacking in important details, some of which are acknowledged in the report. The final siting report, commissioned by the Brunswick County Board of Commissioners (BCBC) on July 6, 2010, will contain technical assessments of the following components, based upon the requirements of Rule .0536 of the North Carolina Administrative Code (15A NCAC 13B .0536):

1. Characterization Study
2. Proposed Facility Plan
3. Site Hydrogeologic Report
4. Floodplain Location Restrictions
5. Wetlands Location Restrictions
6. Unstable Area Location Restrictions
7. Cultural Resources Restrictions
8. State Nature and Historic Preserve Location Restrictions
9. Water Supply Watersheds Location Restrictions
10. Endangered and Threatened Species Location Restrictions
11. Local government approvals for C&D landfills
12. Traffic Study

It is unclear when the siting study will be completed. A recent update discusses a planned completion date of January 9, 2011, which was not met, but indicates that the majority of the research required for the report has been collected, and the delays are due to unforeseen complications (Dewberry 2011). The study must be submitted to the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Waste Management (DWM) for review and approved prior to applying for a permit to build and operate the landfill, as per Rule .0536.

LOCATION AND TOPOGRAPHY

The existing Brunswick County Construction and Demolition Landfill (CDLF) is located northeast of Supply and west of Bolivia off of NC 17 in Brunswick County, NC (Dewberry 2008). The proposed expansion site encompasses two adjacent tracts of land (designated Tract 3 and Tract 4 by the county, not to be confused with US census tracts), which share a north-south border with each other and portions of their eastern borders with the current landfill Figure 6, below). No road access exists to Tract 3, but the shared border with the current landfill presents a probable means of access; Tract 4 borders State Road 1448 to the north, to which a dirt road has previously been cut (Dewberry 2008).
Between the proposed site and the current landfill lies an unnamed tributary to the Beaverdam Swamp, which lies to the north of the site. Along the western border of both tracts runs a tributary to the Royal Oak swamp, which forms the southern border of Tract 3. The totally area of the combined tracts is 247 acres, more than a four-fold increase from the size of the current landfill.
The useable area of the plots taken together is estimated to be 177 acres, after required buffer zones have been removed from the total acreage (Dewberry 2008). If the site is regarded as an expansion of the current landfill then the 200-foot horizontal buffer will not be required along the shared border (see Figure 7, at end of section). However, that border still has significant riparian features, and would probably require a 50-foot riparian buffer. The site also falls within the one-mile buffer required for the Green Swamp Preserve, but since the site is expected to be regarded as an expansion to the existing landfill rather than a new development it will most likely be exempt from this requirement (Dewberry 2008).

Both tracts are relatively flat, with moderate grades (6-8%) present at the boundaries with water features. The flat nature of the tracts is beneficial for landfill operation as potential for surface runoff and erosion is decreased, meaning that materials disposed of on the site are more likely to stay on site (Dewberry 2008). However, the increased grade at the boundaries, coupled with the especially swampy conditions at the borders, greatly complicate the building of an access road. Ideally, the sites would be connected directly to the existing landfill in order to share facilities, but doing so would necessarily effect the riparian environment at the border between the two plots, and would incur a rather large cost, as well as additional permitting requirements due to the destruction or alteration of wetlands.

**GEOLOGY**

The tracts are associated with the Waccamaw geological formation, an unconfined surficial aquifer with a typical depth of 20 feet, and overlay the Peedee geological formation, which is a confined aquifer for parts of the county, but unconfined and in direct contact with the surficial aquifer in
other areas (USGS 2003). It is possible that clay or silt deposits in this area have confined the Peedee formation at this site, but the Dewberry preliminary siting study does not indicate whether this is in fact the case (Dewberry 2008). The soil is primarily loosely consolidated sand, meaning that it is exceptionally permeable and liquid additions to the surface can infiltrate downwards quickly. Some silt and clay are present as well, but it is unclear how they are distributed or in what amounts (Dewberry 2008).

Karstic terrain has been observed in this general area, though it is unknown at this point whether it exists at this particular site. Karst in Brunswick County is more commonly associated with the Castle Hayne formation, but has been observed in areas of the Peedee Formation (USGS 2003). Karst is the formation that occurs when carbonate (i.e., limestone) bedrock is partially dissolved, the most noticeable and important feature of which is the development of sinkholes, wherein the ground collapses due to the dissolution of bedrock. This is a natural process that may be both accelerated or delayed by the additional loading and surface hydrology changes introduced by the existence of a landfill (Yang & Drumm 2002). Sinkholes can increase the exchange of water between the surficial and underlying confined aquifers, beyond any physical disruptions they may cause upon formation, such as breaching containment barriers built beneath the landfill (Dewberry 2008). The development of a sinkhole beneath the landfill would likely allow waste materials from the landfill to escape and enter the ground water, as well as increase the scope of distribution of ground water contaminants than would otherwise be the case. Certain techniques can be used to predict and minimize the formation of sinkholes in the context of landfills, but they hinge on knowledge of the characteristics of the karstic terrain on which the landfill sits (Yang & Drumm 2002). A detailed geotechnical survey would be required in order to determine whether karst is
present, and though it is unclear whether Dewberry is investigating this for the siting study, Rule .0538 indicates that such information would be required for a complete report (15A NCAC 13B .0538). The Dewberry update on April 14, 2011 indicated that a geotechnical investigation has been conducted, though no mention was made of karst (West 2011).

HYDROLOGY

Brunswick County receives an average of 55 inches of precipitation per year. Approximately 11 inches infiltrate to the surficial aquifer, and a further inch infiltrates to recharge the deep aquifer each year. The site has significant surface hydrology characteristics (See Figure 8, at end of section), with an estimated 43 acres between the two tracts qualifying as wetlands, and subject to protection (Dewberry 2008). The county would either have to fragment the useable area within the site or pay into the North Carolina Ecosystem Enhancement Program (NCEEP) to mitigate the destruction of the wetlands, which could cost from $23,774 per acre of wetlands to $64,777 per acre, depending on how they are classified (NCEEP 2011). Additionally, impacts to streams and neighboring wetlands must be considered, even if construction of the landfill does not directly impact them, as surface runoff, erosion, and ground water flow from the site may effect surrounding areas due to the proximity of riparian and swamp features on three sides of the site.

Approximately 48 acres of the combined tracts lie in the 100-year floodplain. Dewberry initially stated that there was conflicting information regarding the location of the flood plain, but has reevaluated the data since the releasing preliminary report. They are awaiting permitting information from the county regarding development in the 100-year floodplain, but have made no specific information regarding the reevaluated 100-year floodplain location available to the public.
Building in the floodplain could risk material from the landfill being washed away in a heavy rain event, potentially contaminating nearby surface and ground waters.

The seasonal high water table (SHWT), the highest level that ground water reaches in the soil in an average year, ranges from 0-5 feet for this site, meaning that the surface is effectively saturated with ground water for portions of the year in certain areas (NCDWQ 2005). Coupled with the exceptionally permeable soil on this site, this surface saturation makes for relatively easy and fast transfer of landfill wastes into the ground water and eventually offsite. The state recognizes this danger, and requires a minimum four-foot vertical separation between the lowest layer of landfill debris and the SHWT for all landfills, the upper two feet of which must be compact clay or its equivalent (NC General Assembly § 130A-295.6.(f) ). The separation is based upon the settled height of the contents above the SHWT, meaning it must be maintained throughout the operation of the landfill, regardless of shifting or settling landscape after construction. Though specifics have yet to be released, Dewberry anticipates that settling will occur on the site following construction, meaning that additional separation must be constructed in the building of the landfill in order to achieve the required separation into the future (West 2011). Personal correspondence with a professional in the field of landfill construction in NC yielded cost estimates, based upon recent projects of a similar nature of conducted recently, of $18 per ft² for a 24 inch clay liner. If such a depth of clay must be brought in for all 177 acres of the landfill at this rate, the cost would be upwards of $138 million. This certainly represents an extreme upper bound of the potential cost of the project, as some clay is found onsite, not all 177 acres will require the clay liner, and cheaper alternatives may exist, such as the use of a geosynthetic clay liner or mixing bentonite with the local sand in a 1:9 ratio to create an impermeable barrier (EPA 2001, Kockar 2005). However, the
cost to comply with the vertical separation requirements will certainly be considerable for this site in any case, as fill material up to four feet in depth must be brought on site to achieve the separation necessary. Information regarding the percentage of the site's acreage that overlays a four foot or less SHWT would be instrumental in determining the total amount of fill that must be brought in; however, it is surprising that the county has not shown more concern at the additional cost and difficulty presented by a site with areas of zero-foot SHWT.

Ground water can be understood as flowing in much the same manner as streams, from points of higher elevation to lower, and in a consistent direction. Dewberry has determined that most of this site flows towards the east or northeast, feeding into the unnamed tributary to Beaverdam Swamp, which is also the primary destination of ground water flow from the existing landfill. A small section in the southwest corner of the site flows to the southwest, where upon it enters the unnamed tributary to Royal Oak Swamp or directly into the swamp itself. Dewberry expects these surface water features to be useful as monitoring points for water contamination originating from the expanded landfill. They also assert that results of the monitoring of the Beaverdam Swamp tributary, forming the eastern border of the site, suggests that the current landfill has not has not contaminated the expansion site during its operation (Dewberry 2008). However, monitoring reports show that the ground water from the current landfill has elevated concentrations of certain contaminants, including arsenic, chromium, selenium, cobalt and vanadium (MACTEC 2011). If such elements are not finding their way onto the proposed expansion site to which they are flowing, it follows that they are entering the tributary and flowing away from the landfill, most likely to find lengthy residence in the swamp.
RISKS ASSOCIATED WITH LANDFILL EXPANSION

The implied assertion made by these findings is that a C&D landfill operating on this site poses virtually no risk of contaminating the wells of the communities near the site, nor does it pose a threat to any municipal water supplies. There are no private wells within 500 feet of the area on which waste may be buried, though there are 12 within 500 feet of the property lines of the tracts. The characteristics of the location’s ground water flow suggest that any contaminant would be swept into the surface water, which borders the site on three sides, and removed from the ground water servicing nearby wells. This may well be a reasonable assertion, but an assessment the ground water hydrology of the surrounding areas is important for determining the long term potential for contamination by the landfill. For instance, should any private wells be “downstream” of Beaverdam Swamp, contaminants carried by the tributary running between the sites could infiltrate into the ground water and be drawn up in the wells. It may also be that the dynamics of a swamp ecosystem may prevent any such infiltration from occurring. However, potential effects to the swamp ecosystems need investigation as well.

STRENGTH OF CONTAMINATION PREVENTION MEASURES

Though the EPA and the State of North Carolina, among others, regulate design elements of C&D landfills in an effort to prevent ground water contamination, many experts challenge the effectiveness of the requirements, asserting that most measures are insufficient to prevent ground water contamination over the life of the materials. Though these concerns are typically raised over the landfilling practices for municipal solid waste (MSW), which is typically considered to be more hazardous than C&D waste, it is beneficial to examine many of these objections in the context of this project in order to fully explore any potential risks of environmental damages.
There is no guarantee that any “impermeable” barrier put in place to contain waste will be free from defect or construction error, especially over a large area such as this. Furthermore, even a perfectly installed containment system may suffer damage and be breached during the operation of the landfill. A single weak point is all that is needed to render an impermeable barrier permeable, allowing for the exchange of material from the landfill with the ground water. A 1988 EPA report detailed at least six sites with various forms of compacted clay liners, some in tandem with plastic liners, which failed during the course of operation, leading to ground water contamination. Three failed due to incorrect liner installation, one to physical damage during the course of installation, one failed due to the unknown addition of hazardous materials that chemically impaired the liner, and one failed due to the chemical weathering of carbonate elements in the clay liner over time due to acidic conditions in the landfill. These landfills were not all C&D and were under a variety of different geological and hydrological conditions, but they used a liner technology similar to what will be required for the proposed expansion in Brunswick County, and demonstrate the possibility of clay liner failure (U.S. Environmental Protection Agency 1988)

Note, these failures all occurred while the landfills were operational. It is widely acknowledged that no liner system is permanent, and all will degrade and fail eventually. Therefore a key element in liner design is ensuring that it outlives any of the hazardous or undesirable waste it contains. However, the current “dry tomb” style landfills, which attempt to separate the waste from moisture in an effort to prevent contamination, also prevent the breakdown of waste for the large part, practically ensuring that any undesirable waste in the landfill remains upon liner failure (Lee 2011).
The term “impermeable barrier” is somewhat misleading; in fact, all barriers are somewhat permeable, but in order to meet regulatory definitions of “impermeable,” a barrier must have a maximum permeability of $1 \times 10^{-5}$ cm/s for a C&D landfill in NC (§ 130A-295.6.). Some calculations assert that under certain “average range” conditions, a 12-inch compacted clay liner with maximum permeability of $1 \times 10^{-7}$ cm/s (100 times less permeable than the North Carolina maximum) could be breached in as little as 5 years (Lee 2011).

The nature of containment barriers ensures that they are mostly hidden once installed; any flaws or damages will only become apparent upon contamination appearing in monitoring systems, such as ground water monitoring wells (Lee 2011). It is easy to imagine the difficulty in pinpointing liner damages and initiating repairs under layers of waste even if contamination is discovered quickly. However, if the containment system fails at a point at which ground water contamination can bypass monitoring wells, it is possible that years may pass before the failure is discovered, if it is at all. It has been asserted that traditional monitoring well spacing yields a relatively low probability of detecting thin plumes of contaminated ground water, and as such are insufficient to ensure the integrity of the landfill barrier system (Lee 2011).

The concerns discussed above represent potential issues that may arise in any landfill operation; this is not to say that they are all likely to occur should the proposed landfill expansion be built. Any landfill that is built on this or any site, however, should be explicitly designed to mitigate these concerns to every extent possible. A concerned citizen should be aware of these possible undesirable outcomes, and demand assurance that these concerns are being addressed, over and beyond the requirements of State and Federal regulations if necessary. The following two case
studies help to illustrate what can go wrong at landfills with characteristics similar to the proposed landfill expansion; they may also offer insight to help guide efforts towards prevention of the problems discussed in other locations.

CASE 1: FAIR STREET C&D SITE, PATTERSON, NY

Though a small (3 acre) and unpermitted site, it shared many features with the proposed site, including wetlands, shallow water table in an unconfined aquifer that discharges to wetlands, and a relatively even topography. The soil was primarily sand, with some gravel and silt, but almost no clay. A one-foot-thick clay-silt cover was used, but there was no liner system in place. Also absent were surface runoff controls and a leachate collection system. The landfill was under-engineered, but presents a good picture of what happens to C&D waste when placed in a location with these physical characteristics and lacking containment. Surface water percolated through the waste and into the water table, leading to significantly elevated levels of antimony, cadmium, copper, cyanide, iron, and zinc in the surface water and of magnesium, manganese, sodium, and exceptionally high values of total dissolved solids in the ground water.

This case serves as a fair warning that without proper containment, C&D waste has the strong potential for generating a variety of surface and ground water contaminants. It also speaks to the need of preventing surface water from infiltrating the waste and for systems to collect and properly handle any leachate that is formed above the containment barrier. Neither of these considerations are discussed in detail in this report, but certainly deserve consideration when assessing any specific designs put forward for the proposed landfill expansion (United States Environmental Protection Association 1995).
CASE 2: COX’S DARBYTOWN ROAD LANDFILL, HENRICO COUNTY, VA

A 100-acre C&D site, this landfill also sat above a shallow aquifer with a seasonal high water table of 1-14 feet, relatively gentle topography and evidence of sandy soils. It was required to have a 1-foot compacted clay liner, three feet of vertical separation from the SHWT, and a leachate collection system. These requirements are similar to, though somewhat less stringent than, the requirements for the proposed landfill expansion. Insufficient cover of the waste materials was discovered upon an inspection, while several years later monitoring wells revealed significantly elevated levels of organic carbon, as well as lowered pH. This demonstrates again the potential for failure of a clay liner in locations with characteristics similar to the proposed site, as well as raising concern over the importance of a properly functioning cover on C&D waste (United States Environmental Protection Agency 1995).
Figure 7. Property line and private well buffers in proposed expansion area (Dewberry 2008)
Figure 8. Wetlands in proposed expansion area (Dewberry 2008)
III. ENDANGERED SPECIES

Biodiversity is important both to the current economic standing of an area and to any future economic growth derived from particularly diverse regions. This section works in line with the Federal and State Endangered Species Acts to identify all species of concern given the habitat(s) at hand. With this information, any interested party should be able to determine whether or not an environmental review would be necessary; in addition, whether or not a permit would be necessary, or even possible, to attain. The proposed landfill expansion tracts are located in close proximity to Beaverdam Swamp and Green Swamp, both of which have potentially high levels of biodiversity. The proposed tracts are largely populated by longleaf pines, as well as other evergreens; this assists in determining which endangered species are present.

SPECIES CURRENTLY PROTECTED UNDER FEDERAL LEGISLATURE

An estimate based on information gathered from the US Fish and Wildlife Service suggests that sixty three plant and animal species in this area are endangered, threatened, or federal species of concern. Seven of the species are listed as historic or obscure, meaning that their appearance in the proposed landfill tracts is highly unlikely. Appendix 9 lists the endangered/threatened/federal species of concern in Brunswick County (US Fish and Wildlife Service 2011)

SPECIES CURRENTLY PROTECTED UNDER STATE LEGISLATURE

There are other species that are granted protection under the State Endangered Species Act (G.S. 113-331 to 113-337). Appendix 10 is a list of endangered and threatened species in North Carolina that are protected by state law; species which are also under federal protection are noted in the appropriate column. (NC Wildlife Resources Commission 2008)
At this stage of analysis, with only a remote literature-based analysis possible; results are inconclusive as to whether any of the potentially present species of concern currently inhabit the proposed landfill tracts. In order to determine which, if any, species of concern inhabit the proposed landfill tracts, a habitat assessment would have to be performed. Such an assessment would need to thoroughly cover the entire range of potentially present species seen in Appendices 9 and 10.

**FEDERAL PERMITTING**

After a habitat assessment is performed, it is very likely that some of these potentially present species will be shown to inhabit the proposed landfill tracts; as such, the Brunswick County Landfill operators would need to obtain a permit for continued operation, pursuant to section 10 of the Federal Endangered Species Act (Department of Interior, US Fish and Wildlife Service 2003).

Any individual or organization planning to conduct any activity that would result in the taking of an endangered or threatened species must first obtain a permit to perform the aforementioned activity; in this particular case, the operation of a construction and demolition landfill. There are two types of permits issued under the Endangered Species Act: Permits for scientific research, or to enhance the survival of the species (pursuant to ESA section 10(a) (1) (A)); and permits which allow the incidental taking of species, while performing an otherwise lawful activity (pursuant to ESA section 10(a) (1) (B)). The latter permit, which is the more relevant, must also come in combination with a Conservation Plan, also commonly referred to as a Habitat Conservation Plan (Department of Interior, US Fish and Wildlife Service 2003).
The application for a permit contains a variety of requirements, as seen on the National Marine Fisheries Service website; a copy of the requirements is seen in Figure 9 below:

I. One of the titles below as appropriate:

II. Date of the application.

III. The name, address, telephone, and fax number of the applicant. If the applicant is a partnership, corporate entity or is representing a group or organization, include applicable details.

IV. A description of the endangered or threatened species, by common and scientific name, and a description of the status, distribution, seasonal distribution, habitat needs, feeding habits and other biological requirements of the affected species.

V. A detailed description of the proposed activity, including, but not limited to:
   A. The anticipated dates and duration of the activity.
   B. The specific location of the activity. Please include latitude/longitude coordinates if possible.
   C. For a general incidental take application, include an estimate of the total level of activity expected to be conducted.

VI. The application must include a conservation plan based on the best scientific and commercial data, which specifies:
   A. The anticipated impact of the proposed activity on the listed species, including:
      1. The estimated number of animals of the listed species and, if applicable, the subspecies or population group, and range.
      2. The type of anticipated taking, such as harassment, predation, competition for space and food, etc.
      3. The effects of the take on the listed species, such as descaling, altered spawning activities, potential for mortality, etc.
   B. The anticipated impact of the proposed activity on the habitat of the species and the likelihood of restoration of the affected habitat.
   C. The steps that will be taken to monitor, minimize, and mitigate such impacts, including:
      1. Specialized equipment, methods of conducting activities, or other means.
      2. Detailed monitoring plans.
      3. Funding available to implement measures taken to monitor, minimize and mitigate impacts.
   D. The alternative actions to such taking that were considered and the reasons why those alternatives are not being used.
   E. A list of all sources of data used in preparation of the plan, including reference reports, environmental assessments and impact statements, and personal communications with recognized experts on the species or activity who may have access to data not published in current literature.

Figure 9: Permitting process for incidental takings under ESA (1973); data available from the National Marine Fisheries Service at [http://www.nmfs.noaa.gov](http://www.nmfs.noaa.gov).
Although this process would take a large amount of time and capital, the Brunswick County Construction and Demolition Landfill could obtain a permit, assuming that the habitat assessment didn’t show an overabundance of endangered or threatened species concentrated within the proposed expansion tracts.

**CONSERVATION PLAN**

In order for a permit to be attained, a Conservation Plan must be designed that would afford protection for all endangered or threatened species. Such would require some planning: some of the employees of the C&D landfill would have to be educated on identifying any of the sensitive species which are identified; procedure would need to be developed pertaining to the preservation of the aforementioned species; and the plan would have to address any problems relevant to individual species that have yet to be seen.

**FEDERAL ENFORCEMENT**

Citizens play an important role in the enforcement of this statute. Under the Endangered Species Act, any person may file a civil action against any violator of this act. Citizens must give 60 days’ notice of the alleged violation to the alleged violator, andto the Secretary of the Interior. A notice and delay period have been built into the statute to allow the violator time to correct his violation, and to allow the Secretary time to enforce compliance; this helps to alleviate the necessity of citizen enforcement (Department of Interior, US Fish and Wildlife Service 2003).
STATE PERMITTING

In accordance with section 113-333 (c) of the State Endangered Species Act, the scope of the takings clause (section 113-337 (a) (1)) is extended only to state or federally owned property; as the proposed expansion sites are owned by the county, they wouldn’t even need any sort of state level permit for their development purposes. However, the Wildlife Resources Commission (WRC) is permitted to petition any unit of local government in implementing a state designed conservation plan, as also seen in section 113-333 (c) of the State Endangered Species Act. This means that the WRC could potentially petition Brunswick County to follow a conservation plan of their design, assuming that any state protected species are discovered in the proposed landfill tracts.

STATE ENFORCEMENT

In accordance with section 113-337 (b) of the State Endangered Species Act, any person convicted of violating the provisions of the act is guilty of a Class 1 misdemeanor; but as previously mentioned, this punishment is only applicable to takings committed on state or federal property. As the proposed landfill tracts are owned by the county, they would be exempt from enforcement; this excludes a scenario where the county was petitioned by the WRC, as previously mentioned.

OTHER LEGISLATION

The Clean Water Act is the main law in the United States that governs water pollution; permits are necessary for discharge into navigable waters of the United States, including some of the wetland areas that surround the proposed landfill tracts. The Brunswick County Landfill already is permitted for discharge into Beaverdam Swamp, according to a report from the Environmental
Protection Agency’s Facility Registry System (Environmental Protection Agency 2011); accordingly, no further Clean Water Act permitting would be necessary.

The National Environmental Protection Act is one of the most important pieces of legislature in terms of protecting environmental interests in the United States. It requires a procedural analysis of any federally funded project that may have an impact upon the environment, in accordance with section 102 (2) of the National Environmental Protection Act (US Congress 2000). As the proposed landfill expansion is to be performed on the county level, and doesn’t draw from federal funding, it is exempt from any action under the National Environmental Protection Act.

RECENT FINDINGS
As of April 12th, 2011, the US Fish and Wildlife Service had requested a survey of the foraging and nesting habitat for the red-cockaded woodpecker in the proposed landfill tracts (Lewis 2011); this indicates that the USFWS believes that there is a potential for takings of this particular endangered species within the proposed landfill tracts. Results from the survey aren’t yet available, but if the report finds that there is a large population of red-cockaded woodpeckers in the proposed tracts, the progress of the proposed landfill expansion could be impacted.
IV. PROJECTED HEALTH IMPACTS OF LANDFILL EXPANSION

Understandably, some of the greatest concerns for residents of the Royal Oak community are the potential health impacts of the proposed expansion of the Brunswick County C&D landfill. The potential health impacts resulting from changes in local land use must be carefully considered before expansion plans move forward. The residents of Royal Oak, who obtain their drinking water primarily from groundwater sources, have expressed concern that their water could become (and indeed might already be) contaminated by landfill materials (Moss Joyner, 2011). The area around the Royal Oak community is currently host to several other undesirable land uses including the existing landfill, an animal shelter, a wastewater treatment center and a sand and gravel mine—all of which may already be negatively impacting the health of the community (Moss Joyner 2011). Fear that the additional burden of the C&D landfill expansion might push chemical exposures above the threshold levels established by health and environmental protection agencies is not unwarranted. Citizens are rightfully concerned that this landfill expansion might become yet another burden driving them towards poor health outcomes.

CURRENT CONCERNS OF COMMUNITY MEMBERS

C&D landfills are not meant for the dumping of hazardous materials and thus it is unlikely that residents living in the surrounding areas would be at risk of acute, high-level exposures of any single chemical of concern – especially considering the physical distance between residences and the landfill. However, hazardous materials undoubtedly will still find their way into the site and smaller dose chronic exposures should remain a concern because of their greater relative likelihood and long-term health implications. The proposed expansion of the Brunswick County C&D landfill is expected to increase the life expectancy of the site to at least one hundred additional operational
years (Moss Joyner 2011). This means that if even small exposures to hazardous materials were to occur, the exposures could become chronic and cause long-term health effects for residents who have settled permanently in the area. The landfill expansion has the potential to influence the health of community members for generations. The decisions of policymakers today will certainly have repercussions far into the future.

Members of Royal Oak community have been noted as obtaining drinking water primarily from private wells less than thirty-five feet in depth (Moss Joyner), but they do not have the resources to test their drinking water regularly for safety (Moss Joyner). The contamination of their vulnerable drinking water source is one of their main concerns with the landfill expansion. Primary contaminants of concern include chemicals found in demolition wastes: “[…] adhesives, caulk, paint, wood preservatives, formaldehyde resins, stains and varnishes, appliances, batteries, mercury-containing switches and lights, PCB-containing transformers and capacitors,” (Moss Joyner). The materials in this list indeed contain many chemicals with known toxicity in humans.

Though some of the contaminants of concern for the Royal Oak community are not officially allowed in an unlined C&D landfill like the one in Brunswick County, the fact remains that these sorts of materials still end up in the landfills anyway. The dumping of hazardous materials might be likely in the event of a natural disaster, for example, when there is simply too much debris to sort it all properly. Assuming that Brunswick county will make efforts to properly monitor materials dumped into the landfill and will continue its recycling and hazardous waste programs in accordance with state and federal regulations, it is advisable for opponents of the landfill expansion for focus their concern on the health effects of materials that even the most conscientious programs
cannot eliminate from a landfill site. There are many common building and construction materials that innately contain harmful agents and that end up in C&D landfills even if the waste is carefully screened. Formaldehyde and PCBs are just two of these types of materials that the community rightfully listed as health concerns.

**FORMALDEHYDE**

Formaldehyde is likely to be found in demolition debris and thus is a concern of the Royal Oak community that deserves further consideration. There are many construction materials that contain or that are manufactured with formaldehyde, including composite wood products like particle board, paints, and some fabrics (California Department of Toxic Substances 2005). Formaldehyde resins are often used to hold these materials together, but as the materials break down – as they might in a landfill – the formaldehyde is released into the environment (California Department of Toxic Substances 2005). This formaldehyde can be present in gaseous form but can also dissolve in water (California Department of Toxic Substances 2005).

The OEHHA has recommended that chronic exposure to formaldehyde gas remain below 2.4 ppb on average (California Department of Toxic Substances 2005), and noted that concentrations below 76 ppb are typically tolerable and have few adverse effects in instances of acute exposure (California Department of Toxic Substances 2005). At concentrations above threshold values, formaldehyde has been shown to cause cancer in humans, specifically nasopharyngeal cancer (California Department of Toxic Substances 2005) and it can also cause other short-term health effects in the case of acute exposure such as irritation of exposed eyes, skin and lungs (California Department of Toxic Substances 2005). Resources from the state of California suggest that the
formaldehyde concentration within a typical home is seldom found above 37 ppb, and even this value depends heavily on the materials used in construction and the age of the home (California Department of Toxic Substances 2005).

Ultimately, the characteristics of the Brunswick County landfill do not suggest that exposure to formaldehyde gas should be of particular concern for residents of the Royal Oak Community. Because the landfill is uncapped and exposed to the open air, it is unlikely that the decay of building materials alone in an outdoor space could raise formaldehyde gas concentrations to any level of concern for residents who live outside of the landfill buffer. Formaldehyde concentrations tend to be higher in new homes where composite materials have been more recently manufactured (California Department of Toxic Substances 2005) and formaldehyde levels stemming from these materials tends to decline over time (California Department of Toxic Substances 2005). Given that older homes are often the ones being demolished (although hurricane-vulnerable Brunswick County also sees newer homes being demolished), the potency of their formaldehyde gas will likely have dissipated long before the materials ever reach the Brunswick County landfill.

**POLYCHLORINATED BIPHENYLS (PCBs)**

PCBs are hazardous chemicals used in the production of transformers and capacitors in household electronics which can sometimes end up in landfills (California Department of Health Services Hazard Evaluation System and Information Service 2008). Polychlorinated biphenyls (PCBs) have been shown to cause cancer in animal studies and their use in manufacturing has been limited since the discovery of their possible carcinogenic effects (California Department of Health Services Hazard Evaluation System and Information Service 2008). Because PCBs are highly regulated,
they should not be a great burden in properly regulated landfills. Even some household electronic items did end up in the landfill and PCBs from their transformers and capacitors did somehow made it into drinking water, it is unlikely that they would be detected in concentrations that would be cause for concern for local residents. Known human health impacts from PCBs have been derived mainly from retrospective case studies of factory workers exposed to massive amounts of chemicals during manufacturing (California Department of Health Services Hazard Evaluation System and Information Service 2008). Blood tests have shown that PCBs can be measured in the blood, but no one is quite certain what any given level of PCBs will do to a person or what the health outcomes will be (California Department of Health Services Hazard Evaluation System and Information Service 2008). Given the uncertainty surrounding the likelihood of exposure to residents and the health effects of low-dose exposure if it were to occur, PCBs should perhaps not rank among the Royal Oak community’s top concerns.

CONCERNS FROM HEALTH LITERATURE ADDRESSING C&D LANDFILLS

A review of literature addressing the health risks associated with C&D landfills suggests a set of concerning contaminants similar to the list proposed by the Royal Oak community, but more focused on a handful of key chemicals. When considering potential exposures to contaminants from construction and demolition landfills, there are two major routes of exposure: exposure via drinking water and exposure via air. Though air pollution from the landfill was not listed as a major concern of the Royal Oak community, it is a potential exposure route that should also be addressed before the expansion is undertaken. Though drinking water contamination is a more commonly debated environmental health concern, air contamination also has the potential to affect communities in the long term—especially those citizens who already have underlying respiratory issues.
WATER EXPOSURES AND ASSOCIATED RISKS

In 1995 the EPA collected case-study reports from eleven non-municipal C&D landfill sites in New York, Virginia and Wisconsin that directly led to the contamination of local groundwater (United States Environmental Protection Agency Office of Solid Waste 1995). Offending sites most commonly leached non-biological contaminants, with manganese, lead, iron and total dissolved solids being the most common (United States Environmental Protection Agency Office of Solid Waste 1995). Further review of environmental health literature highlighted the following potential water exposures of concern for C&D landfills: manganese and iron, lead, and arsenic. All of these elements can be found in materials common to construction and demolition waste and each will be addressed below.

MANGANESE AND IRON

Some metal contaminants do not have negative health impacts in humans but affect the quality and taste of drinking water at certain concentrations. Two such metals are manganese and iron (Weber 2011). These types of metals will cause potentially noticeable changes in the taste or appearance of water. (Weber 2011). They can be removed via filters or water softeners, but these are expensive cosmetic processes that would place further burden on families in Royal Oak, who already cannot access safe alternative water sources (Weber 2011). These types of non-toxic metals are important because they might be indicators of a larger, more serious contamination problem. If residents begin noticing that their water tastes strange, this may be a sign that iron and manganese are leeching into the ground water from the landfill site and that other metals (such as lead or arsenic which cause no obvious changes in drinking water at low concentrations) might also be entering the drinking water via the landfill as well.
**LEAD**

Lead is a well-known heavy metal with toxic effects. Though most Americans are probably familiar with the threat of lead from lead-based paints and leaded gasoline, the potential for lead exposure through drinking water is one that cannot be ignored. According to the EPA, as much as twenty percent of all lead exposure occurs through drinking water (Basic Information about Lead in Drinking Water 2011). This type of exposure is most common in older homes with lead piping, (Lead in Drinking Water 2011) but lead can also contaminate drinking water if there is source of contamination affecting groundwater. Based on the standards set forth by the Safe Drinking Water Act, lead concentrations in water should ideally be 0 ppb to be safe for human consumption (Basic Information about Lead in Drinking Water 2011). Lead paint waste in construction and demolition materials is classified by the EPA not as hazardous waste but as household waste; therefore it can be dumped in C&D landfills like other materials and is not subject to additional lead regulations noted in other types landfills (Wadanambia et al. 2011). The health effects of lead poisoning have been well documented, particularly in children, whose mental development can be disrupted by the heavy metal. As with arsenic contamination (described below) it is impossible to assess the risk to residents without further information about how much lead-material is actually in the Brunswick County landfill, how much metal can lead through the soil and into groundwater, and what concentrations of lead are typically found in the taps of local residents. Further research and testing would be required to answer these questions.

**ARSENIC**

Wood preservatives were listed among the waste materials of concern put forth by the Royal Oak community (Moss Joyner 2011), likely because the wood preservation process involves arsenic
compounds (California Department of Health Services Hazard Evaluation System and Information Service 2011). Arsenic is a heavy metal and is commonly known for its toxic properties. Common wood preservatives include chromate copper arsenic (CCA) and ammonium copper arsenate (ACA) (California Department of Health Services Hazard Evaluation System and Information Service 2011). These materials help protect wood and are valued in construction (California Department of Health Services Hazard Evaluation System and Information Service 2011). Because of the popularity of treated wood, arsenic can potentially accumulate in C&D landfills where old treated wood is left to break down. It has been noted that arsenic treated wood is common in southern homes where the climate is often damp and conducive to damaging unprotected wooden construction materials (Saxe et al. 2011). Though CCA and ACA are arsenic containing compounds (as opposed to pure arsenic metal), there are still adverse health effects to consider. Health effects of chronic arsenic exposure are serious and include damage to the nervous system (sometimes heralded by tingling in the extremities) and skin, as well as birth defects in unborn children (California Department of Health Services Hazard Evaluation System and Information Service 2011).

Currently 10 μg/L is considered the safe drinking water standard for arsenic (Saxe et al. 2011). There have been mixed reports about whether or not arsenic from treated wood in landfills has the potential to become a health risk in groundwater used for drinking. A recent field site study in Florida suggested that arsenic contamination of groundwater beneath landfills should not be a concern (Saxe et al. 2011), but a different experimental study in landfill tests cells found that arsenic concentrations might actually surpass primary water quality standards (Wadanambia et al. 2011). This same study noted the high potential for iron and manganese contamination concurrent
with arsenic exposure, as well as additional contamination by aluminum, copper, sulfate and total dissolved solids (Wadanambia et al. 2011). These studies suggest that it is possible for materials contained within a C&D landfill to impact ground water, but they do not make conclusive findings about how these contaminants find their way into drinking water. It is important to remember that the health effects from chemical exposures often depend on the concentrations rather than the mere presence of concerning materials in water. Calculating the concentrations of metals like manganese and iron, lead and arsenic in the water collected in samples from homes in the Royal Oak community seems like a logical next step in determining whether materials from the existing landfill are already leeching into community water source. The potential for this leeching to occur has been addressed (Lewis et al. 2011).

AIR EXPOSURES AND ASSOCIATED RISKS

Though residents of the Royal Oak community seem to have been primarily concerned with the health risks associated with landfill-contaminated drinking water in their homes, a second major route of exposure to landfill materials is via the air. Unlike water, which can have varying quality levels depending on its source and the treatment it experiences on its way to a tap, all individuals in a given environment are exposed to the same air quality. Everyone breathes in ambient air twenty-four hours a day, seven days a week. The idea that a C&D landfill could potentially contribute to air contamination is not as intuitive as its effects on groundwater quality, but it is equally concerning. Aside from formaldehyde, two additional air contaminants of concern stemming from construction and demolition landfills are hydrogen sulfide gas and particulate matter.
**HYDROGEN SULFIDE**

A lesser-known exposure risk associated with construction and demolition landfills is that of hydrogen sulfide gas. Hydrogen sulfide is the gas commonly associated with the smell of rotten eggs. Gypsum, a vital ingredient in drywall, breaks down into hydrogen sulfide (among other sulfur compounds) when in the environment of a landfill (Colledge & Wilder 2011). Not only does this breakdown produce an unpleasant odor that can surround landfill sites with high gypsum composition, but hydrogen sulfide gas can be toxic at high concentrations (Colledge & Wilder 2011). Although NIOSH recommends that hydrogen sulfide concentrations in the air remain below 10 ppm, some landfill sites have measured levels as high as 95 ppm (Colledge & Wilder 2011). The health effects of hydrogen sulfur exposure are primarily irritating and acute, but even low-level exposures can be harmful to people with preexisting respiratory, cardiac or nervous system conditions (Colledge & Wilder 2011). In at least one documented case, landfill workers were killed by exposure to high concentrations of hydrogen sulfide when the gas control system of that landfill leaked (Colledge & Wilder 2011). Exposure to this gas at levels over 100 ppm for longer than 15 minutes can certainly be fatal (Colledge & Wilder 2011).

Luckily for the residents of the Royal Oak community, adverse health effects from hydrogen sulfur exposure seem unlikely. The Brunswick County landfill is uncapped and open to the air and environment - it is improbable that concentrations of hydrogen sulfide in the air around the community would be high enough to cause health problems. It is however advisable for residents with preexisting conditions to be aware of the effects of hydrogen sulfide in the event that prevailing wind and air conditions allowed local concentrations to rise and their health conditions became irritated. One helpful feature of hydrogen sulfide is the fact that the gas has a highly
noticeable and repugnant odor. Residents will know if they are being exposure to hydrogen sulfide gas and can react accordingly before any harm comes to them. At the same time, this odor is also perhaps the most unpleasant feature of the gas. If the Brunswick County landfill were to ever amass large amounts of gypsum drywall, the community might be forced to deal with unpleasant odors. This would be bad not only for the morale of community members, but also for property values. It is important, however, to remember that this situation would be the result of extreme hydrogen sulfide concentrations, large enough to spread out past the landfill buffer and impact the surrounding community. It is unclear from the currently available data which factors might influence the actual concentrations of hydrogen sulfide experienced by Royal Oak community. Further onsite research would be advisable.

**PARTICULATE MATTER**

Unlike hydrogen sulfide, particulate matter is a more common and more obvious air contaminant in the context of C&D landfills. Whenever materials are dumped into the landfill or whenever trucks traverse the dirt roads leading into and out of the landfill site, particulate matter is stirred up into the air and can be carried into the lungs of nearby residents. Fires are possible at C&D landfill sites, and could lead to the inhalations of not only dust, but smoke and potentially hazardous gases if not controlled (Lewis et al. 2011). As a part of the federal Clean Air Act, air particulates levels are required to be monitored and exposure limits have been established suggested by the Environmental Protection Agency. Current ambient air quality standards for particulates are as follows: PM$_{2.5}$ should not exceed 15 μg/m$^3$ annually, or 35 μg/m$^3$ in a 24-hour period, and PM$_{10}$ should not exceed 150 μg/m$^3$ more than once per year (averaged over three years) (United States Environmental Protection Agency Office of Air Radiation 2011).
The general rule with particulate matter is that the smaller the particulate, the further the material can penetrate into the respiratory system and the more damage it can cause (United States Environmental Protection Agency Office of Air Radiation 2003). Any particle under 10 micrometers (μm) can be considered dangerous. For reference, dust particulates are typically around 10 μm and particulate from smoke or smog leaning are closer to 2.5 μm (United States Environmental Protection Agency Office of Air Radiation 2003). As with many environmental exposures, particulate matter tends to have the greatest impact on children, the elderly, and people with pre-existing health conditions (United States Environmental Protection Agency Office of Air Radiation 2003). Additionally, according to the EPA, “[…] scientists are evaluating new studies that suggest that exposure to high particle levels may also be associated with low birth weight in infants, pre-term deliveries, and possibly fetal and infant deaths” (United States Environmental Protection Agency, Office of Air Radiation 2003). Acute exposure to high levels of particulates can lead to asthma attacks or lung infections, and chronic exposures can lead to long-term decreased lung function (United States Environmental Protection Agency Office of Air Radiation 2003). Particulates are an unpleasant but likely risk associated with the Brunswick County landfill expansion. Further research into quantitative exposure risks as well as methods for reducing particulate concentrations in the air around the landfill if levels were to rise would be advisable.

According to the North Carolina Department of Environment and Natural Resources Division of Air Quality, there are approximately 70 air pollution-monitoring stations in North Carolina spread across 45 counties. Unfortunately there are no stations in Brunswick, County (North Carolina Department of Environment and Natural Resources Division of Air Quality Ambient Air...
Monitoring Section 2007). As of 2011, only three North Carolina counties have ever reported higher than acceptable PM$_{2.5}$ levels since monitoring began. Unfortunately, these sites cannot provide meaningful information to residents in the Royal Oak community concerning their local risk to particulate exposure. Local testing and monitoring would be the only way to predict levels of exposure to particulates in Royal Oak. Fine particulates are often measured intermittently and manually in North Carolina, and the process requires a high level of technical skill. Typically these methods involve collecting air through an inlet that selects for PM$_{2.5}$ and then traps the particulate matter onto a filter. After the collection period is complete, the weight of the filter is compared to its clean weight to determine the amount of particulates in the air. PM$_{2.5}$ monitors are meant to be placed in living and working areas, and can be used to calculate exposures at the neighborhood level (approximately 2.5 mi radius) (North Carolina Department of Environment and Natural Resources Division of Air Quality Ambient Air Monitoring Section 2007).

Though it is certainly a different landfill site with different relative amounts of construction and demolition materials, a 2006 an air quality study performed on an 80-acre C&D landfill site in Kenner, Louisiana can serve as a useful reference for the Brunswick County landfill (Chef Menteur C&D Landfill 2000). The Kenner landfill was noted to accept a great deal of hurricane demolition debris (Chef Menteur C&D Landfill 2000). The study in question tested asbestos, arsenic, cadmium, chromium, lead, PM, VOCs and hydrogen sulfide concentrations in the air at four different locations physically on the landfill and at one control location off-site (Chef Menteur C&D Landfill 2000). The on-site locations included areas that were and were not downwind of the site (Chef Menteur C&D Landfill 2000). The findings were promising: almost all chemical concentrations were below the detection limits of the equipment, or even below the quantitation
limit of the equipment (Chef Menteur C&D Landfill 2000). The one exception was particulate matter, which was measured at 0.561 mg/m$^3$ at only one of the testing sites (Chef Menteur C&D Landfill 2000).

A common theme in air contamination associated with C&D landfills is that each site is unique. Site-specific data collection would have to be carried out to determine how each of these potential respiratory concerns might actually affect the surrounding community. If collected and made available, reference air measures from the current landfill could be used to project future exposures based upon the dimensions and location of the proposed expansion site. It would also be helpful to know the current composition of the existing landfill. Unlike with water as a vector for contamination (where potential contaminants must not only come in direct contact with water but also must flow in a specific static direction for exposure to occur), air conditions are variable. Changes in weather patterns or wind direction influence who is exposed to which air contaminates at which times.

**ADDRESSING POTENTIAL EXPOSURES FROM EXISTING LULUs**

It is important to remember that the potential contaminants of concern associated with the C&D landfill expansion, as well as the Royal Oak Community itself, do not exist in a vacuum. Any physical, chemical, or biological agents introduced into the ambient environment from the expansion of the construction and demolition landfill would only be adding to the pre-existing burden of contaminants from other locally unwanted land uses (LULUs). In the initial presentation of concern put forth by the representatives of the Royal Oak community, the idea of social justice in association with LULUs already in the vicinity of Royal Oak was a major theme. Local LULUs
addressed included hog farms, aquaculture farms, an animal shelter, a solid waste transfer site, wastewater treatment facilities, and salt, peat, fill, rock and sand mines (Moss Joyner 2011). Several of these LULUs are addressed below in reference to their potential health effects.

ANIMAL SHELTER

Brief research into the Brunswick County Animal Shelter and the nearby wastewater treatment facility (addressed below) indicate that these facilities need not be pressing health concerns to current residents of the Royal Oak community (though they may indeed be unpleasant additions to the community otherwise). As of October 13th 2011, the Brunswick County Animal Shelter was home to only eighteen dogs and four cats (View All Animals 2011). Though animals – particularly dogs – have been cited as sources of drinking water contamination, most warnings relating to pets and fecal contamination are for surface as opposed to ground waters (United States Environmental Protection Agency Office of Water 2011). Dogs can introduce biological agents such as Cryptosporidium, Giardia, Salmonella, and parasitic worms into drinking water systems if they are allowed to freely defecate near community water sources. As long as the animal shelter manages its waste properly, such as by flushing the wastes into the county sewer lines, it seems unlikely that the Royal Oak community could be put at risk from the animal shelter any more than they might be from their own pets. (United States Environmental Protection Agency Office of Water 2011)

WASTEWATER TREATMENT FACILITY

Another LULU (locally unwanted land use) of concern for the Royal Oak community is the local wastewater treatment center. Wastewater treatment facilities carry the double risk of biological agents from the contaminated water being treated and chemical agents from the treatment process
itself. The good news for residents of the Royal Oak community is that any health risks associated with wastewater treatment facilities are typically restricted to workers in these facilities (Brown 1997). Though the wastewater treatment process involves the aerosolation of biological and chemical agents of health concern, these aerosols are much more likely to affect employees who work within feet of the treatment process rather than community members who live farther away (Brown 1997). The issue of the C&D landfill expansion exacerbating any potential biological contaminants from the animal shelter or the local wastewater treatment facility is unlikely because C&D landfills are not known for being sources of biological contamination in the first place.

**QUARRIES AND MINES**

The Royal Oak community’s concern that the Brunswick County C&D landfill expansion might exacerbate health problems already stemming from existing quarries and mines in the area is valid. In the case of quarries and mines, particulate matter and air pollution are the primary contaminant and route of exposure of concern, respectively. Runoff is also sometimes cited as an environmental concern in areas around mines and quarries. As of 2000, there were 35 sand/gravel mine sites in Brunswick County, North Carolina, 28 of which were still active (North Carolina Geological Survey 2011).

In 2002, the office of Congresswoman Hilda S. Solis prepared a report to address community health concerns related to gravel mining in Irwindale, California. The ultimate outcome of the report was to indicate that there is still little known about the potential adverse health effects of living near these types of facilities (United States House of Representatives 2002). The gravel mines in this area were found to contribute to elevated levels of PM$_{2.5}$ from mining activities as
well as product transport (United States House of Representatives 2002). The study also determined that it was difficult to calculate the exact level of air contamination coming from the mines using only the existing air quality monitoring equipment in the area (United States House of Representatives 2002). A particularly relevant quote from the conclusion of the Irwindale, CA report is as follows:

“[…] information [is] held by numerous separate offices in local, state, and federal agencies. Extensive follow-up with numerous agency personnel was required to obtain even minimal explanations of the information provided. An average citizen or community group would be unlikely to have the access, expertise, and time to conduct the investigation necessary to obtain even the basic data used for this report. As a result, the people most directly affected by the gravel mining operations do not have access to meaningful health and environmental information about a dominant industry in their community” (United States House of Representatives 2002).

Though nearby sand and gravel mines are not their primary concern, in terms of access to information, it is difficult not to draw parallels between the situation in Irwindale, CA and the situation that the residents of the Royal Oak Community are currently facing with the Brunswick County landfill.

**MONITORING AND MITIGATING POTENTIAL RISKS**

Overall, the good news is that C&D landfills are not known for being particularly dangerous to human health, though certainly they do come with their risks (Collledge & Wilder 2011). In each of the case studies from New York, Wisconsin and Virginia (mentioned above) where a C&D landfill was identified to pose potential health risks to the community, there were problems with the
facilities that could have been prevented or fixed (United States Environmental Protection Agency Office of Solid Waste 1995). Chief issues included allowing hazardous materials to be dumped on-site; failing to control leeching and run-off mechanisms; and choosing poor locations that put the landfill in close proximity to groundwater (United States Environmental Protection Agency Office of Solid Waste 1995). While the proposed landfill expansion site in Brunswick County has been shown to be close to the water table, and thus to drinking water sources (Moss Joyner 2011), there are some practices that can be undertaken to safeguard the health of the community as much as possible.

Obviously, the best course of action for minimizing human exposure to hazardous materials is careful monitoring. For air, it might be helpful to measure air quality due to dust and particulates at least once per week at the landfill site and/or to use techniques to keep dust settled and out of the air. Monitoring air quality, however, is expensive and can require technical expertise. For water, lab tests exist to measure quality at point-of-use; simple tests for measuring lead content in the water, for example, are available but can cost between twenty and one hundred dollars (Basic Information about Lead in Drinking Water 2011). If testing cannot be performed for economic or logistic reasons, there still are steps residents can take to protect themselves and mitigate their risk if they are concerned with their drinking water. The EPA recommends drinking only cold water (in which lead and other particulates have decreased solubility) and letting taps run a few seconds before obtaining drinking water (Basic Information about Lead in Drinking Water 2011). These are small practices that residents could take into their own hands to protect their health, and are generally good practices for monitoring and protecting drinking water in general.
Another option for protecting the community from potential water contamination risks is to encourage residents to collect their drinking water from safer, more closely monitored water sources, such as municipal water. For now, the Royal Oak community does not have access to Brunswick County public water because connections to the town supply do not reach all the way into their community. Even if the lines were extended in order to make them accessible to the community, the cost of switching a household off of well water and onto town water might be outside of the financial means of many residents.

The residents of Royal Oak have been placed in a difficult position. Though it is possible that their water will not be contaminated by the landfill expansion (or by other locally unwanted land uses in their community), in the event that there were a contamination of their ground water, it would be difficult for residents to find alternative means of collecting their water in order to avoid chronic exposures to potentially harmful chemicals. In the event of air contamination, the residents would have even more difficulty protecting themselves from exposure.

**GAPS IN EXISTING RESEARCH AND FURTHER INFORMATION OF INTEREST**

This discussion of the health risks associated with the Brunswick County C&D landfill expansion is certainly not exhaustive. There are many chemical agents of concern for this community and this review has only touched upon a few of the agents more thoroughly documented in environmental health literature. There is much that we do not know about the common routes of exposure and the acute and chronic health effects of environmental agents. Just because all of the risks associated with C&D landfills have not yet been identified or fully understood does not mean they do not exist. Unfortunately, it is difficult to use potential threats and unknown risks to argue against a
profitable landfill expansion that is, for all intents and purposes, not nearly as bad for the community as it could be.

There is a great deal of information that we do not know about the potential health effects of this landfill expansion. However, there is more data that we could collect in reference to the health of Royal Oak residents that would be helpful to know should the landfill expansion moves forward. Ideally, air quality monitoring stations could be placed around the landfill and community to assess exposure to air pollutants. Just as many mines are required to monitor air quality at their facilities, this would offer feedback to the community and the county so that they could control access to the landfill and protect residents from unnecessary exposures. Additionally, regular water tests would be vital to this community to ensure that they are not exposed to dangerous chemicals in their drinking water. For those residents using ground water as their primary drinking source, their water should be checked on a regular basis for the presence of lead, arsenic and other chemicals of concern. The residents of the community have already suggested that testing their own water would be a financial burden, so the county might consider taking over these costs from the residents. Even better, the county might make public water available to the community.
V. WASTE REDUCTION AND LANDFILL ALTERNATIVES

An expansion of the landfill will likely entail some negative impact on biological species within Brunswick County and the surrounding area but perhaps this effect can be mitigated or negated if overall waste could be reduced, eliminating the need for a landfill expansion. While it is difficult to say whether the C&D landfill expansion will produce any significant risks for the neighboring populations, it would be beneficial to investigate alternatives that could reduce the need for landfill space, and therefore decrease the need for such an expansion. Many of the materials that enter C&D landfills could be recycled or reused in some capacity; decreasing the need for additional space and enhancing the community through recycle and reuse programs. A recycling program could be utilized in conjunction with or as an alternative option to the expansion, and thus produce both environmental and economic benefits to the region.

BACKGROUND

There are broad networks of corporate groups and grassroots programs devoted to educating the public about alternatives to wasteful habits. Sustainable Sources is one such program that has been involved with providing green building information online for over 17 years. According to Sustainable Sources, an average of 8,000 pounds of waste are disposed of in landfills during the construction of a 2,000 square foot home (Sustainable Sources 2011). As previously described in the Demographics portion of this report in Table 4, there are 46,297 homes in Brunswick County (U.S. Census Bureau: Race of Housholder 2011). If each of those homes averaged 2,000 square feet, that would be over 300 million pounds of construction material abandoned for landfill consumption (not including the construction of office and municipal buildings). Providing alternatives for this waste would have a significant impact on the amount of goods going into the
The Sustainable Cities Foundation, an institute within The Home Depot Foundation, is working with communities to help plan and implement alternative green programming. Sustainable Cities notes, “construction and demolition materials comprise an estimated 25-30% of US solid waste annually, but the current recycling rate for construction and demolition waste is only 20-30%” (The Home Depot Foundation 2011). A reasonable goal would be to have a diversion rate higher than seventy percent to ensure that proper control and implementation are being utilized in this alternative waste program. Setting a numerical goal for waste diversion would hold the community and running parties accountable for this alternative use program.

According to the Sustainable Cities Institute, the average costs to recycle are as follows:
- Asphalt debris: $5.70 per ton
- Concrete rubble: $4.85 per ton
- Used bricks and blocks: $5.49 per ton
- Trees and stumps: $37.69 per ton
- Wood scrap: $46.43 per ton

The cost of disposal is typically over $75.00 per ton and can be as high as $98.00 per ton (The Home Depot Foundation 2011). It is important to note that the costs to recycle are substantially lower than the costs to dispose many of the materials associated with construction debris, although it initially may appear easier and less expensive to dispose of them. The surplus money put aside from switching to an efficient recycling program could be diverted to benefit those community members that are most directly impacted by the presence of the current landfill.

In an effort to reduce the need for an expansion, multiple recycling options for construction waste should be explored in order to find the program that best suits Brunswick’s needs. According to Sustainable Sources (2011), “construction waste recycling is the separation and recycling of
recoverable waste materials generated during construction and remodeling. Packaging, new material scraps, old materials, and debris all constitute potentially recoverable materials. In renovation, appliances, masonry materials, doors and windows are recyclable.” Recycling should start at the construction sites so that the materials can then be taken to the appropriate centers. The more concise and immediate the sorting of materials is, the more productive and efficient the recycling program can be. The Sustainable Cities Institute discusses how jurisdictions can issue ordinances to divert C&D wastes from landfills. The ordinances include issuance of project permits tied to the requirements, a waste management plan for the construction or demolition, proof of compliance with weight tickets, a deposit to be returned after compliance is confirmed, and field inspection of the practices. (The Home Depot Foundation 2011).

At The University of North Carolina at Chapel Hill, the Office of Waste Reduction and Recycling publically explains their implementation of the UNC-Chapel Hill Design Guidelines, specifically Chapter II, III and V relating to Construction and Demolition. They claim that “construction waste management practices include deconstruction, reuse, salvage, recycling and disposal” (The University of North Carolina at Chapel Hill Office of Waste Reduction 2011). Executive Order 156 maintains that state agencies actively reduce their waste production throughout project planning, site and building design and construction. They must create and utilize projects and work orders that “result in energy efficiency, water conservation, pollution prevention, solid waste reduction, and land preservation during the construction and operation of agency facilities.” In addition, all projects must have a waste plan that is shared with the University’s Office of Waste Reduction and Recycling (OWRR) along with contractors that are educated in proficient waste management that minimizes environmental impact. (The University of North Carolina at Chapel Hill, OWRR 2011).
One way to approach implementing a waste reduction program would be to examine what other people are doing throughout the county and cater to their educational style and overall necessity of recycling programming. The Construction Materials Recycling Association (CMRA) is an Illinois-based program that focuses on the practical applications of recycling within a Construction and Demolition site (CMRA 2011). They have created an online network for C&D recycling companies and promoters around the country. Their site serves as an excellent source for discovering new recycling practices and understanding the benefits of recycling. They have annual conferences and conventions to allow for the dispersal and sharing of ideas.

CURRENT ACTIONS TOWARD EFFICIENT RECYCLING PRACTICES

More locally relevant, Brunswick County already has some recycling practices in place that limit the need for such ordinances. The Brunswick County website reports that its C&D landfill accepts construction materials such as “treated wood, sheetrock, doors, windows, siding (aluminum & vinyl), pipe (pvc, aluminum, metal)” with a disposal cost of $6 per ton, shingles with a cost of $34 per ton, and asbestos with a cost of $56 per ton. There are a number of sites where trucks can drop off C&D materials for the cost of $16 for ¼ a truckload, $32 for ½ truckload, $48 for ¾ truckload, and $64 for full truckload. They also accept mobile homes (Brunswick County 2011). They encourage donating recyclable materials to Habitat for Humanity by calling the Brunswick County office. Recycling Drop-off facilities are located at Belville Elementary School, Leland Community Park, Lockwood Folly Community Building, Lockwood Folly District Park, Shallotte District Park, Town Creek District Park, and Waccamaw Elementary School.
Brunswick County resident Thomas Carpenter was featured in Laura Moore’s *Star News Online* article “Brunswick County reduces landfill waste by ‘swapping’” (Moore 2011). This article discusses the Brunswick County landfill’s Swap Shop—a place for people to drop off their unwanted items that otherwise would become garbage, and instead allow their fellow residents to “swap” for those unwanted goods free of charge. Some items usually exchanged include furniture, tools, gardening equipment, lamps, books, and paint. The purpose of the swap shop is that it can “extend life of products and preserve our landfill space.” (Moore 2011)

**BENEFITS OF GREEN SERVICES**

Wake County developed a study in 1999 that concluded that nearly 22 percent of waste in their landfills originated from construction and demolition sites. The main sources of debris from such sites are: lumber, drywall, metals, masonry, carpet, plastic, pipe, rocks, dirt, paper, and cardboard. Other than more efficient building construction laws, Wake County implemented a Construction and Demolition Surcharge Ordinance that subjects any solid waste facility loads with greater than 10 percent of C&D debris to comply. (Wake County 2003) Guides (like Figure 10) provide as a brief education on recycling procedures and provide as a mean of action for the local community to take part in this green movement towards more efficient trash disposal.

The Reuse, Recycle and Disposal guide produces by Wake County states that the benefits of reducing and recycling C&D waste includes cleaner job sites, more efficient operations, good business practice, comply with local ordinances, extended life of local landfills, over 60% of C&D waste is reusable or recyclable, environmental stewardship, and creates a positive public image (Wake County 2003).
Figure 10. Construction and demolition waste management: Reuse, Recycle and Disposal
Educational efforts like the ones mounted in Wake County, North Carolina foster a closeness and level of common understanding amongst the community. The creation of intensive and cooperative programming also invites job opportunities within the green industry and beyond, as well as opportunities for innovation that could trigger a ticket of possibility out of a low-income trajectory.

The EPA Recycling is Working Program discusses the REI (Recycling Economic Information) study that is focused on the importance of recycling and reuse. It states “By converting waste into valuable raw materials, recycling creates jobs, builds more competitive manufacturing industries, and adds significantly to the U.S. economy.” In addition, recycling benefits the environment by reducing greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Energy is conserved as well by reducing the need to extract raw materials to make new items. The creation of jobs is a huge benefit for the recycling and reuse industry. (EPA Recycling is Working 2002). Figure 11 visually defines the benefits of recycling construction and demolition waste in the economic sense.

![Summary of Estimates of Direct Economic Activity](image)

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Recycling Collection</th>
<th>Recycling Processing</th>
<th>Recycling Manufacturing</th>
<th>Reuse and Remanufacturing</th>
<th>Industry Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishments</td>
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<td>12,051</td>
<td>8,047</td>
<td>26,716</td>
<td>56,061</td>
</tr>
<tr>
<td>Employment</td>
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<td>160,605</td>
<td>759,746</td>
<td>109,163</td>
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<td>Annual Payroll</td>
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<td>29,181,749</td>
<td>2,747,498</td>
<td>36,712,482</td>
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<tr>
<td>Estimated Receipts</td>
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<td>41,753,902</td>
<td>178,390,423</td>
<td>14,182,531</td>
<td>236,301,371</td>
</tr>
<tr>
<td>Estimated Throughput</td>
<td>191,082</td>
<td>191,082</td>
<td>157,545</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1. Throughput is amount of recovered material recycled and includes manufacturing scrap sent for recycling. It excludes materials prepared for fuel use and in-house process scrap returned to the manufacturing process. Throughput estimates are summed to avoid triple counting at collection, processing, and manufacturing stages.

Figure 11. EPA: Recycling is thriving in the United States
Across the country, the Bureau of Planning and Sustainability in Portland, Oregon discusses a number of benefits associated with recycling of C&D waste. It first offers a marketing tool for companies with clients interested in LEED and other green programs. Recycling is also generally cheaper than disposal, and some builders may even make some money by selling the materials they would typically dispose of. Job benefits also exist, as the Bureau of Planning and Sustainability points out by saying that “sending 10,000 tons of waste to the landfill supports six jobs, while recycling the same amount supports 36 jobs.” Recycling also reduces greenhouse gases and saves energy (Bureau of Planning and Sustainability 2011).

Another benefit of green services is highlighted in Nancey Leigh and Lynn Patterson’s “Construction & Demolition Debris Recycling for Environmental Protection and Economic Development” (2004). Their research explains, “C&D waste makes up 25 percent to 45 percent of the waste that goes to our national landfills, thus contributing to the reduced life and increased environmental impacts of landfills across the country.” Leigh and Patterson clarify that recycling goes beyond the obvious benefit of the environment; it also reaches the economy and wellbeing of the community through job creation and financial cycling. As an example they explain that in Minnesota the recycling industry provided close to 9,000 jobs and generated almost $3.5 billion in sales in the year 2000. Leigh and Patterson define the recycling of C&D waste as a necessity (Leigh and Patterson 2004).

Their research lays out the following options:

- Deconstruction: take apart structures and reusing particular pieces
- Remanufacturing: completely reformulate original use of the material for another purpose
Leigh and Patterson, along with the previously mentioned benefactors of green services, strive to educate the community on environmental impacts of reuse and recycling, provide jobs for these communities and encourage the reduction of waste creation in order to create and maintain a sustainable environment for the biological community and the citizens that preside.

**EXAMPLES OF RECYCLING PROGRAMS**

Efforts are being made within Brunswick County to lower the amount of C&D debris ending up in landfills, but there seem to be much more innovative designs—extending from this county throughout the United States—that can provide a great framework for a more effective program.

The “More than $700,000 being invested to divert construction and demolition material from North Carolina Landfills” article found on the Official Web Site of the State of North Carolina (2000) asserts that industry and governments are investing $700,000 per year to divert approximately 42,000 tons of C&D debris from the state’s landfills. Projects include a variety of practices including mixed C&D processing, source-separated recovery, and market development.

Grant Projects that Gladwell’s (2000) lists include:

- **“Lamination of Scrap Lumber,”** which focuses on collecting clean wood scraps while also laminating stair treads and structural wall posts. This project is based in Charlotte, NC.
- **“Accent Construction Recycling and Reuse Initiative”** which takes construction debris and salvages them so that they can be used and sold. This project is based in Raleigh, NC
- Gypsum recycling programs are located in Charlotte, Chapel Hill, and Marshville, NC
- **“C&D RRR project”** provides a storage space for recovered materials. This project is located in Pasquotank County, NC.
• Paint, carpet, and even mobile home recycling projects also exist. One such mobile home recycling project takes place at the Brunswick County C&D landfill.

The Construction and Materials Recycling Association (CRMA) created an online network for all kinds of C&D recycling practices, including those used for “aggregates such as concrete, asphalt, asphalt shingles, gypsum wallboard, wood and metals” (2011). It also includes links to websites associated with recycling facilities nationwide. The organization has taken some legislative action such as securing “a commitment from the U.S. EPA to relax its proposed rule on lead-based paint.” It works to promote recycling practices by working to make such practices more accessible and possible. (CMRA 2011)

Due to the number of jobs that a recycling project could create, the locals of Brunswick County are loaded with potentials. From the sorting of materials to the selling of used materials to the building of green homes from recycled materials, many levels of the job sector could all be positively affected by a recycling program. Education of recycling practices is key to being able to implement such programs. This new skill set could be taught at Brunswick County Community College, and even (in adapted curricula) at elementary schools, so that recycling of C&D materials will become part of the normal routine in any construction job. Recycling programs can be set up at the schools so that the sorting of materials is learned from a young age. The Community College could create a capstone class so that students could research ways in which the residents of Brunswick County can implement recycling programs that will benefit the community. Programs between the schools and the local neighborhoods can be set up so that the skills learned can be applied to local construction projects. Those living near the landfill should be given priority when
it comes to recycling jobs created in an effort to divert waste. The local non-profits should have the first access to reusable materials so that they may use them when constructing homes for those in need in the immediate area.

Portland, Oregon has implemented a recycling program, which starts at the construction level. Portland Online discusses the requirements regarding construction and demolition wastes in Portland, Oregon. The Bureau of Planning and Sustainability for the City of Portland, Oregon asserts, “for all building projects within the city where the total job cost (including both demolition and construction phases) exceeds $50,000, the general contractor shall ensure that 75 percent of the solid waste produced on the job site is recycled” (Bureau of Planning and Sustainability for the City of Portland, Oregon 2011). Some materials such as rubble, land-clearing debris, corrugated cardboard, metal, and wood must be recycled. They point out how “reducing, reusing, and recycling C&D debris keeps valuable resources out of the landfill and helps achieve Portland’s waste recovery and reduction goals” (Bureau of Planning and Sustainability for the City of Portland, Oregon 2011). By making sure that the material is recycled at the job site, the materials are ready to be sent to the appropriate recycling facilities.

An alternative way to make sure waste is diverted from landfills is by giving rebates to contractors. The Sustainable Cities Institute describes a C&D recycling rebate program in Alameda County, California (The Home Depot Foundation 2011). The program allowed for a $10/ton rebate to be given to each constructor that delivered mixed C&D materials to the participating facilities. This program came to an end as of December 2007. The program was in place long enough to begin the diversion of wastes from landfills to recycling centers. The tipping fees for the recycling facilities
were highly cost competitive and that, combined with the incentive programs, allowed for the transition to recycling (The Home Depot Foundation).

In California, CalRecycle (2011) discusses a number of case studies involving the recycling of C&D materials. Monterey Resource Recovery Park is located in Marina, California and “includes a 315-acre permitted sanitary landfill site, a 126-acre buffer area (mostly Salinas River floodplain), and 20 acres for the administration building, scalehouse, and public drop-off recycling station.” A C&D recycling operation is also on site and contracts with other operations to provide those recycling services. They also contract with the Granite Construction Company, which “uses most of the crushed C&D material in a wide variety of area construction projects.” Also mentioned in Calrecycle was the Urban Ore Resource Recovery Park located in Berkeley, California. The program includes building materials exchange, hardware exchange, arts and media exchange, general store, and salvage and recycling. In addition, the San Leandro Resource Recovery Park program works with reuse organizations and education programs. “At the Davis Street Education Center, students learn about garbage and landfill history and why and how to practice the four Rs (reduce, reuse, recycle, and rot/compost).” Education and the cooperation between recycling programs and construction companies are two major components of any recycling program aimed at diverting waste from landfills. (Calrecycle 2011)

San Bruno, California’s Debris Box Program is a great example of how recycling programs can effectively divert waste from landfills. (Recology 2011) The city of San Bruno adopted a C&D recycling ordinance that requires 50% of all C&D debris generated on new construction of residential or commercial building to be recycled. San Bruno’s Recology program collects
materials that can be recycled and takes them to a recycling facility that leads to a diversion rate of about 60%. (Recology 2011)

Useful Web links:

- **Construction Materials Recycling Association** ([http://www.cdrecycling.org/find.html](http://www.cdrecycling.org/find.html)). The CMRA website lists the members of the recycling organization by state. North Carolina recycling facilities that are a part of this organization are Boggs Materials, Inc. and Russo Dumpster Service.

- **Boggs Group Recycling** ([http://www.boggspaving.com/recycling](http://www.boggspaving.com/recycling)). Discusses Boggs’ practices for recycling concrete, asphalt, and shingles. They accept “asphalt shingles, nails and the felt attached to the shingles”. They remark on how recycling such items reduce the amount of items going into landfills. Their recycling yard can be contacted at 704-282-0033.

- **Russo Dumpster** ([http://www.russodumpsterserviceinc.com/](http://www.russodumpsterserviceinc.com/)). They demonstrate their commitment to recycling and green practices. They even proclaim, “the days of overloading our landfills with materials that could be re-used are over!” This company is based in Charlotte, NC and is focused on eco-friendly disposal.

**NON-PROFIT ORGANIZATIONS**

A number of non-profits benefit from recycling programs and directly return those benefits to the community. As waste is diverted from landfills, many non-profits take that waste and reuse it in some form to help those in need. Those who live in Brunswick County could directly benefit from a program set up to not only lead to waste reduction and decrease the need for a landfill expansion but also allow for those in need to have homes and other buildings built from those materials.
Below is a list of non-profits that use recycled materials:

Habitat for Humanity of Wake County
- Re stores accept new and used building materials and then sell them at discounted prices
- The generated revenue is used to build new Habitat homes in Wake County and encourages all citizens to be good stewards of the environment

Stardust Nonprofit Building Supplies, Inc. of Phoenix, AZ
- Residential Deconstruction Program sells recovered materials at reduced prices to those in need
- This program also educates homeowners and the construction industry on the benefits of reuse

Chartwell School of Seaside, CA
- They independently created a program that developed a manual on how to construct and deconstruct buildings using various recycling methods

Materials for the Future Foundation of San Francisco, CA
- Their program has on-the-job construction training provided to youth and other individuals
- One project included constructing wood frame buildings that diverted 2,119 tons of material from landfill disposal

Armstrong World Industries
- Ceiling Recycling program that allows building owners to recycle old ceiling tiles rather than sending them to the landfill

NC Big Sweep
- Focuses on removing litter, which can include building materials that have been left on the ground, and preventing them from ending up in watersheds

Carpet America Recovery Effort (CARE) (http://www.carpetrecovery.org/)
- Their company focuses on diverting used carpet from landfills

The Reuse People (www.trp.org)
Focuses on keeping reusable materials out of landfills

The Loading Dock (www.loadingdock.org/httpdocs/index.html)

- Reuse facility in Maryland that diverts waste from landfills

The Boston Building materials ReUse Center (www.bostonbmrc.org/bostonbmrc/)

- This center accepts materials that can be reused and then sells them to others. Those who qualify can receive discounts when purchasing the items

Reuse Development Organization (ReDO) (www.redo.org)

- Provides training, education, and assistance to those starting reuse programs

Institute for Local Self-Reliance (ILSR) (www.ilsr.org)

- Works on reducing waste and creating environmentally sound communities

Regardless of whether or not the Brunswick County landfill is expanded, Brunswick County can make advances in their recycling initiatives. Recycling programs would not only divert waste from the landfills, they would also create jobs and benefit the entire community in both environmental and economic ways.
VI. CONCLUSION

The issues surrounding the proposed expansion of the Brunswick County C&D landfill are numerous and complex. Such a land-use change, with so many potential impacts, must be carefully examined from every angle before decisions are made. In the case of the Brunswick County C&D Landfill, it has been shown that the community adjacent to the current landfill location and the proposed expansion site currently bear a disproportionate share of LULU burden for the county.

Though a range of technologies and practices exist to reduce and divert waste, ultimately there remains some portion that is useless and potentially dangerous. The modern sanitary landfill represents the best and safest technology available for disposing of such waste; they are imperfect, however, and may be seen as hiding and segregating undesirable materials rather than removing them completely. As such, there will necessarily be risks associated with landfill waste. These risks must be understood and mitigated in order to protect human health and the environment. In siting a landfill, many factors should be considered in order to minimize to the greatest extent possible any negative effects—environmental, medical, and societal—that can arise from the construction of a landfill at that location. This report is intended to enable an informed dialogue between the invested parties by presenting and expounding upon topics concerning the potential risks and benefits of C&D landfills in general and implications for this site and community in particular.

A great deal of uncertainty remains regarding the suitability of the site for housing construction and demolition waste, due to the lack of accessible data detailing the physical characteristics of the site from which such conclusions are drawn. In particular, impairment of air and ground water quality are known issues associated with C&D landfills elsewhere; further information about the
composition and flow patterns of the site’s air and ground water, as well as the implications of the high SHWT for implementing an adequate barrier to contamination is needed in order to determine the form and severity of potential health and environmental damages arising from the expansion. The preliminary report by Dewberry is useful for predicting what particular qualities are of concern for the proposed site, but it raises more questions than it answers. It remains to be seen if the final siting report adequately addresses these concerns. Likewise, the expansion project presents the opportunity of substantial benefit to the neighboring communities and the county as a whole, but more information is concerning the needs, skills, and desires of the nearby communities and how these might be met by the landfill.

Should the topics presented in this report be satisfactorily addressed and it is determined that the expansion at this location should proceed, the county must realize the debt it owes the neighboring communities for bearing the unwanted use of land. It must be particularly receptive to the needs and desires of the affected communities, aware of opportunities to provide assistance and protection in matters of health and well being, besides operating the landfill in a manner fitting of a good neighbor. We commend the county for the steps already taken to gather information about the suitability of this site, and encourage further exploration of the issues and additional consideration of topics beyond their basic structural and environmental responsibilities. The county has a responsibility to protect the health and dignity of all its residents, and if residents have voiced their concern over the impacts of this landfill on their community, they have a right to be heard by their elected officials.
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