Assessing Land-Based Impacts on the Annapolis River Estuary

Prepared By:

Katie McLean
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Clean Annapolis River Project
314 St. George Street, P.O. Box 395,
Annapolis Royal, NS, B0S 1A0
1-888-547-4344; 902 532 7533
carp@annapolisriver.ca, www.annapolisriver.ca

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Contents

1.0 Introduction

Past research has established strong linkages between the types and degree of land cover and/or land use in an area and negative impacts on water quality in receiving waters, which eventually impact downstream estuary ecosystems (Baker et al., 2006; Huang & Klemas, 2012; Mallin et al., 2000). By developing a series of current land-use maps for the Annapolis River watershed, Clean Annapolis River Project will be better able to identify and assess stressors to ecological health in the Annapolis estuary and the Bay of Fundy/Gulf of Maine ecosystems.

Sources of pollution can be generally categorized in two groups: point source pollution and non-point source pollution. Point source pollution refers to a single identifiable source of pollution, and nonpoint source pollution is caused by diffuse activities that occur over a wide area and do not have a single easily identifiable source.

Commonly reported sources of point and non-point pollution include (Carpenter et al., 1998):

Point source pollution:

- Wastewater effluent (industrial and municipal)
- Run-off and leachate from waste disposal sites
- Runoff and infiltration from animal feedlots
- Runoff from mines, oil fields, and unsewered industrial sites
- Storm sewer outfalls
- Flows of combined storm and sanitary sewers
- Runoff from construction sites

Non-point sources of pollution

- Runoff from agriculture
- Runoff from pasture and rangeland
- Urban runoff from sewered and unsewered areas
- Septic tank leachate and runoff from failed septic systems
- Runoff from construction sites
- Runoff from abandoned mines
- Atmospheric deposition over water surfaces
- Logging
- Wetland conversion
- Construction
- Other land development

This report outlines the results of GIS analyses of land-use data for the Annapolis River watershed and estuary. A discussion of the related impacts for each major land-use type, a description of the method used to produce each land-use map and general recommendations for application in future project planning are provided.

2.0 Land-use in the Annapolis River watershed and estuary

2.1 Municipal wastewater/sewage treatment

Description of stressor and associated water quality impacts

Municipal wastewater treatment plants (WWTPs) are a commonly identified source of water pollution in urban and semi-urban areas (Holeton et al., 2011; Hynds et al., 2014). Hynds et al. (2014) reports that despite ongoing efforts to upgrade infrastructure in many cities, coastal and estuarine waters in maritime regions still receive a large proportion of untreated wastewater discharged by WWTPs.

Older infrastructure typically includes combined wastewater and stormwater systems, which do not have the capacity to handle the volume of water that results from heavy rain or snowmelt events, leading to sewer overflows (Brands, 2014). As a result, a mixture of raw sewage, stormwater, and resuspended sewer sediment is able to flow directly into surface waters (Holeton et al., 2011). System bypasses are another possible source of pollution. During maintenance or periods of high flow, wastewater may be rerouted and allowed to bypass the WWTP, resulting in the release of untreated or partially treated wastewater into surface waters (Holeton, 2011).

The typical major pollutants found in untreated domestic wastewater include: phosphorous, nitrogen, nitrogen-based compounds (organic nitrogen, nitrate, nitrite, ammonia, ammonium), chlorine or chlorinated byproducts, sulfates, oil and grease, volatile organic compounds, fecal coliforms, and cryptosporidium oocysts (Holeton et al., 2011; Tchobanougloud et al., 2003). Other hazardous pollutants may also be present, depending on specific commercial and/or industrial inputs (Holeton et al., 2011). Associated water quality impacts include eutrophication, increased biological oxygen demand, increased chemical oxygen demand, and increased total suspended solids.

Methods

Municipal sewage maps were generated using multiple data sources including municipal sewage GIS data from:

- Annapolis County: Deep Brook, Lequille, Cornwallis Park, Granville Ferry, Bridgetown North, Bridgetown, Carleton Corner, Nictaux, Nictaux Falls
- Digby District: Conway, Smiths Cove, Seabrook, Bayview
- Annapolis Royal

No GIS files were available for the Town of Digby, but engineering drawings displaying the location of sewage lines were made available. Municipal sewage service areas were estimated using the engineering drawings.

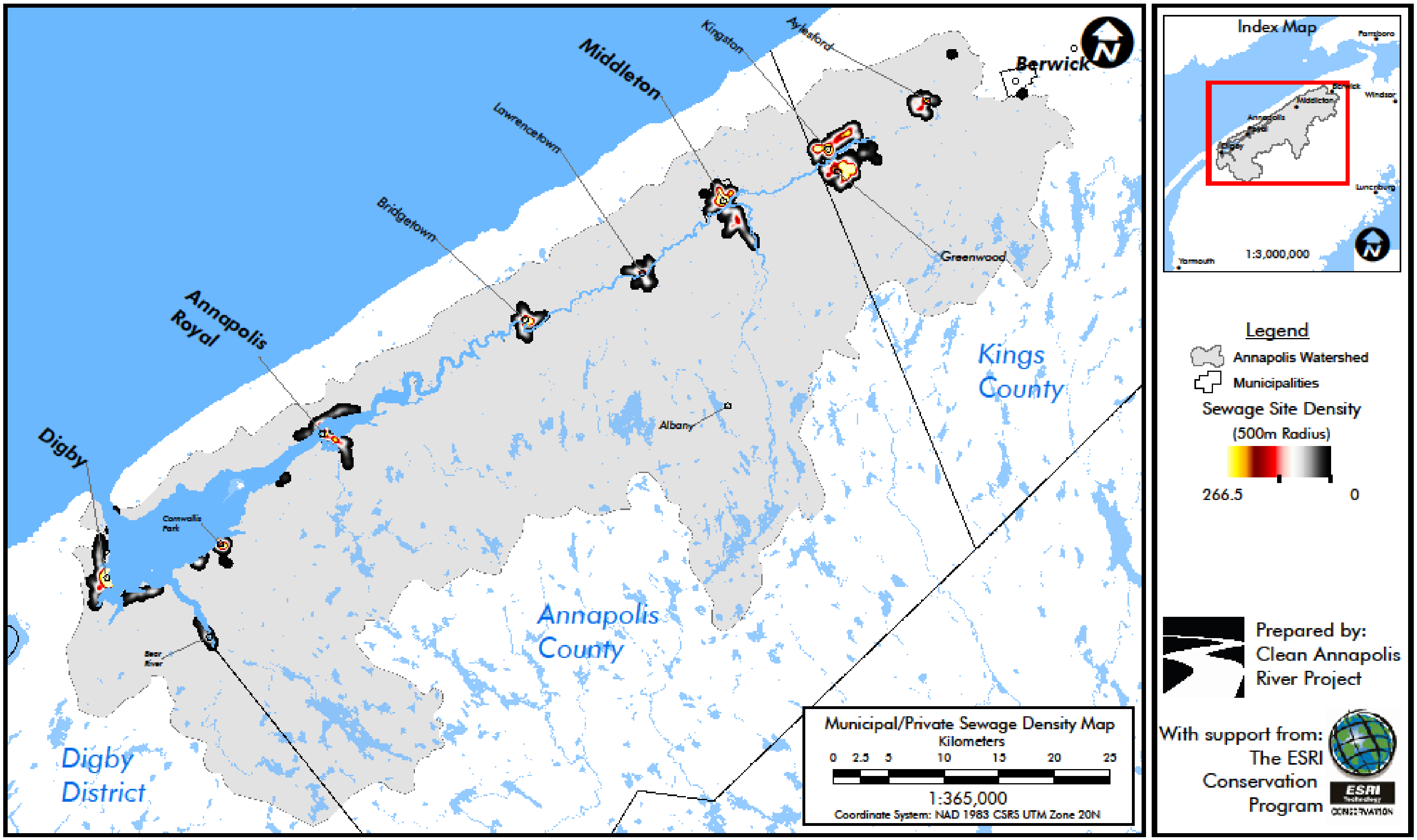
No GIS files were made available from Kings County. Municipal sewage areas were estimated by physically scouting sewage lift station locations in Greenwood, Kingston and Aylesford.

Areas serviced by private sewage treatment plants were estimated by using the Sewage Treatment Plant GIS files supplied by The Province of Nova Scotia.

Nova Scotia Civic Address Files (NSCAF) were obtained from the Province of Nova Scotia, and each point was assigned a code for its sewage type:

1. Onsite
2. Municipal
3. Private Treatment Plant
4. Unknown

Municipal and Private Sewage System Density Map



Recommendations

Key communities in the Annapolis River watershed for projects assessing or addressing issues with municipal WWTPs include: Digby, Bear River, Cornwallis, Annapolis Royal, Granville Ferry, Bridgetown, Lawrencetown, Middleton, Kingston, Greenwood, and Aylesford.

Clean Annapolis River Project has implemented the River Guardians Water Quality Monitoring program since 1990, providing a long-term dataset on parameters including: temperature, dissolved oxygen, nutrients (phosphorous and nitrogen), E. coli, turbidity, and pH. Water Quality Index scores for 2014 and 2015 at each of the 8 sites monitored on the Annapolis River indicated that water conditions were either marginal or poor (Figure 1) (CARP, 2015). Nitrogen, phosphorous, and E. coli levels, which are frequently associated with pollution from WWTP's were assessed to be poor or fair for the Annapolis River in 2014.

Ongoing monitoring through the River Guardians program and increased monitoring efforts at sites located on the up and downstream sides of WWTPs are one option for beginning to assess their contribution to water pollution.

Projects that aim to reduce stormwater run-off, therefore reducing the risk of system overflows and bypasses, is another option that could be explored. This includes activities that aim to increase the amount of permeable surface to improve infiltration of stormwater, increasing tree canopy cover and vegetative cover to reduce the rate of surface run-off, or installing rain gardens in high risk areas.

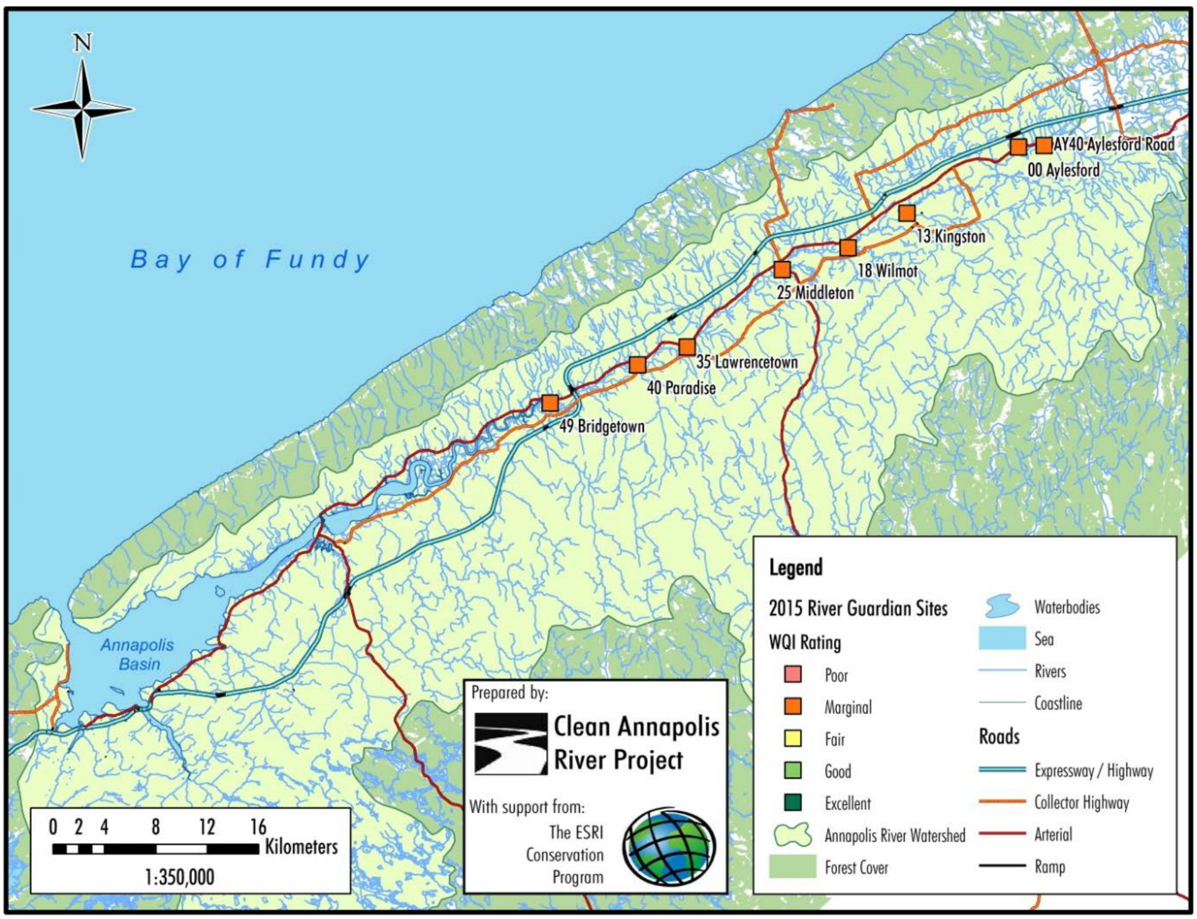


Figure 1. Annapolis River Guardians Water Quality Monitoring Sites

2.2 On-site sewage

Description of stressor and associated water quality impacts

On-site sewage systems are designed to treat and dispose of effluent on the same property from which it is produced. In the Annapolis River watershed septic systems, consisting of septic tanks in combination with a drainfield, are the predominant type of onsite sewage treatment system used. Improper designs or installations, lack of maintenance, system deterioration, poor wellhead hygiene, or system failure have all been identified as mechanisms for septic system contribution to groundwater pollution (Hynds et al., 2014). Household wastewater typically contains pollutants such as nitrogen, phosphorous, bacteria and viruses. When systems fail or do not effectively treat wastewater it leads to pollution of ground water, which eventually enters nearby surface water.

Methods

Onsite sewage heatmaps were generated using multiple data sources including:

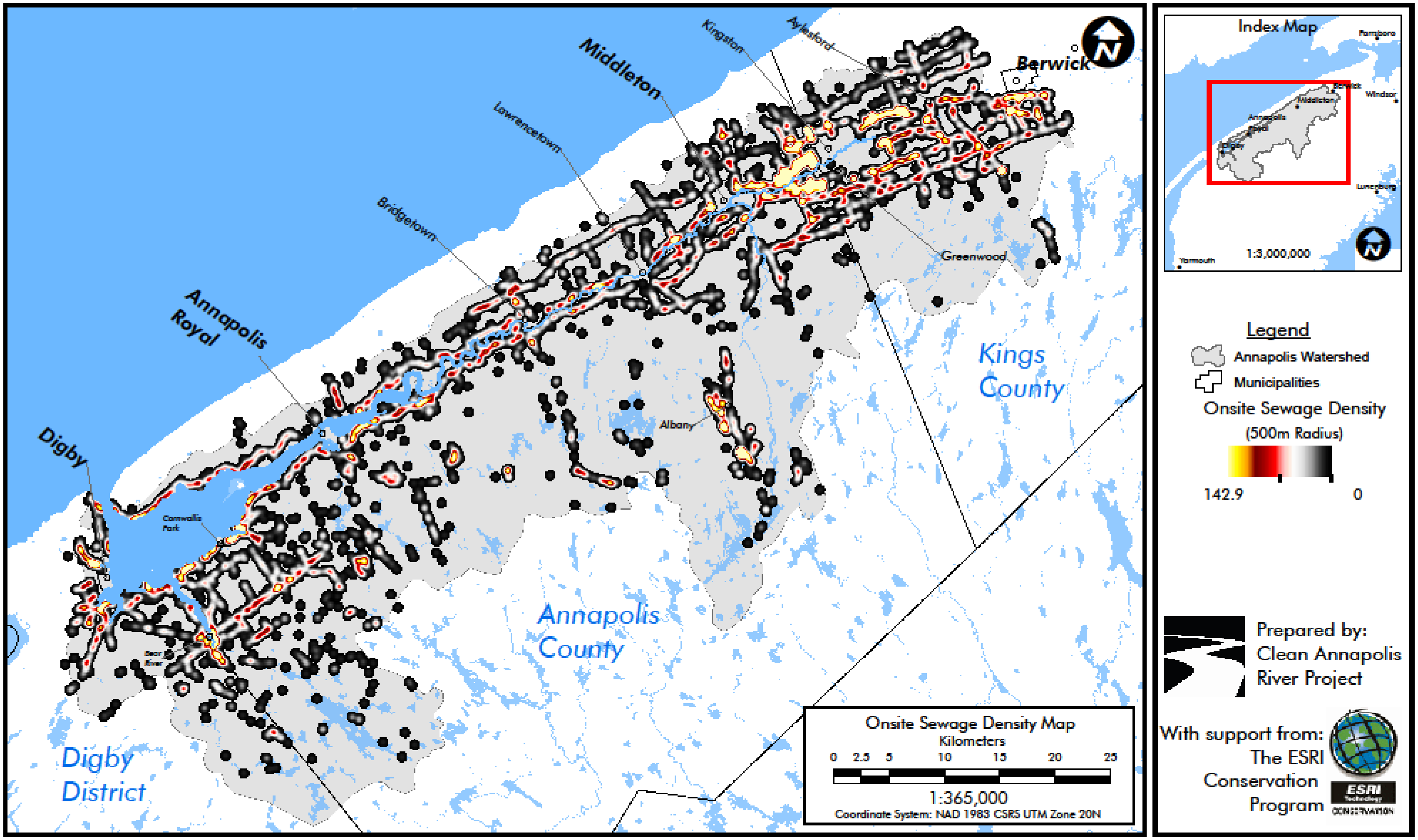
- NSCAF (Nova Scotia Civic Address File) points GIS files
- Annapolis County, Digby District and Annapolis Royal waste water GIS files
- Engineering drawings from The Town of Digby
- Correspondence with town and village staff for Middleton and Lawrencetown sewage service areas
- In-field observation of municipal sewage service areas for Kings county (Kingston, Greenwood and Aylesford)
- Sewage treatment plant and onsite sewage GIS files

For areas where wastewater GIS files were made available, a sewage type code was assigned by comparing the NSCAF points to the location of the sewage lines. NSCAF points not already classified as being within a municipal or private sewage service area were assumed to be using an onsite sewage system. These were the points used to generate the onsite sewage heatmaps.

The sewage type codes assigned to each NSCAF point were the following:

1. Onsite
2. Municipal
3. Private Treatment Plant
4. Unknown

Onsite Sewage Density Map



Recommendations

The use of on-site sewage systems is prolific across the Annapolis River watershed. Cost and education have previously been identified as the main barriers preventing private home and business owners from addressing issues related to their septic systems (CARP, 2014). Educational programs, such as CARP's former Rural H20 Water Guardians are one approach to working with private homeowners to encourage best practices in terms of septic system installation and maintenance (CARP, 2014). This would help to reduce the amount of pollutants entering waterways from improperly functioning septic systems.

Several of the areas that were identified as having high densities of on-site sewage systems coincide with areas identified as cottages/camps, including the areas surrounding Albany and Grand Lake. Because camps and cottages tend to have older infrastructure and be located in close proximity to water, they may be at higher risk for contributing to pollution of groundwater and nearby surface waters. Therefore, targeting these using educational programs and incentives to improve existing infrastructure could significantly help to reduce water pollution.

2.3 Impervious surfaces

Description of stressor(s) and associated water quality impacts

Studies of urban impacts on water quality highlight a significant relationship between urban development and conversion of land into impervious surfaces, such as roofs, roads, driveways, sidewalks and parking lots, and negative impacts on receiving water quality (Brabec et al., 2002; Dauer et al., 2000; Mallin et al., 2000; Webster et al., 2014). In a study of five coastal watersheds, the amount of impervious surfaces was identified as the most important anthropogenic factor affecting fecal coliform abundance in receiving waters (Mallin et al., 2000). The amount of impervious surfaces in urban landscapes has been proposed as a key environmental indicator of urban land-use impacts because of its strong influence on the pattern and magnitude of infiltration and surface water runoff (Wang et al., 2001).

General water quality impacts include increased sedimentation, increased volume of water during storm events, and increased pollutant load (Dauer et al., 2000; Webster et al., 2014). In landscapes with large areas of impervious surfaces stormwater collects and is transported as surface water. Potential contaminants in urban stormwater include nutrients, fecal coliforms, viruses, grease and oil, rubber/plastics, heavy metals, surfactants, sodium, and sulfate (Cooper et al, 2014; Mallin et al., 2009; Wang et al., 2001). Studies have also shown impacts on river and stream environments including increased erosion, channel destabilization and widening, loss of pool habitat, excessed sedimentation, and reduced woody debris (Wang et al, 2001).

Other landscape alternations that are not typically considered as impervious surfaces can also impact runoff rates. For example, in a study comparing various permeable surfaces demonstrated that certain surfaces, such as gravel driveway and bare soil, acted similar to an impervious surface (Brabec et al., 2002).

Methods

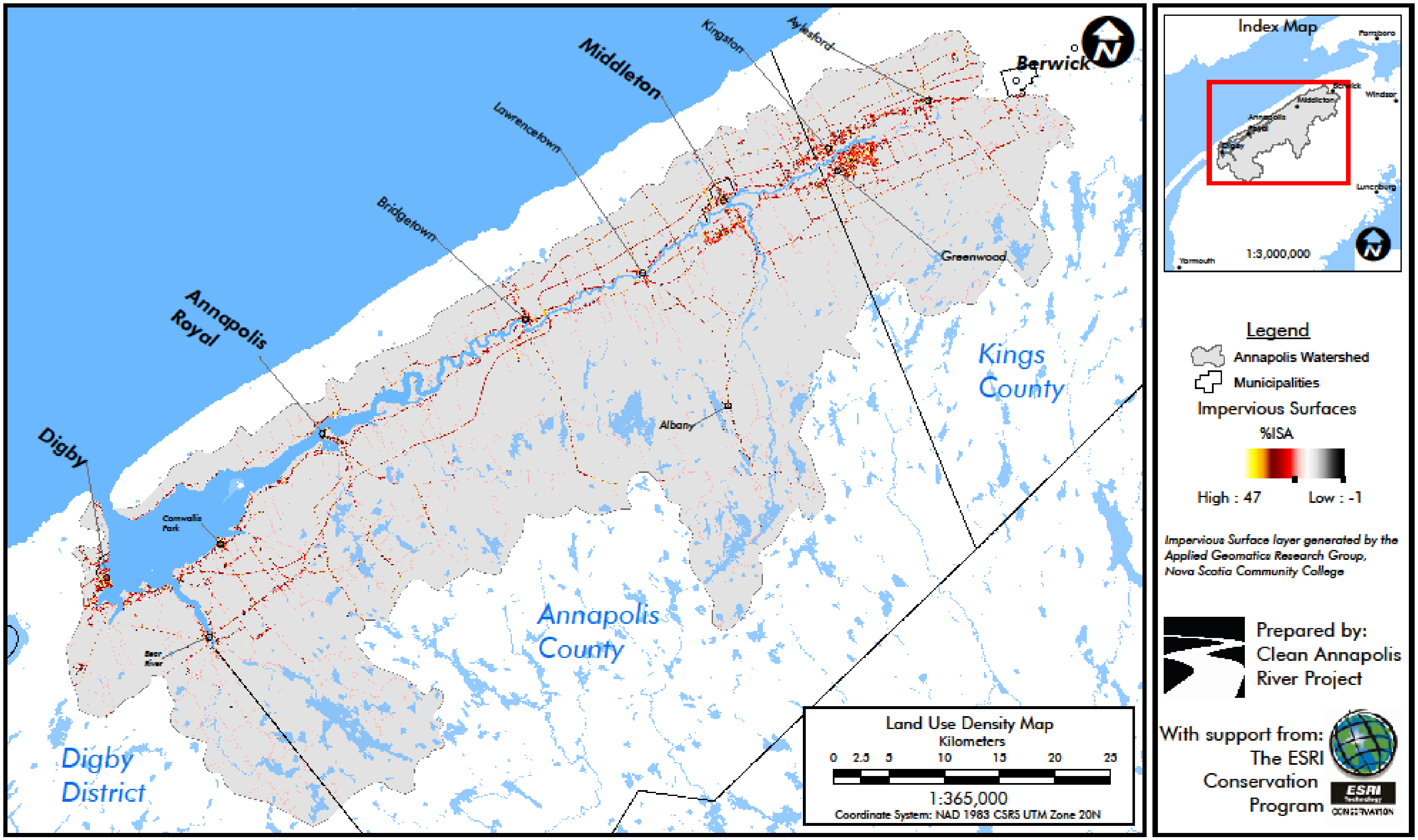
Data for the impervious surfaces layer was obtained from the Applied Research and Geomatics Group (AGRG) impervious surface map of Nova Scotia, and was accsessed online from : http://agrg.cogs.nscc.ca/data_for_download/impervious_surfaces_nova_scotia.

Recommendations

The areas of greatest impervious surface cover coincide with the major towns, villages and other communities within the Annapolis River watershed, including Digby, Cornwallis, Annapolis Royal, Bridgetown, Middleton, Kingston, Greenwood, Aylesford, and Bear River. With the exception of Bear River, all of these communities are located directly adjacent to the shores of the Annapolis River. The village of Bear River is located adjacent to the Bear River, a major tributary that feeds into the same estuary ecosystem as the Annapolis River.

Actions that reduce the rate of surface water flow or provide a buffer between watercourses and impermeable surfaces may be appropriate in these areas. Riparian buffers are often used to mitigate the impact of runoff from impervious surfaces (Brabec et al., 2002; Young & Chen, 2002). Vegetated buffers of at least 15 metres in width are considered a best management practice for providing the benefits of surface water infiltration and the capture of water bound sediment and pollution, and areas within the watershed where there are a lack of adequate riparian buffers should be investigated more closely for further possible actions. The installation of rain gardens or other land uses that promote water infiltration surrounding impermeable surfaces could also be explored. Reforestation and urban forestry may also be a beneficial activity, increasing tree canopy cover, which has been shown to reduce the rate of urban surface water flow, and could be incorporated into urban reforestation programs to further reduce the impacts of impermeable surfaces within urban communities in the watershed. The increased use of constructed wetlands and the enhancement of existing wetlands is another option for improving surface water management. Wetlands have been shown to mitigate hydraulically driven variables including sediment, nutrients, temperature, and disturbance (Richards et al., 1996).

Impervious Surface Cover Map



2.4 Urban, Commercial, and Industrial Land Use in the Annapolis River watershed and estuary

2.4.1 GIS Mapping methods

Landuse layers were derived from the Department of Natural Resources' (DNR) Forest Inventory GIS layer and were updated using the most current set of DNR orthophotos. Urban/Commercial/Industrial landuse types were then classified into the following categories:

- Residential
- Commercial (office, retail, schools, churches, etc.)
- Industrial
- Paved parking
- Parks/recreational
- Golf courses
- Camps/Cottages
- Airstrips
- Utilities
- Aggregate extraction

2.4.2 Urban impacts

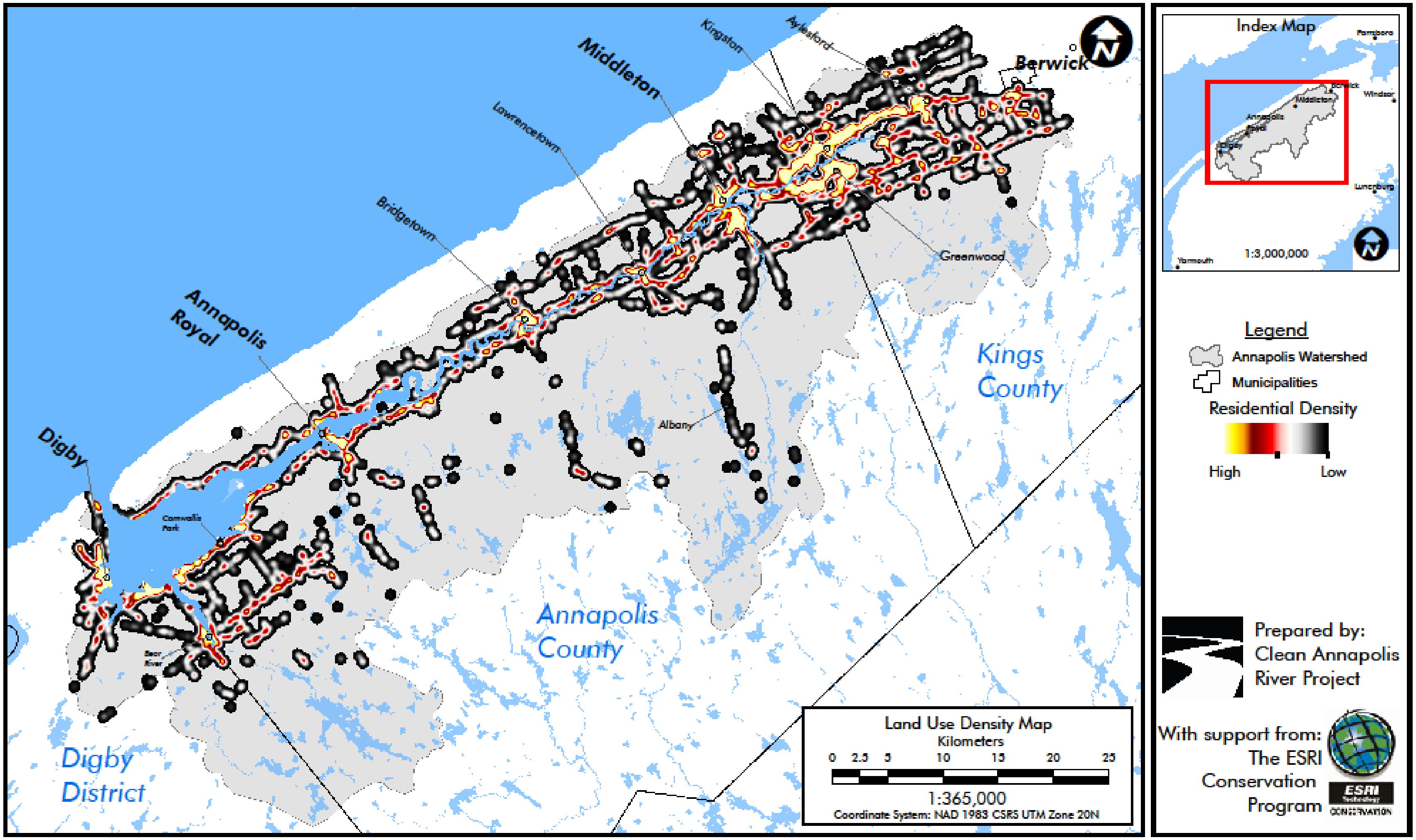
Urban development and land-uses provide a variety of pathways for the introduction of physical, chemical, and/or biological pollutants. The conversion of land into impervious surfaces plays the most significant role in the degradation of water quality (Atasoy et al., 2006; Brabec et al., 2002; Mallin et al, 2000) , and is discussed separately in section 2.3. Other examples of activities and land uses that could impact water quality include: increased use of lawn fertilizers on residential and commercial properties, leading to increased nitrogen in lawn runoff (Atasoy et al., 2006); decreased ecological connectivity as a result of road networks in tandem with the creation of increased edge habitat (Binstock & Carter-Whitney, 2011); increased rates of erosion from construction or other activities that expose mineral soils, leading to increased sedimentation and a higher potential for the transport of sediment bound N and P (Atasoy et al, 2006; Carpenter et al., 2008); and increased contribution of P and N from pet wastes in runoff from residential properties (Carpenter et al., 2008). Specific commercial or industrial activities may also have associated pollutants or other impacts.

Recommendations

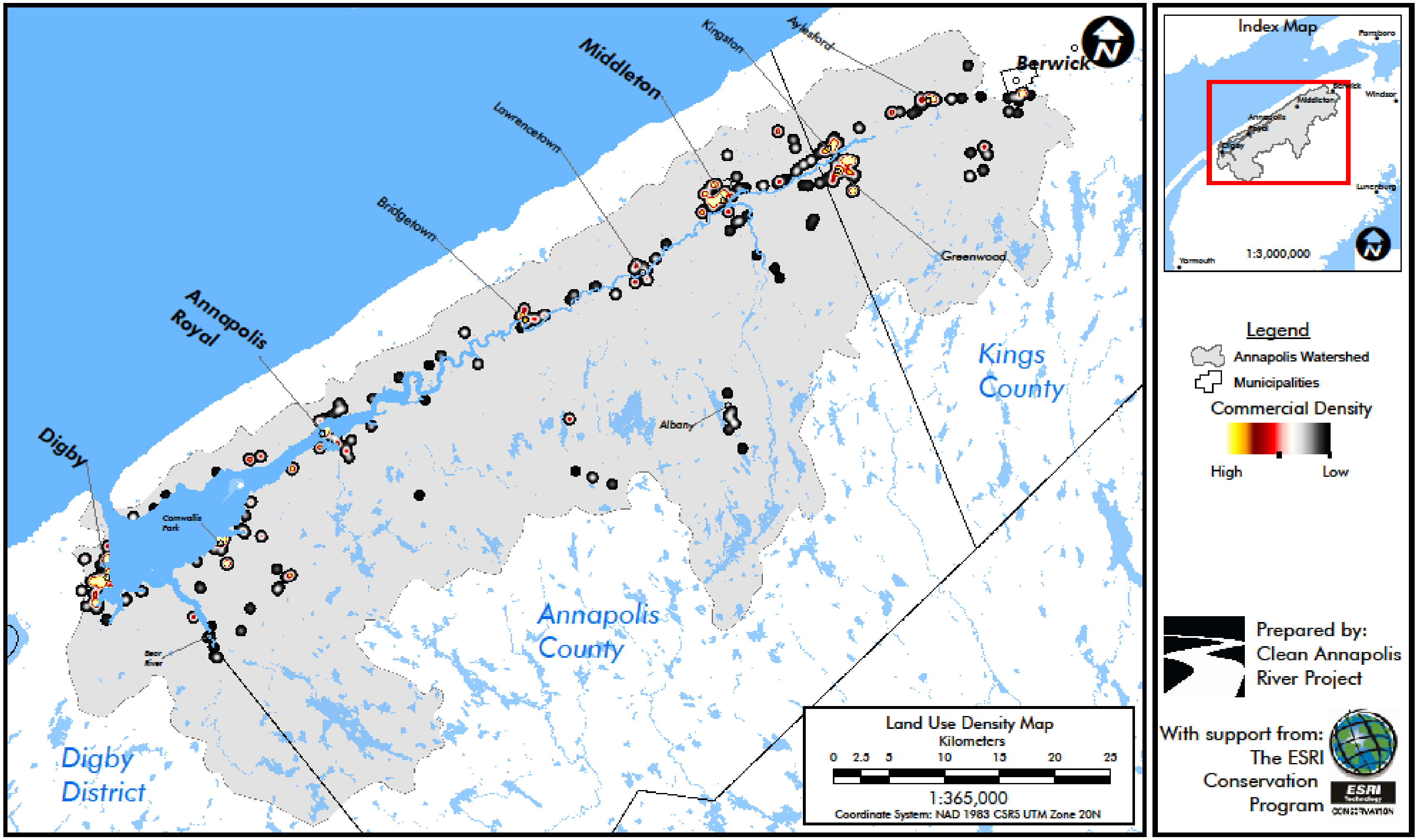
The areas of greatest urban activity, including commercial and industrial activities, coincide with the major towns, villages and other communities within the Annapolis River watershed, including Digby, Cornwallis, Annapolis Royal, Bridgetown, Middleton, Kingston, Greenwood, Aylesford, and Bear River. Most of this activity is also located within close proximity to the Annapolis River, reinforcing the importance of working with the general public to provide education and capacity for implementation of best environmental practices relating to water quality. Household use of fertilizers, pesticides and other chemical products have potential to pollute watercourses. Private land practices such as clearing of riparian vegetation is common along the Annapolis River, and leads to impacts such as increased rates of erosion, and reducing buffering of surface runoff. Public education and outreach programs are one option for addressing these issues.

Several of the specific threats associated with urban development and commercial activity are discussed separately in other sections of this report (e.g. on-site septic systems, impermeable surfaces, etc.). Industrial activity is fairly limited in the watershed. Future work to identify the specific types of industry that these sites represent will allow for activity specific threats and impacts to be assessed.

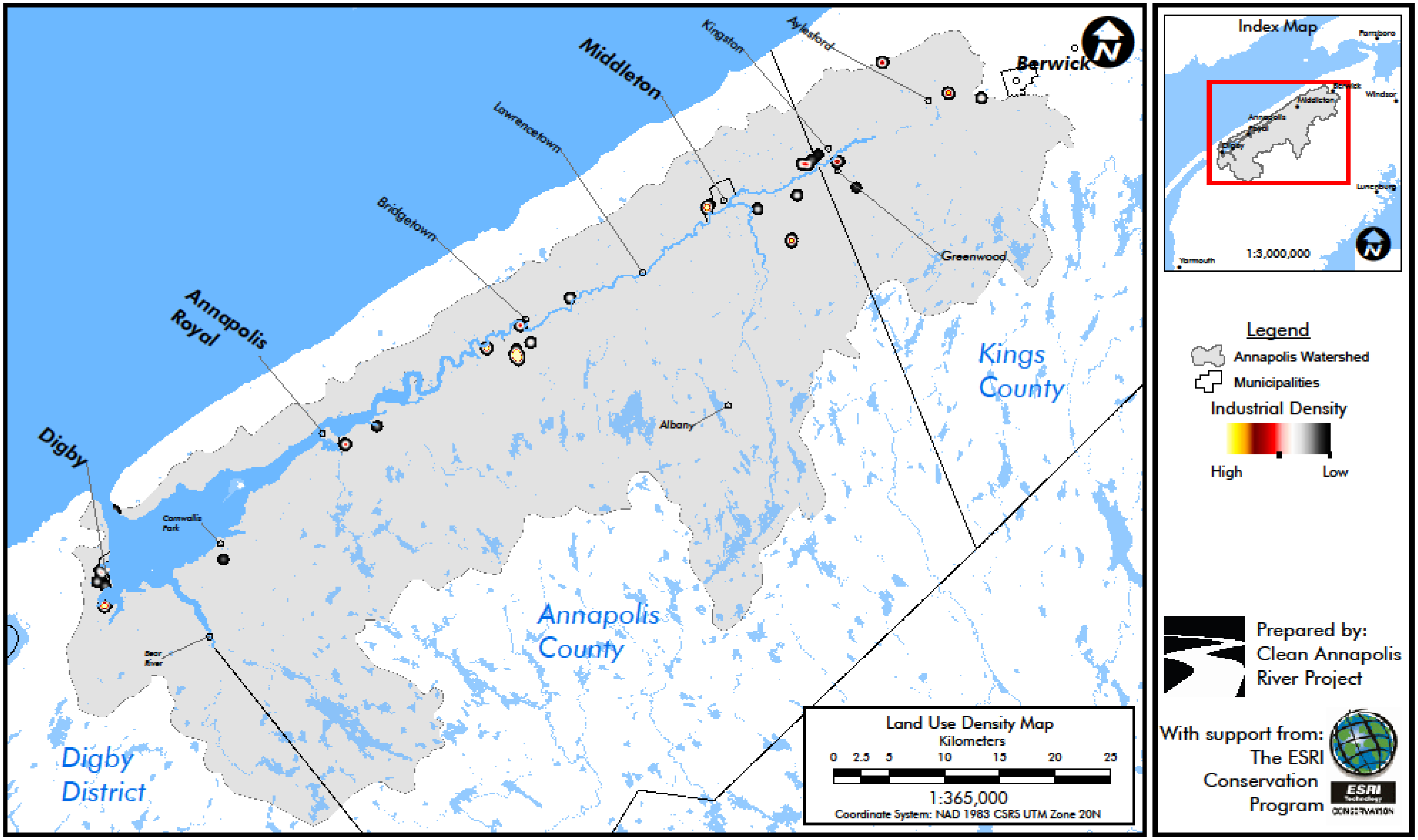
Residential Density Map



Commercial Density Map



Industrial Density Map



2.4.3 Aggregate Extraction

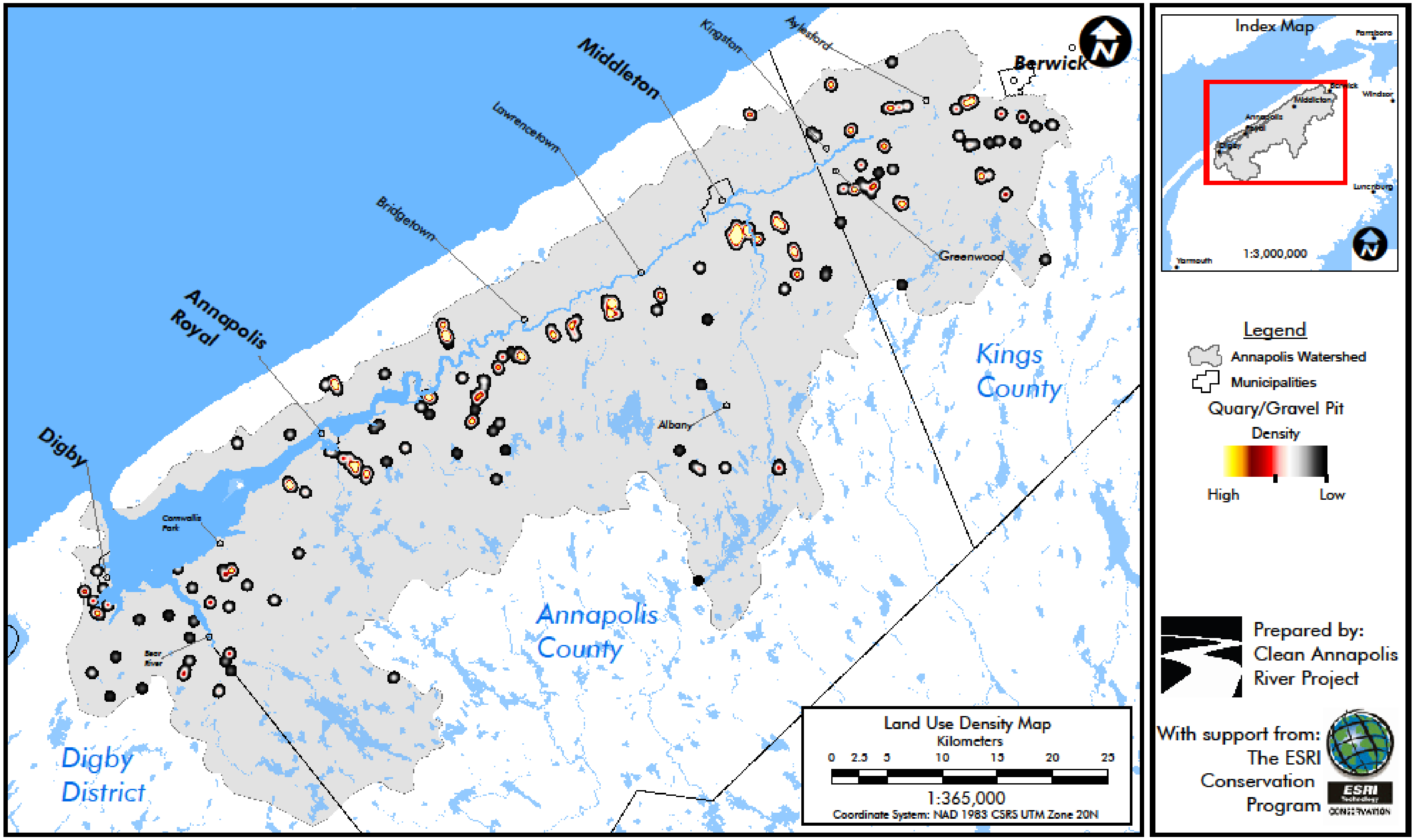
Activities such as quarries and gravel pits are considered as the main aggregate extraction activities relevant to the Annapolis River watershed. Major ecological impacts associated with aggregate extraction that may potentially affect surface water quality, include: increased sediment load and suspended solids in surface water and adjacent watercourses; acid rock drainage; release of petrol products or hydraulic fluid; issues relating to the maintenance of storm water ponds located on extraction sites the construction of road networks and associated infrastructure (eg. culverts & bridges); decreased biodiversity as a result of habitat loss (Blackport Hydrogeology Inc.; & Golder Associates, 2006; Binstock & Carter-Whitney, 2011; Terry W Hennigar Water Consulting).

In a review of source water protection issues related to aggregate mining it was found that operations where there is unmitigated quarry dewatering, where the water table is lowered below the pit or quarry, cause the greatest impact to surface water quality (Blackport Hydrogeology Inc., & Golder Associates). Mines or pits located on karst formations have been identified as the highest risk for contributing to surface water pollution.

Recommendations

There are a number of gravel pits and quarries identified adjacent to the Annapolis River or one of its major tributaries, including the Nictaux River system. Several other sites are located on the northeastern boundary of the Annapolis River watershed, which would place them at a point of high elevation, making them more susceptible to high velocity surface water flow. Detailed investigation of these sites is required to determine potential impacts and mitigation or remediation options.

Aggregate Extraction Density Map



2.4.4 Golf Courses

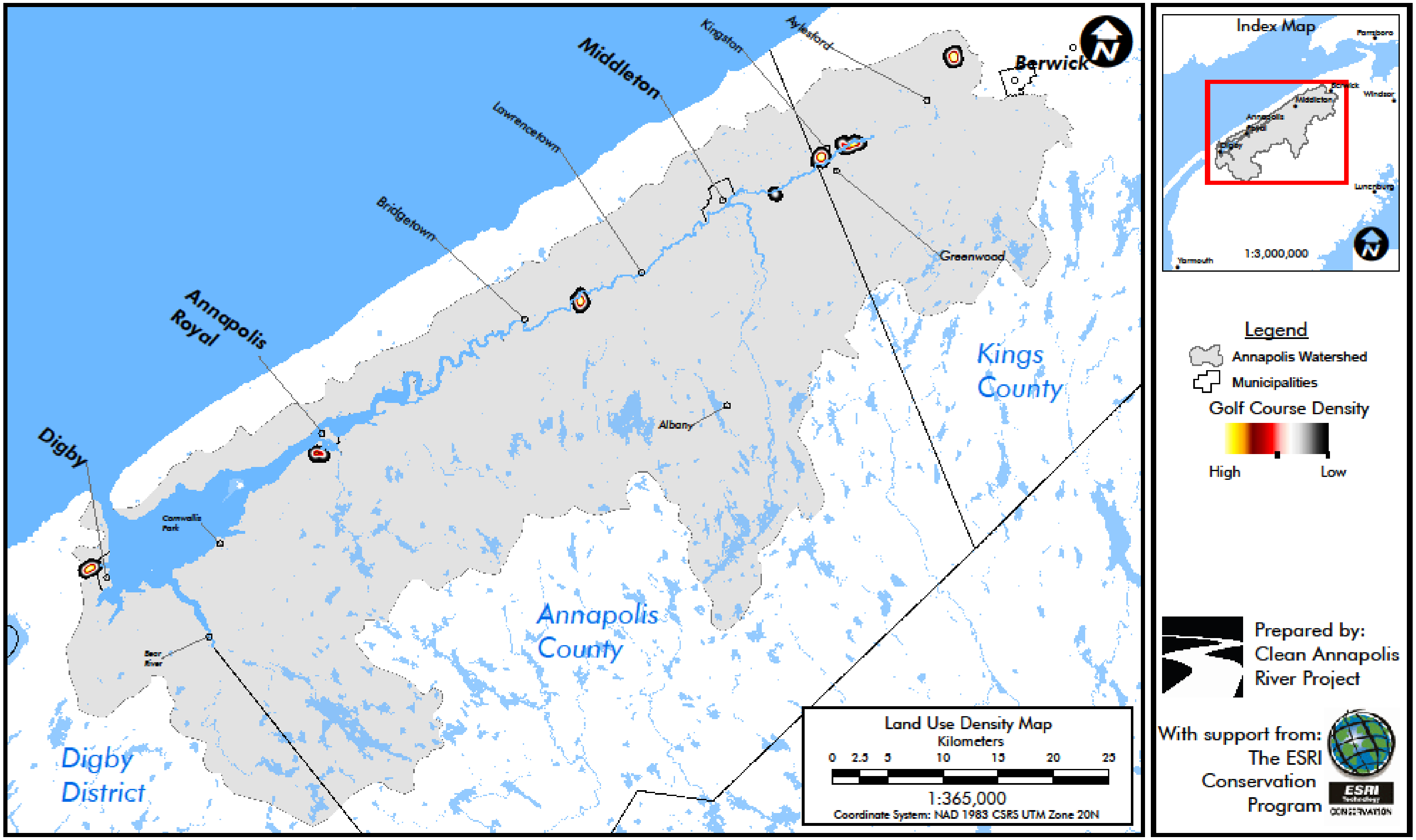
The use of fertilizers is common practice on golf courses, and creates the potential for nutrient pollution to ground and surface waters. Other potential types of contamination include pesticides, petroleum and thermal pollution. A wide variety of pesticides may be used for turf management, including insecticides, fungicides, and growth regulators (Cohen et al., 1999). Cohen et al. (1999) identified a list of 59 different pesticides that were used on different golf courses in the United States.

Kenna (1995) notes that it is not appropriate to make assumptions about water quality impacts caused by golf courses based on results from studies of agricultural practices, because of several significant differences in management practices, including plant canopy, surface mat, and density of plant root systems. Surface water runoff tends to be lower than on agricultural land, because of practices that promote good drainage, and because rates of evapotranspiration are usually higher than crop production (Cohen, 1999). Leaching potential is also expected to be lower for turf management systems compared to cropland.

Recommendations

There are seven golf courses located within the Annapolis River watershed, all of which are located directly adjacent to the Annapolis River or Annapolis Basin, increasing the risk of impacts from surface water runoff and thermal pollution as a result of vegetation removal from riparian areas. Water quality monitoring, including parameters for nutrients and pesticides at sites up and downstream of golf courses is an assessment option that could be used to identify issues associated with these specific sites.

Golf Course Density Map



2.4.5 *Cottages and camps*

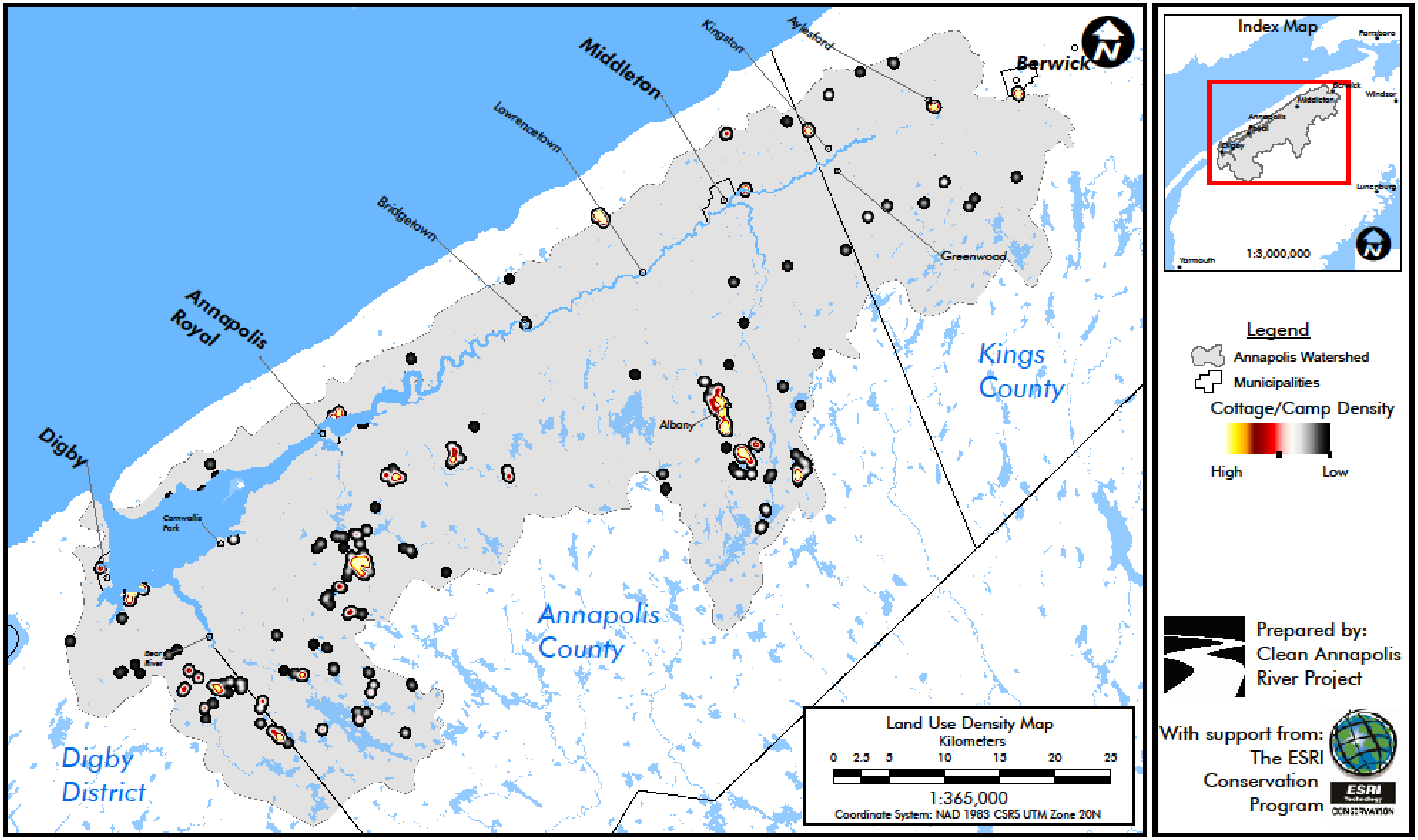
A vast majority of camps and cottages would be serviced by private on-site septic systems, creating the potential for the pollution of ground water, and eventual contamination of adjacent surface waters (See section 2.2, On-site Septic Systems). Waste disposal services tend to be limited in these areas, and could lead to water quality impacts if precipitation is able to leach through uncovered waste piles. Specific recreational activities that cottage/camp users participate in could also contribute additional sources of pollution such as fuel, oil or other chemicals associated with powerboats, ATVs, snowmobiles, etc.

Recommendations

Water quality monitoring programs could be developed and implemented in order to assess and monitor specific pollutants affecting areas that support camps and cottages. Parameters that could be measured include: total phosphorous, chlorophyll a, secchi depth, total nitrogen, pH, turbidity, colour, conductivity, and temperature (CARP, 2009).

The main barriers preventing property owners from addressing septic system maintenance and repairs have been identified as cost and education (CARP, 2014). Education and outreach programs, in addition to rebate programs, are methods that could be used to address this.

Cottage and Camp Density Map



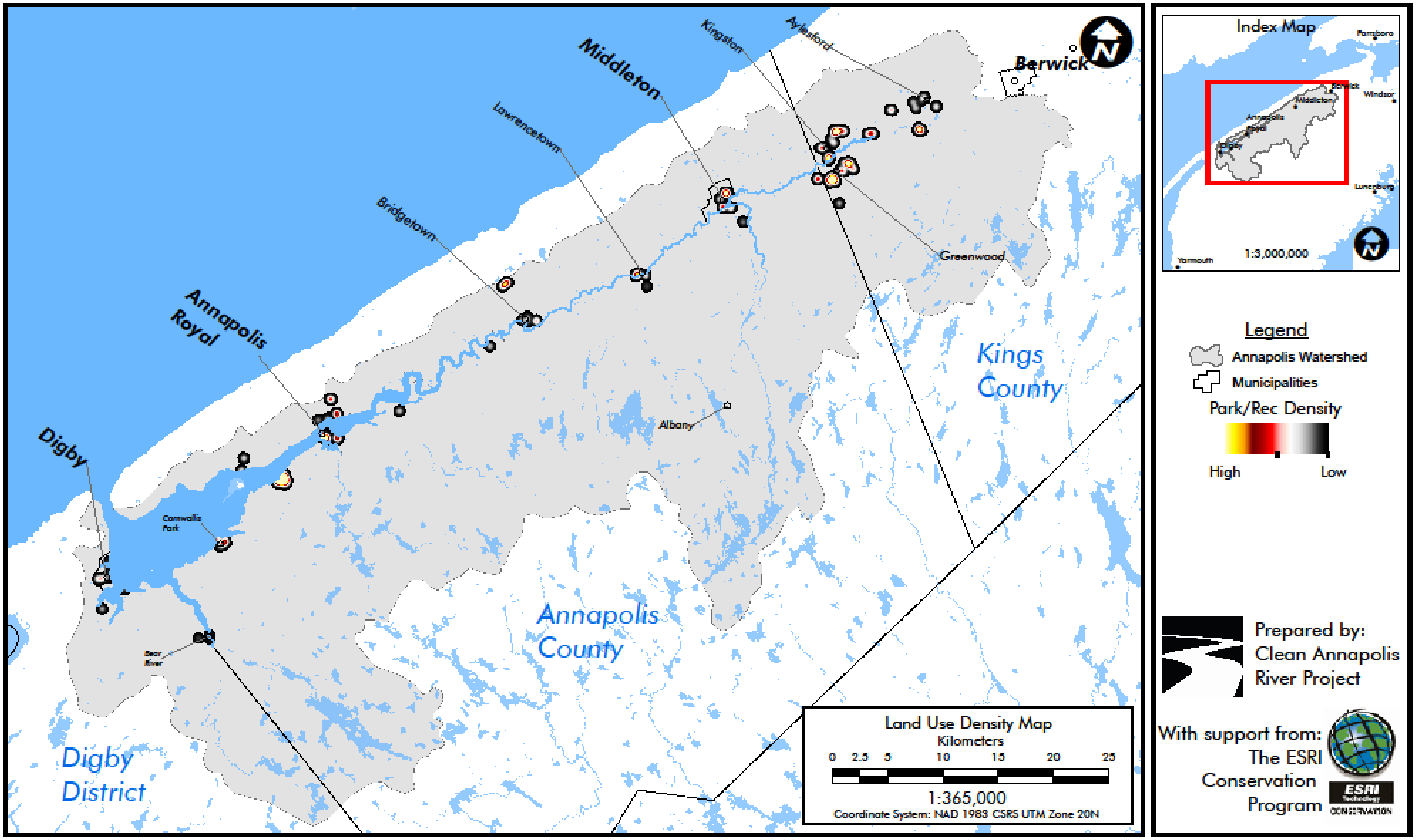
2.4.6 Park and recreational spaces

In some cases parks or recreational spaces may be maintained in order to provide scenic viewscapes or open space for recreational activities, contributing to the loss of vegetative cover that would otherwise play a role in slowing down surface water runoff and filtering waterbound pollutants. Alternatively, some parks and recreational spaces may protect vegetative cover, enhancing their ecological value. The periphery of parks and recreational spaces create edge habitat, which can also be more susceptible to invasive plant species.

Recommendations

Most of the park and recreational spaces identified are directly adjacent to the Annapolis River or one of its tributaries. Most of these sites fall within towns, villages or other major communities centers, in which case the land would likely be owned and managed by the respective town, village or county governance unit. These units include the Counties of Digby, Annapolis, and Kings, the Town of Digby, Town of Annapolis Royal, Village of Lawrencetown, Town of Middleton, Village of Kingston, and Village of Greenwood. It is also possible that there are parks managed federally through Parks Canada or provincially through the DNR.. Depending on the site, actions such as the creation and maintenance of vegetated watercourse buffers or other impermeable surfaces (rain gardens, wetlands, etc.) may be beneficial.

Park and recreation Spaces Density Map



2.5 Agricultural Land-use in the Annapolis River watershed and estuary

2.5.1 Method

Agricultural landuse layers wee derived from the DNR Forest Inventory GIS layer and updated using the most current DNR orthophotos. Agricultural areas were then categorized into:

- Open field (pasture, tilled crop, hay, etc.)
- Livestock
- Orchard/vineyard
- Greenhouse
- Cranberry Bog

2.5.2 Open Field and Livestock Agricultural Areas

Agricultural land use is generally associated with a number of water quality issues, including high nutrient concentrations, increased variability in dissolved oxygen concentrations, increased turbidity, high chlorophyll-a levels, and impacted macroinvertebrate populations (Brisbois et al., 2008). In a study of stream systems in the Cornwallis watershed, Nova Scotia, Brisbois et al. (2008) found that agricultural activity can lead to flashy runoff responses with lower base flows. Contaminants associated with various agricultural practices such as cropping and livestock farming include: nutrients (nitrogen and phosphorous) from both synthetic fertilizers and organic inputs from livestock; pesticides; microorganisms and bacteria from livestock waste; pH agents; and salts from irrigation residues.

Intensive farming can make soils more susceptible to erosion, leading to increased stream sediment loads. Increased sedimentation resulting from cultivation leads to the transport of sediment-bound pollution, such as phosphorus (P), in run-off, leading to eutrophication of surface water even when fertilizers are not applied (Howarth et al., 2002). Rates of runoff tend to be reduced on grasslands, compared to fields under crop rotations (Kinley et al., 2007).

The use of fertilizers, particularly synthetic fertilizers containing ammonium (NH4) and nitrate (NO3-), is a common practice for intensive crop production (Tilman et al., 2002). The nitrogen in fertilizers that is not removed through crop harvest is either stored as organic nitrogen in soil, volatized into the atmosphere, or leached into ground and surface waters. There are several factors that affect the amount and rate of leaching, including soil type, climate, fertilizer type, and specific farming practices (Howarth et al., 1996).

Fertilizers containing phosphorous are also commonly used in crop production. The amount and timing of rainfall after application are significant factors in the rate of export of P. While P export from agricultural systems is usually dominated by surface runoff, important exceptions occur in sandy, acid organic, or peaty soils that have low P adsorption capacities, and in soils where the preferential flow of water can occur rapidly through macropores, which can result in transport to groundwater.

The use of subsurface tile drains by many agricultural producers creates a more direct pathway for fertilizer-based P to enter surface water (Kinley et al., 2007). Long-term application of fertilizers leads to increased levels of soil P, which then contributes to increased loss of P as it leaches through drainage systems. In a study of P leaching from tile drained agricultural fields in Nova Scotia, Kinley et al. (2007) found that fields with long histories of treatment with poultry or swine manure had consistently high total phosphorus (TP) concentrations, exceeding environmental guidelines, when compared to fields treated with dairy manure. They also observed that Nova Scotia farms with permanent cover crops tended to use dairy manure, and crop rotations received a mix of manure types that include poultry and/or swine manure, and that the practice of crop rotation led to increased risk of P loss.

Cropping practices, including the use of fertilizers, herbicides, insecticides, tillage, irrigation and drainage systems all have potential implications for water quality. The use of row or non-row cropping and the sequence of crop rotations can also influence impacts on water quality. Contaminants associated with cropping include: nutrients, pesticides, sediments, salts and trace elements.

Livestock practices such as the operation of feedlots, wintering sites, pasturing, cow-calf operations, watering sites, and waste management and disposal can impact water quality. Contaminants associated with livestock farming include: nutrients, microorganisms (bacteria, faecal coliforms, Cryptosporidium Giardia), and organic materials produced by livestock.

Recommendations

Open field agricultural activity types are prevalent across the watershed, with the highest density of activity located directly adjacent or in close proximity to the banks of the Annapolis River. Density of these activities is particularly high on the north side of the Annapolis River from Paradise, east through Aylesford.

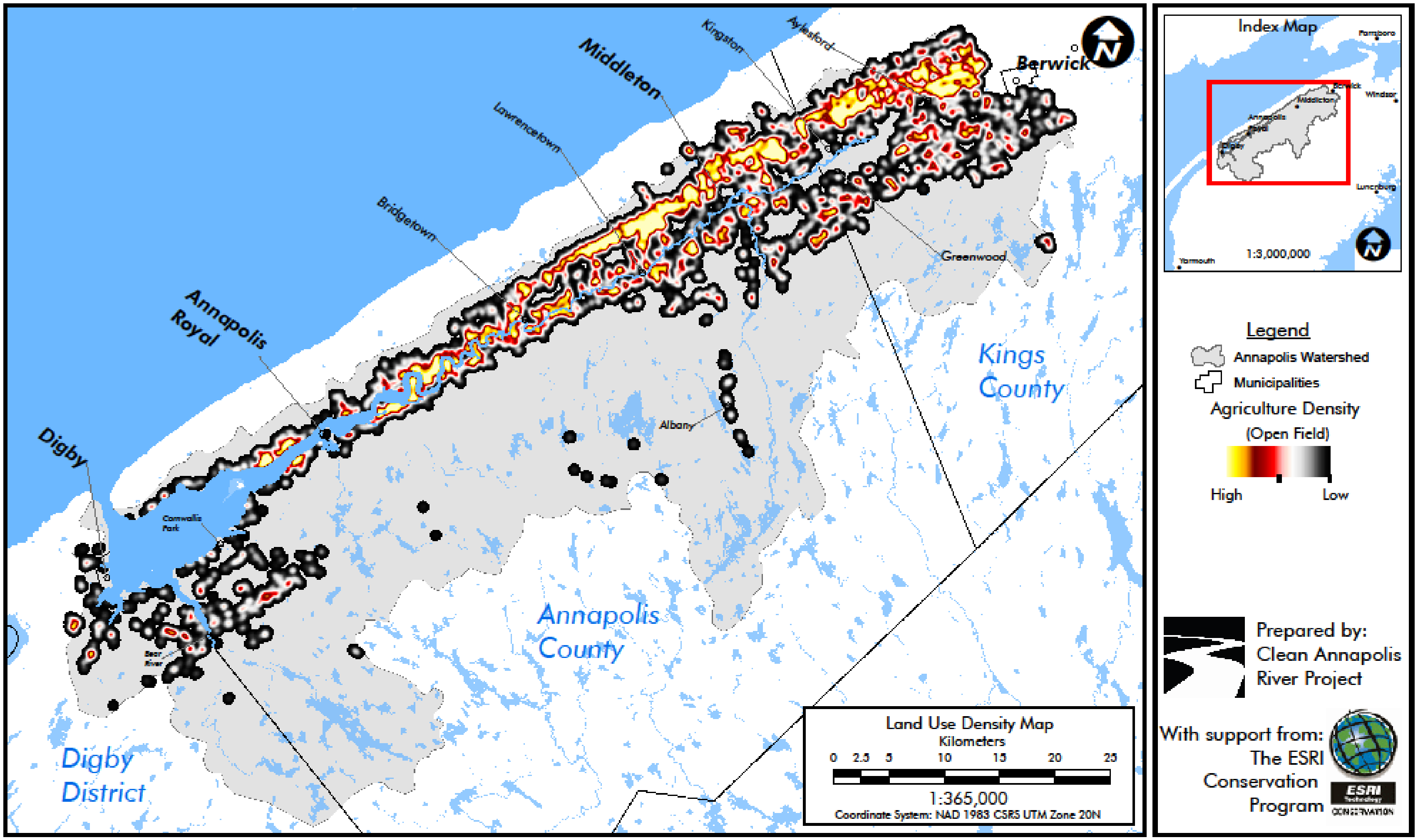
Work to further refine the open field layer, including field-based data collection and additional ground truthing, will allow for a more accurate understanding of areas supporting specific activities such as pasture land, tilled crop, hay or other agricultural practices associated with open fields. Because each of these activities has differences in the impacts they may cause and the options for assessment, restoration and mitigation, it is highly recommended that further work be pursued on refining this data set.

Depending on specific farming practices and site features (e.g. soil types, drainage), there are a number of actions that could be considered to address nutrient pollution, such as riparian revegetation, the establishment of permanent riparian buffer zones, or wetland construction/restoration. The development of nutrient management plans are another method of addressing nutrient pollution on farmlands contributing contaminants to the Annapolis River estuary.

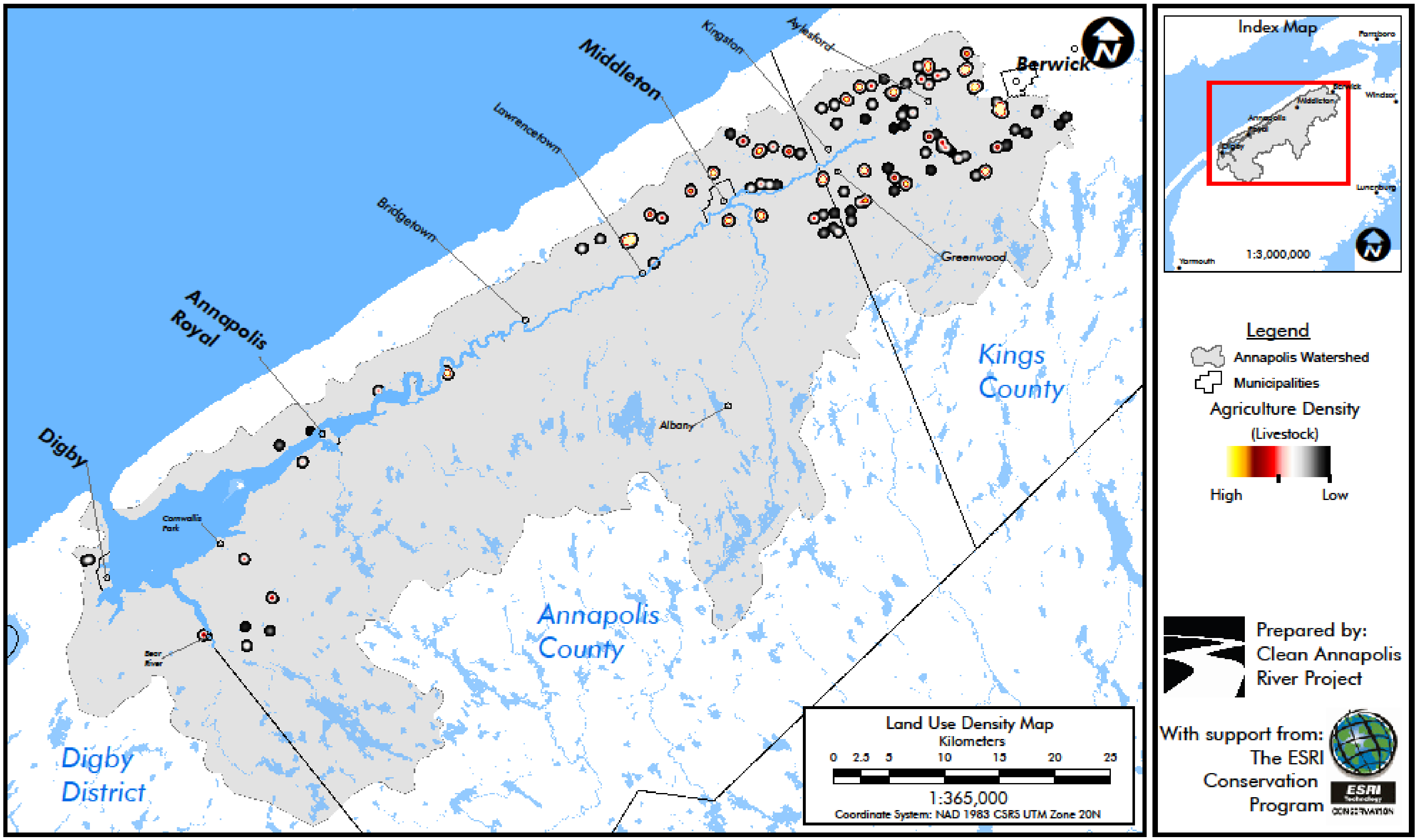
The methods used for producing the map for livestock related agricultural land use was limited in its ability to detect areas that may support low-intensity livestock agriculture. Those areas identified on the livestock map support large, intensive livestock operations; it should be noted that this includes mink farming operations. These areas pose a risk for contributing bacteriological pollution resulting from animal wastes. It is also common practice to allow livestock to water directly in watercourses, contributing to erosion and direct bacteriological contamination of watercourses. In these cases the installation of livestock exclusion fencing in tandem with an alternate watering system could reduce or mitigate negative impacts. Other actions relevant to livestock farming including the installation of manure pads and covered manure storage areas could be used to reduce rates of leaching caused by precipitation. In areas that have been impacted by erosion or soil compaction as a result of livestock watering in natural watercourses or wetland areas, bank stabilization (e.g. live sill construction) or riparian revegetation may also be options that could help to alleviate pollution.

In the case of mink farming operations there is also a high risk for nutrient-based pollution. Mink farm operations have been suggested as one of the key contributors to surface water pollution in waters adjacent to their operations (Brylinksy, 2012). There is particular concern about the contribution of phosphorous from these operations. Constructed wetlands may be able to play a role in the management of high nutrient wastewater on fur farm operations (Lautman, 2014), however this is not current practice in Nova Scotia.

Agricultural Activity- Open Field Density Map



Agricultural Activity- Livestock Operations Density Map



2.6 Vineyards and Orchards

A review of grape growing operations in Canada by Agriculture and Agri-Food Canada (AAFC) (2009), it was identified that pesticides were applied to 93.7% of the grape growing areas analyzed. Fungicides were applied to 91.3% of all grape growing areas, accounting for the greatest volume of all pesticide types applied. Insecticide application ranged from 30.7% to 74.9% between provinces, and herbicides were applied to 50% or more of total grape growing area in each province. Sulphur, which is used to manage powdery mildew, was the pesticide applied to the greatest area and in the greatest volume. Other consistently used pesticides identified include Mancozeb, captan, and glyphosate (AAFC, 2009).

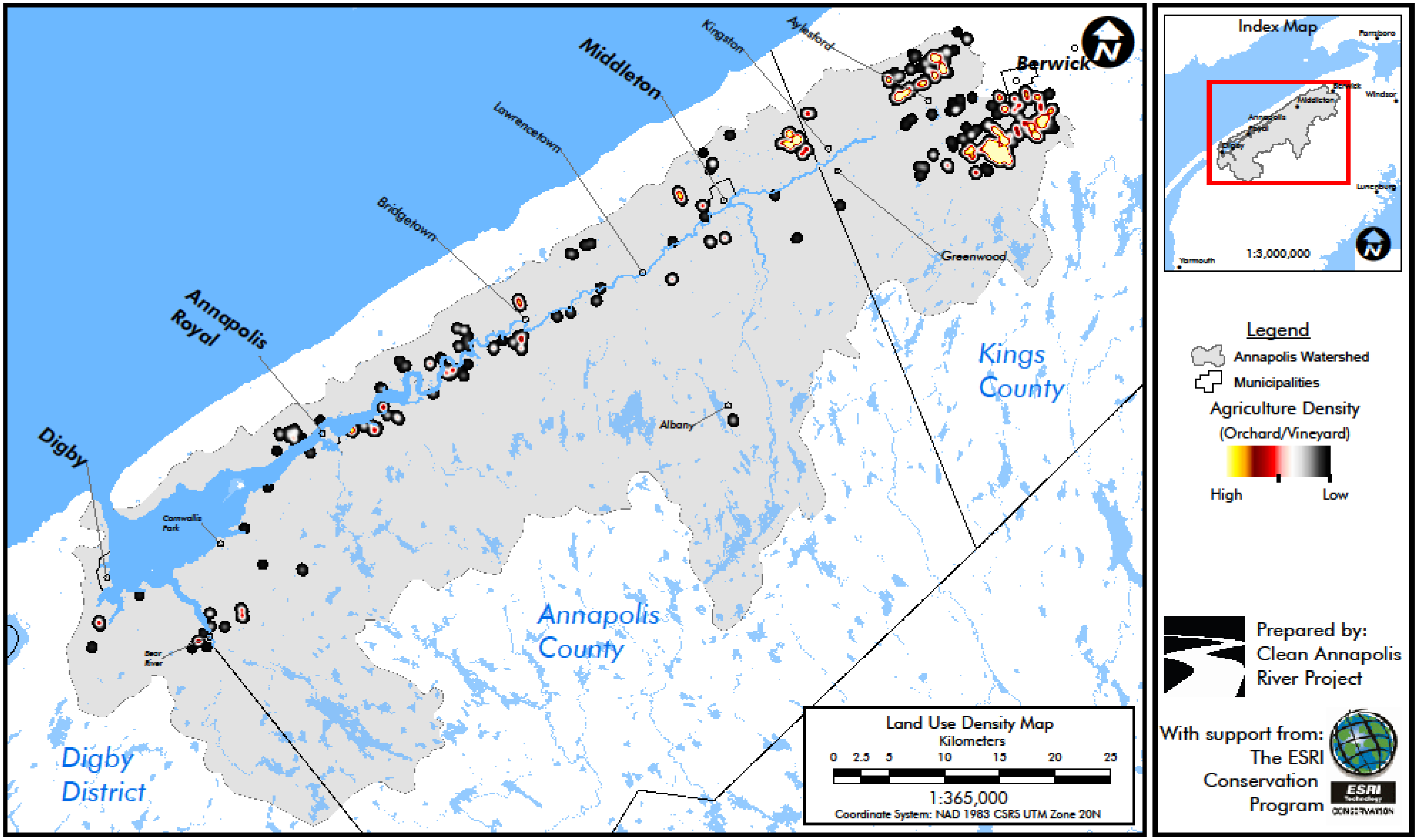
The use of pesticides is common practice among apple growers in Canada. A review of apple production in Canada by Agriculture and Agri-Food Canada (2011) identified that pesticides were applied on 91.8% of apple producing areas. Insecticides were applied to over 90% of apple growing areas; fungicides were applied to 86.6% of areas, and herbicides to 37.1% of areas. Fertilizers are also commonly used on orchards, increasing the risk for nutrient pollution to receiving waters (OMFARA, 2013).

Recommendations

Pollution from pesticides and fertilizers are key concerns related to orchards and vineyards. There are many orchard/vineyard sites identified adjacent to the Annapolis River and a high density of sites identified in the headwaters of the Annapolis River watershed, around Aylesford, creating the potential to cause downstream impacts across the full extent of the river system and estuary.

Consultation and collaboration with individual farm owners and managers is likely necessary to address the impacts resulting from individuals sites. Water quality monitoring that includes parameters for pesticides are one option for assessing impacts on water quality. Continued water quality monitoring through programs such as the Annapolis River Guardians and Environment Canada's water quality monitoring programs are also important assessment and monitoring tools. Additional monitoring sites and/or parameters could be considered to bolster existing programs.

Agricultural Activity- Vinyard and Orchard Density Map



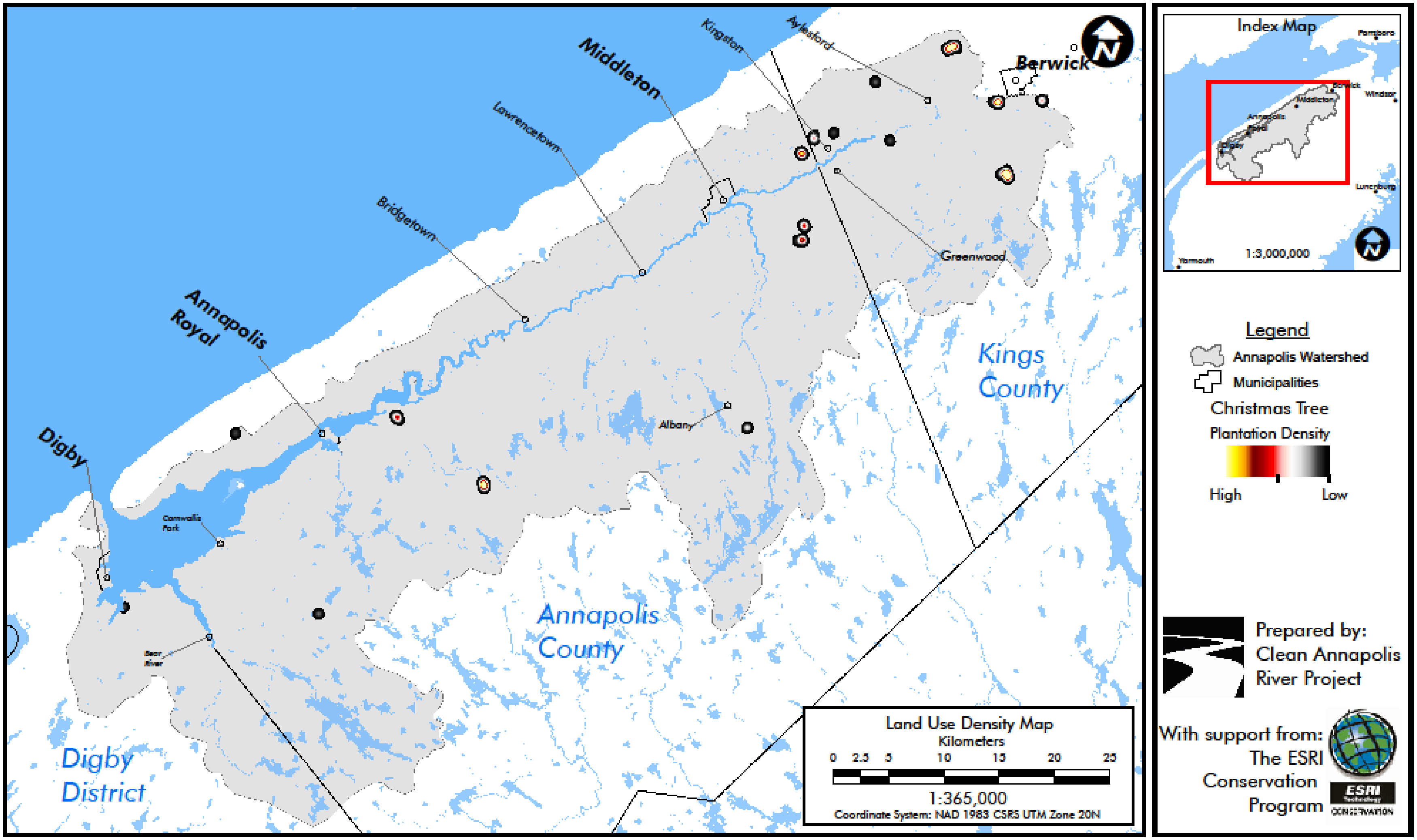
3.0 Christmas Tree Farms

Christmas tree production typically involves the creation of monoculture plantations, usually of balsam fir in Nova Scotia. Common practices include routine use of pesticides to ensure a high quality product; this includes herbicides to regulate undesirable regeneration, as well as insecticides and fungicides depending on the specific pests and diseases that an operation may need to manage. Nitrogen fertilizers and growth regulators are also commonly applied to ensure vigorous growth.

Recommendations

There are a number of Christmas tree farms scattered across the watershed. In Nova Scotia the more common insect pests on Christmas tree plantations include balsam fir sawfly, balsam gall midge, balsam woolly adelgid, gypsy moth, hemlock looper, spruce budworm and whitemarked tussock moth (NS DNR, 2016). There are a variety of chemical and biological control options that could be used to manage these insect pests. Consultation and collaboration with individual landowners and managers would be required to identify specific control options being used. The move towards integrated pest management approaches, which consider manual, chemical and biological control options, may encourage less application or more conservative application of pesticides.

Agricultural Activity- Christmas Tree Farm Density Map



4.0 Forestry-Clearcuts

In Nova Scotia the operational definition of a clearcut is an area of forest harvest "where less than 60% of the area is sufficiently occupied with trees taller than 1.3 m" (NS DNR, 2012). Clearcutting is a common harvest practice in Nova Scotia. According to the Canadian Council of Forest Ministers, in 2010 clearcutting accounted for 95% of total harvest in Nova Scotia (CCFM, 2010).

There are a number of impacts associated with clearcutting that can negatively affect aquatic environments, including: sedimentation of waterways, increased rates of surface runoff, increased rates of erosion, loss of minerals and nutrients through subsurface flow, increased water temperature, increased leaching of nutrients, decreased ability of soil to retain water, and an increase in the risk of flooding events in adjacent watercourses (Nieminen, 2004).

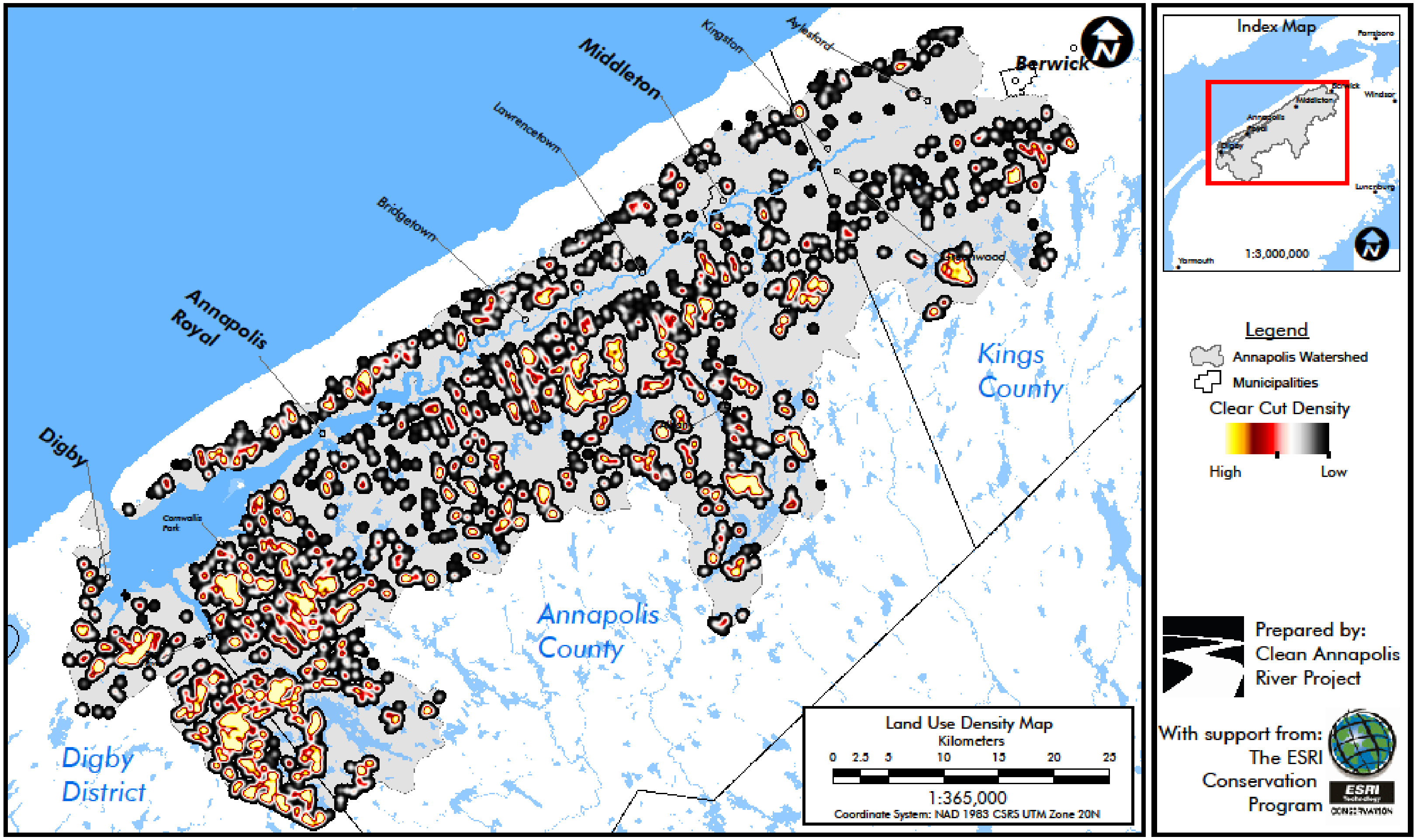
Method

Foresry landuse layers were derived from the DNR Forest Inventory GIS layer and updated using the most current DNR orthophotos.
Landsat 8 orthophotos were used to digitize clear-cut polygons in the eastern portion of the watershed.

Recommendations

The application of clearcutting as a harvest method is prolific across the Annapolis River watershed. While Nova Scotia *Wildlife Habitat and Watercourse Protection Regulations*, under section 40 of the *Forests Act* makes some provisions that relate to the protection of watercourses from the potential negative impacts associated with clearcutting, such as the creation of special management zones, there is still risk for adverse effects to occur. A next step would be to identify which of the land included in the clearcutting map is Crown Land versus privately owned land. Outreach and education programs are one method for increasing awareness about the potential impacts of clearcutting on water quality. Collaboration with woodlot owner groups and associations is another option to addressing issues on privately owned forest lands.

Forestry Activity- Clearcut Density Map



5.0 Aquaculture

In Nova Scotia, aquaculture activities include: open pen finfish aquaculture, closed pen finfish aquaculture, shellfish aquaculture, and marine plants. Other related activities in the Annapolis River estuary include commercial harvest of shellfish (e.g. softshell clams). The impacts associated with these activities are highly variable, depending on the specific activity.

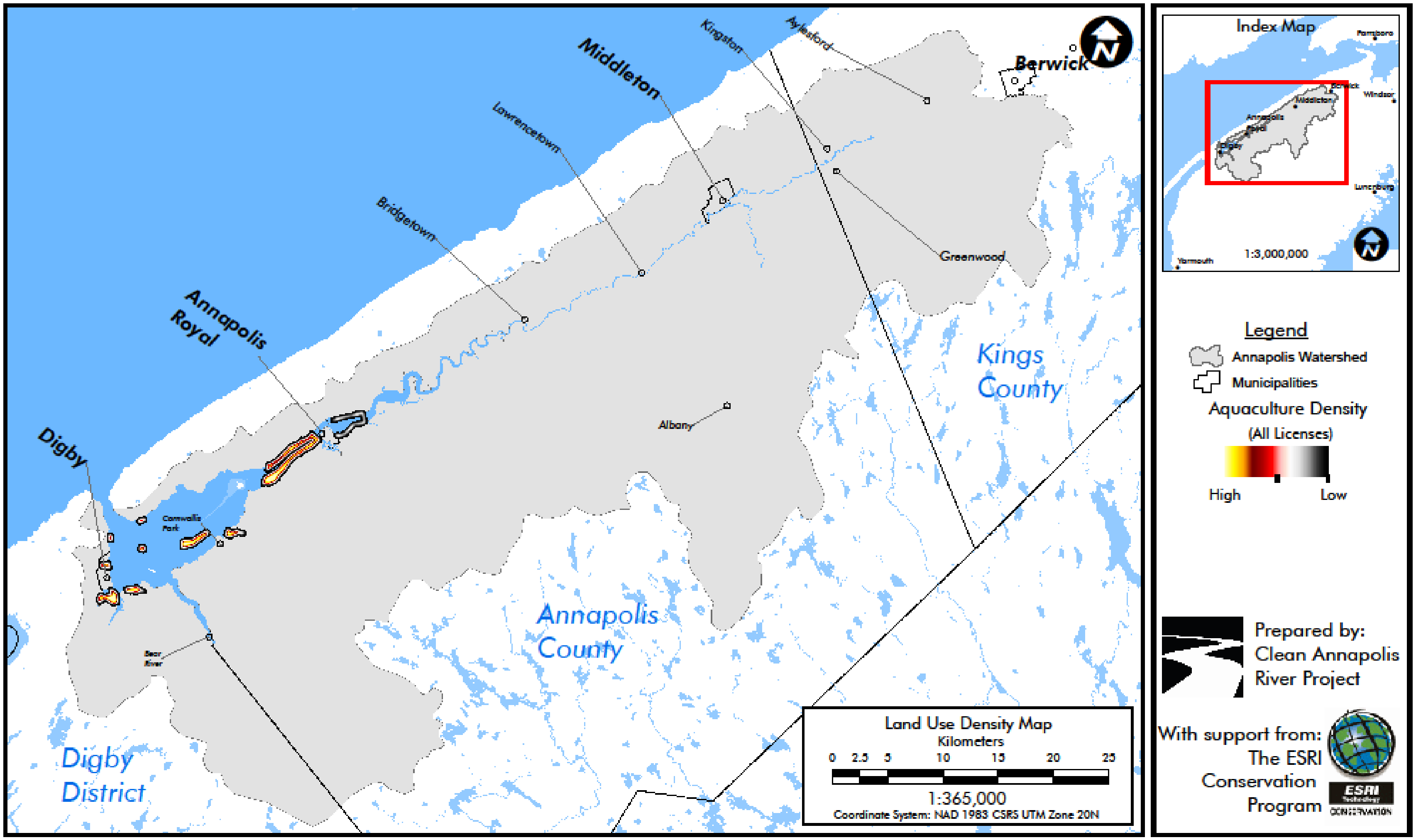
Open pen finfish aquaculture is perhaps the highest risk activity in terms of potential negative impacts on the marine environment. Issues related to open pen aquaculture include: pollution of marine/estuary waters with feces, excess feed, anti-foulants, and pesticides, transmission of disease and parasites between farmed and wild fish, and escape of farmed fish (Royal Society of Canada, 2012).

Recommendations

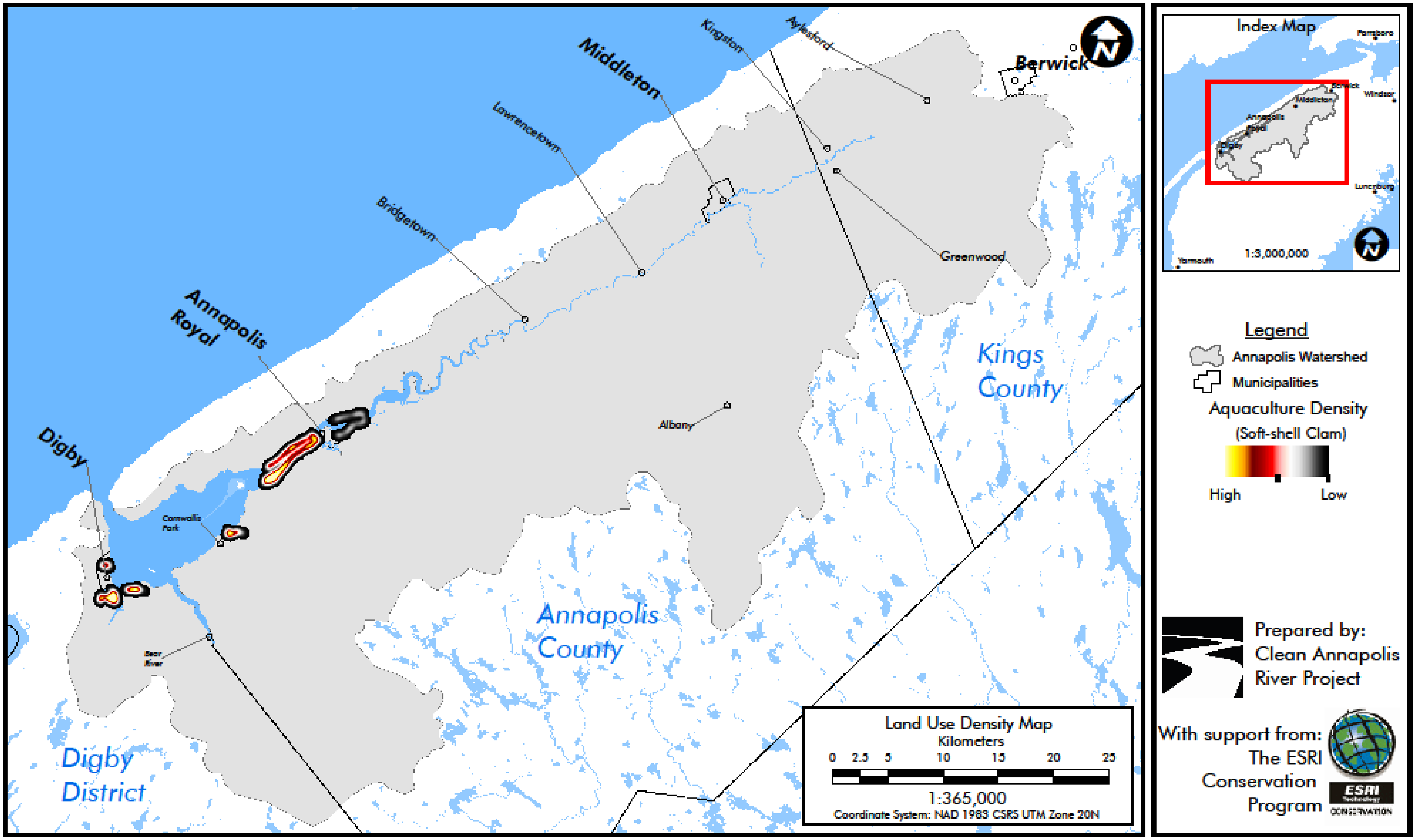
A majority of the areas identified through mapping of aquaculture and shellfish harvest activities include softshell clam harvesting. CARP is currently collaborating with the Clam Harvest Area 2 clam harvesters' organization (CHA2) to address issues related to this industry.

Of greatest concern are the potential impacts of open pen finfish aquaculture. A number of these sites are located in close proximity to Digby, and there is potential for future expansion of the industry. A 2013 report by the Atlantic Coalition for Aquaculture Reform (ACAR) concluded that, based on marine monitoring results from Nova Scotia's marine aquaculture industry, marine environments are being overwhelmed by the volume of waste released from fish farms (Milewski, 2013). While there are regulations that guide the monitoring of aquaculture activities, additional monitoring may be required to assess and evaluate the local impacts of open pen aquaculture in the Annapolis River estuary. Interactions between farmed salmon and wild Atlantic salmon have the potential to lead to transmission of diseases and parasites, increased predation of local wild fish as result of predator attraction, and hybridization of farmed escapees with wild salmon, leading to lower genetic fitness (DFO, 2011). Currently the Southern Upland population of Atlantic salmon are listed as endangered, making these potential impacts a serious concern.

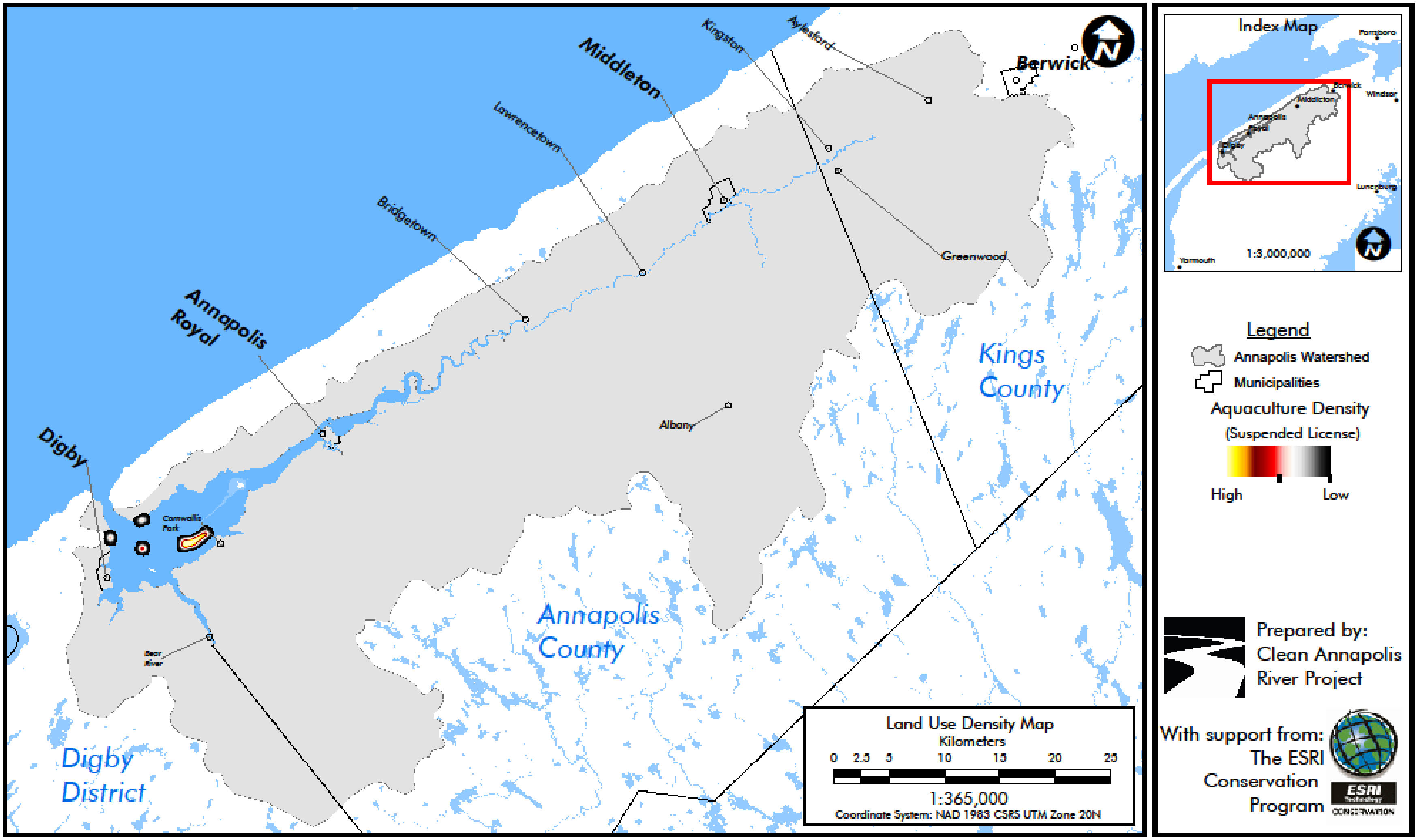
Aquaculture and related activities- All Issued Licences Density Map



Soft Shell Clam Harvest Area Density Map



Aquaculture Areas with Suspended Licences Density Map



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