Land Use at the W.K. Kellogg Biological Station: Assets and Opportunities

Final Report
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Contacts: Dr. Katherine Gross (grossk@kbs.msu.edu) or

Dr. Steve Hamilton (hamilton@kbs.msu.edu)

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Executive Summary

In September 2004, Acting Director Dr. Katherine (Kay) Gross formed an *ad hoc* Land Use Committee, to provide an overview of the current land and site uses at the Kellogg Biological Station (KBS) and how any policies had developed. Dr. Steve Hamilton (KBS faculty) and Dean Solomon (KBS Land and Water Program) were appointed as co-chairs of the committee. Other members included Jim Bronson (Kellogg Farm manager), Dr. Tom Getty (KBS/Zoology faculty), Greg Kowalewski (Kellogg Forest manager), Steve Norris (Lux Arbor manager), Dr. Phil Robertson (KBS/Crop and Soil Sciences faculty), and Dr. Doug Schemske (KBS/Plant Biology/Horticulture faculty). The charge to the committee was "to document and assess the assets and capacities of the current land base at KBS", to serve as a prelude to the formulation of a strategic Land Use Plan and Policy for KBS. The committee originally was charged with evaluation of the KBS Main Site (i.e., lands contiguous to the KBS campus) and the Lux Arbor Reserve. The Kellogg Forest and Brook Lodge properties were subsequently added to the inventory even though they are not part of KBS because these are MSU properties near KBS and are frequently used for research, teaching, and outreach activities that are done in conjunction with programs at KBS.

A new Geographic Information System was created in ArcGIS software by Suzanne Sippel to organize and display spatial data on land use and cover, including what areas are most utilized for research, teaching, and outreach activities. The committee also recommended a policy for evaluating future requests to use the land base at KBS, which might serve as the prelude to the eventual formulation of KBS Site Use Committee that would evaluate site use requests. Finally, the committee was charged with considering alternatives for future use of the KBS land base in the context of new initiatives that were under discussion at that time.

The KBS Mission Statement[1], which was used to guide the development of this report, stresses integration of activities on site:

> "Development of programs in research, education and outreach directed toward a comprehensive understanding of natural and managed terrestrial and aquatic systems, and the interdependence of these systems for conservation of natural resources."

Also germane to land-use planning at KBS are the three focal areas driven by the Mission, that were developed at the March 2004 retreat and are described in the report from that retreat "Sustaining the Vision"[2]: 1) Ecology and evolution; 2) Sustainable practices on agricultural landscapes; 3) Species conservation and habitat restoration.

In this report the recent history and present structure of land-use decision-making at KBS is reviewed to provide a context for past and current land use at KBS. The most

[1] The KBS Mission Statement was revised slightly in 2004 from the 1994 version to better reflect the focus on integration. This statement was developed as part of a KBS Strategic Planning Retreat in March 2004.

[2] "Implementing the Mission and Vision" for the W. K. Kellogg Biological Station, Michigan State University. A report to Dean Jeff Armstrong, CANR; Dean George Leroi, CNS; Director Ian Gray, MAES; Director Maggie Bethel, MSUE. Submitted April 2004 by Dr. Katherine L. Gross, Acting Director of KBS, on behalf of the KBS faculty, staff and community.

recent land-use plan was done in 1984, prior to the establishment of the Lux Arbor Reserve and the NSF-funded Long-term Ecological Research (LTER) site. During the 1990's several committees made recommendations for land use at the KBS Main Site and Lux Arbor but these were not formally integrated into a Land Use Plan.

This report inventories the multifarious assets of the KBS land base at the Main Site and the Lux Arbor Reserve. Less comprehensive, but supporting data are included for two other MSU properties in SW Michigan: the Kellogg Forest and Brook Lodge. The GIS layers and maps prepared for this report were done to make more apparent to persons seeking sites for research, education or outreach, what MSU resources were available at KBS and in the surrounding area. Our intent is that this information will facilitate land use evaluation and decision-making and provide the background information for making future decisions on land and site use at KBS. The GIS also serves as a foundation for maintaining a historical record of land cover and uses in this area that will benefit future users.

The impacts on land use of several future or pending initiatives are also discussed in this report. These include the potential for scaling up the LTER agricultural treatments to larger field sizes, incorporation of the KBS land base as a site in the NSF National Ecological Observatory Network (NEON), and establishing a new program in Conservation and Restoration Ecology at KBS.

Overall, the KBS land base and nearby MSU properties offer outstanding research, education, and outreach opportunities not available at other MSU field stations or perhaps any other field station in the Midwestern U.S. The greatest assets and opportunities afforded by this land base can be summarized as follows:

1) The extensive and diverse land cover and use includes a complex mosaic of managed and unmanaged lands and is representative of the broader southwest Michigan landscape and many areas of the Upper Great Lakes region;

2) The close proximity of these diverse land covers and uses facilitates comparative study and research that explicitly addresses effects of landscape heterogeneity;

3) The required infrastructure and expertise is in place to support research, education and outreach involving land use, management, and conservation, including agricultural activities;

4) The history of long-term research, including the LTER in agricultural ecology, and data collection that provides a valuable baseline from which other research can be leveraged;

5) The large contiguous area of the properties enables studies that require large spatial scales (e.g., tracking wildlife movements or study of metapopulation dynamics across the landscape);

6) The lack of public access to some of the land base facilitates research activities such as wildlife observational studies, field experiments, and instrument deployment that might otherwise be subject to disturbance.

7) The public access to and visibility of other areas allows for structured and passive educational and outreach programs.

1. Introduction and charge to the committee

In September 2004, Acting Director Dr. Katherine (Kay) Gross formed an *ad hoc* Land Use Committee, to provide a overview of the current land and site uses at the Kellogg Biological Station (KBS) and how any policies had developed. Dr. Steve Hamilton (KBS faculty) and Dean Solomon (KBS Land and Water Program) were appointed as co-chairs of the committee. Other members included Jim Bronson (Kellogg Farm manager), Dr. Tom Getty (KBS/Zoology faculty), Greg Kowalewski (Kellogg Forest manager), Steve Norris (Lux Arbor manager), Dr. Phil Robertson (KBS/Crop and Soil Sciences faculty), and Dr. Doug Schemske (KBS/Plant Biology/Horticulture faculty). Funding was provided by KBS and MAES to support part-time work by Suzanne Sippel to build a Geographic Information System (GIS) of the KBS lands. KBS/Zoology graduate student Amy Burgin assisted the committee and co-chairs in gathering and organizing information.

The charge to the committee was "to provide a report on the assets and capacities of the current land base at KBS for research, teaching and outreach", which could serve as a prelude to the eventual formulation of a Site Use Plan. Such an assessment must be informed by current information on land use and cover, and on which areas are most utilized for specific purposes related to the MSU mission (research, teaching, and outreach), and therefore considerable effort was expended to update and expand that information using GIS. The committee also was asked to recommend a policy for evaluating future requests to use the land base at KBS, which would serve as the prelude to the eventual formulation of a KBS Site Use Committee that would evaluate site use requests. Finally, the committee was charged with considering alternatives for future use of the KBS land base.

Figure 1 shows the locations of the lands covered in this report. The committee originally was charged with evaluation of the two KBS properties: the Main Site (i.e., lands contiguous to the KBS campus in Ross Township, Kalamazoo County) and the Lux Arbor Reserve (Prairieville Township, Barry County). Two other MSU properties in SW Michigan and which are managed by other units, the Kellogg Forest (MSU Forestry Department) and Brook Lodge (MSU Kellogg Center), were subsequently added to the inventory because they offer important opportunities for research, teaching, and outreach and are often used by programs based at KBS. Less detailed information is provided for these additional properties.

Land use assets and opportunities are evaluated here in the context of the KBS Mission Statement, which in 2004 was revised slightly from a 1994 version to:

> "Development of programs in research, education and outreach directed toward a comprehensive understanding of natural and managed terrestrial and aquatic systems, and the interdependence of these systems for conservation of natural resources."

Also germane to this report and future land-use planning at KBS are the three focal areas for programs at KBS that were identified as central to the KBS Mission at a Strategic Planning Meeting in March 2004 and elaborated upon in the subsequent report on the

retreat[3]: 1) Ecology and evolution; 2) Sustainable practices on agricultural landscapes; 3) Species conservation and habitat restoration.

2. Recent history of land use planning and decision-making at KBS

The organizational structure of the Kellogg Biological Station (KBS) is complex, and this complexity extends to jurisdictions over land use. The MSU Land Management Office (LMO), operating under the Vice President for Finance and Operations and in conjunction with the Michigan Agricultural Experiment Station, is ultimately responsible for managing all KBS lands as well as capital investments and facilities infrastructure. KBS is jointly administered by the College of Agriculture and Natural Resources (CANR), which is the lead, and the College of Natural Sciences (CNS). The Kellogg Biological Laboratory (KBL) is a unit within KBS that includes the resident faculty, graduate students, and other academic personnel. MSU Extension operates the KBS Land and Water Program, and also has its Southwest Regional Office at KBS. The W.K. Kellogg Experimental Forest is managed through the MSU Department of Forestry, and the Brook Lodge property, which includes a conference center, is managed through the MSU Kellogg Center. The KBS Director has administrative and budget oversight for all programmatic activities at KBS, except programs administered by the Southwest Regional Office of MSU Extension.

KBS currently does not have a comprehensive land-use plan or policy that can be used to evaluate land or site-use requests. The most recent plan is the "1984 Land-Use Plan" compiled from three distinct studies by a consulting firm (O'Boyle, Cowell, Rohrer & Associates, Inc.). The plan includes records of meetings with a KBS Land Use Committee (including then KBS Director Dr. George Lauff and a number of KBS staff) on research and education initiatives such as the Dairy Center and the Farming Systems Center, which were funded in part by a grant from the W.K. Kellogg Foundation. There is much information in this report that is still pertinent and useful to development of a land and site use plan, particularly regarding what facilities should be open to public and the suitability of individual fields for agriculture or forestry.

The 1984 Land-Use Plan focused mainly on the KBS Main Site with some consideration of Kellogg Forest as well. The report evaluated existing facilities, program relationships, and land use, then proposed future land use and measures to better integrate the multiple facilities and activities of KBS. The individual fields and forest stands were numbered (total of 100), and their acreage and current use were tabulated along with rankings of their potential for production agriculture, forestry, "natural ecosystems", and wildlife management. The report also gave recommendations for future use. Maps of current interest include agricultural potential based on soils and slope (prepared by Dr. E.P. Whiteside, MSU Department of Crop and Soil Sciences; a report is available in the KBS Library) and, folded into a pocket in the back, a map of the KBS Main Site showing recommended land use for the 100 land units as well as the Bird Sanctuary (treated as a single unit). Additional information included in the 1984 report included

[3] "Implementing the Mission and Vision" for the W. K. Kellogg Biological Station, Michigan State University. A report to Dean Jeff Armstrong, CANR; Dean George Leroi, CNS; Director Ian Gray, MAES; Director Maggie Bethel, MSUE. Submitted April 2004 by Dr. Katherine L. Gross, Acting Director of KBS, on behalf of the KBS faculty, staff and community.

recommendations of logos and signage, establishment of walking, skiing and cycling trails, windbreaks, roadside maintenance, and landscape development and maintenance at the Education Center.

The 2004 Land Use Committee was provided with several more recent reports and memos that collectively represent attempts since 1990 to formulate land-use policy at KBS, of which the following were most important:

1) Preliminary Lux Arbor Land Use Plan, 1991 Recommendations (by the Lux Arbor Land Use Committee: Jim Bronson, Kay Gross, Steve Norris, Dean Solomon, Andy Turner; committee was charged by KBS Director Dr. Patrick Webber);

2) Recommendations Report for KBS Land Use and Natural Areas Classification (1997; authored by postdoctoral researcher Bryan Foster for submission to the KBS Land-Use Committee under a charge by KBS Director Dr. Michael Klug);

3) W.K. Kellogg Farm Report, 1992-2002, pertinent sections only (authored by Dr. Bernie Knezek and Jim Bronson);

4) "Implementing the Mission and Vision for the W.K. Kellogg Biological Station, MSU" (2004, submitted to CANR and CNS Deans and MAES and MSUE Directors by Dr. Kay Gross)[1].

MSU received the Lux Arbor property subsequent to the 1984 Land-Use Plan. The "1991 Lux Arbor Recommendations" (#1 above) were never enacted in a land-use plan. Restrictions on access and teaching and research uses were proposed as interim measures until a land-use plan could be adopted, which was optimistically projected to occur within a year. Site use request forms were recommended for all users. Certain areas at Lux Arbor were considered worthy of protection as "ecological preserves". The 1991 report recommended changes in agricultural land management such as the development of a soil conservation plan, use of integrated pest management, no-till cropping, cover crops, and temporary suspension of manure applications pending soil testing. Guidelines were also offered to manage conifer plantations, including timber stand improvement as well as eventual harvest of non-native stands. For unmanaged areas at Lux Arbor, recommendations included a complete inventory of species composition and habitat characteristics (including the ~30 ponds), delineation of sensitive wetland areas, and more detailed mapping of vegetation and soils. A few immediate needs for intervention in the unmanaged areas were recognized to involve deer management, the maintenance of barriers (road crossings) between ponds, and the planting of native grass buffer strips along the margins of ponds adjacent to row crops. Several memoranda from that time provide more detailed suggestions on agronomic and silvicultural management at Lux Arbor.

The "1997 KBS Recommendations" by Bryan Foster (#2 above) included maps of the KBS Main Site and Lux Arbor, although the specific recommendations regarding land use dealt mostly with the Main Site and emphasized unmanaged areas. That report included a Lux Arbor "habitat map" that is reproduced in digital form in the present report; habitat classes included agriculture, non-native and native conifer plantations,

hardwood forests, open fields, wetlands, and open water. These recommendations were never adopted in any formal land-use plan.

The 1997 KBS Recommendations noted that the 1984 Land Use Plan for KBS existed but was considered "of little or no use", and suggested that decisions had been impeded by the lack of a unified conceptual approach to land-use planning, and the absence of a simple land classification system. The 1997 report proposed a landscape approach that included a classification system modeled after one developed by the MSU Campus Natural Areas Committee, but expanded to include the more intensive land use at KBS. Foster argued that the diversity of land cover in varying states of ecological succession at KBS was an asset for research and education, and that future maintenance of this landscape diversity might require "periodic rotational disturbance management". For example, successional fields ("old fields") could be periodically tilled or even farmed on a rotational schedule to prevent their natural conversion to shrubland or forest.

The land classification system proposed in the 1997 report was depicted in maps of the KBS Main Site and Lux Arbor. At the Main Site, land units were delineated and assigned categories ranging from Category II (High quality undeveloped areas with significant natural attributes; only limited impact sampling and manipulation allowed) through Category V (Lands of lowest priority for natural ecosystem attributes that are used for, or will be held in reserve for, intensive large-scale agricultural manipulation). Agricultural fields used by the KBS Dairy for row-crop agriculture and grazing were not included in this classification because the report dealt only with natural areas. At Lux Arbor, natural areas were not mapped in the same manner as on the KBS Main Site, but four mature hardwood forest sites were proposed as examples for Category I designation (natural areas managed at the highest level of protection and lowest level of usage). Foster concluded that a comprehensive "biodiversity survey" was needed to support this kind of classification. His report also included the recent research history at each of the land units he delineated on the main KBS site.

Hence for at least the past decade, KBS has operated without a land-use plan for either its properties at Lux Arbor or the Main Site. Nevertheless, these efforts represent substantial progress towards comprehensive land-use planning, and will be incorporated into the recommendations of this report.

3. Present jurisdictions and responsible parties for land-use decisionmaking

Historically, decisions about land use at KBS have taken place at various levels and with various objectives depending on the situation. As noted above, the MSU Land Management Office (LMO), as an arm of the Vice President for Finance and Operations, has ultimate authority over all MSU land holdings and the KBS Director has oversight in regard to programmatic matters. **Table 1** lists several major "jurisdictional land units" within KBS, their managing units, and who based at KBS is primarily responsible for their management. Some of these jurisdictional land units do not have fixed boundaries. The Kellogg Forest is distinct from the rest of the KBS lands because of its separate management by the Department of Forestry. The Brook Lodge property (received by MSU in July 2000) has not been integrated into the overall land management at KBS.

Table 1. Present land-use jurisdictions and responsible parties. The Land Management Office (LMO) at MSU has management responsibility for all lands and facilities at MSU, including those at and near KBS; however different units and offices at MSU have operational responsibility for specific properties. The Local Manager is the locally based MSU staff to be contacted for access to each site.

Jurisdictional land unit	Programmatic Lead	Managing unit	Local manager
KBS Main Site:	KBS Director	LMO	
Dairy, crops & grazing fields		Kellogg Farm (MAES)	Jim Bronson
Farming systems Center (incl. LFL)		Kellogg Farm (MAES)	Greg Parker
LTER experimental site		LTER Executive Committee	Andrew Corbin
Bird Sanctuary		KBS	Joe Johnson
Other natural areas		KBS	KBS Director & Faculty
Lux Arbor Reserve:	KBS Director	LMO	
Dairy crops		Kellogg Farm (MAES)	Jim Bronson
Tree plantations		Kellogg Forest	Greg Kowalewski & Steve Norris
Natural areas		KBS	KBS Director & Steve Norris
Kellogg Forest	Forestry Dept	Forestry Dept./LMO	Greg Kowalewski
Brook Lodge (not incl. conference center)	Kellogg Center	LMO/Kellogg Center	Jim Brand

The Kellogg Farm is a field research facility run jointly by the Michigan Agricultural Experiment Station (MAES) and MSU Extension, and includes the Kellogg Dairy Center and the Farming Systems Center. The Kellogg Dairy Center was established in the mid-1980s and serves for public demonstration of dairy operations as well as for teaching and research. Since 2000 a herd of approximately 120 Holstein cows has been maintained in a conventionally-managed, free-stall housing system; larger herds of up to 148 head were maintained in the 1990s. Much of the agricultural land base at KBS is devoted to farm operations that support this herd and entails mainly production of alfalfa, high-moisture shelled corn, and corn silage; soybeans are also grown for sale and wheat is occasionally planted for rotation purposes. Dairy-managed row crops are planted throughout the KBS Main Site, at Lux Arbor, and in some fields west of the KBS Main Site that are currently leased from the Turner family (the current lease expires in 2006). Agricultural fields assigned to the KBS Dairy are also used to support research and outreach activities, such as pasture-based animal production (R. Leep, Department of

Crop and Soil Sciences and adjunct at KBS). Some fields northwest of the Dairy are irrigated with a center-pivot system, although the acreage that is irrigated has diminished somewhat in recent years. The minimum area of agricultural land dedicated to the Dairy farming operations is dictated by the requirements of manure recycling more than feed production for the herd; at present the amount of land allocated to farming by the Dairy is somewhat above that minimum acreage because the supplemental income from crop sales is important to the economic solvency of the Dairy. Manure is applied to fields in accordance with the Generally Accepted Agricultural and Management Practices (GAAMPS) associated with Michigan's Right to Farm Act, and application rates are primarily limited by accumulation of soil phosphorus.

The Farming Systems Center (FSC) is a support unit for field research focusing on traditional, sustainable, and organic crop production for a variety of commodities, generally involving small plots. The Michigan Agricultural Experiment Station established the FSC in the early 1980's. The FSC maintains a variety of research plots to support the KBS LTER project, the Living Field Lab, and various other agricultural research and extension projects. Included among the FSC acreage is the Living Field Laboratory (LFL), a long-term crop rotation experiment designed to test alternative strategies for achieving nutrient cycling efficiency and overall reduction in input requirements. Dr. Richard Harwood, a former LTER-coPI and C.S. Mott Chair in Sustainable Agriculture who retired in 2001, initiated and maintained the LFL plots. The LFL is ancillary to the KBS LTER experimental design (see below) and has served both research (including several doctoral dissertations) and outreach goals for developing programs in sustainable agriculture at KBS. Farming and some field sampling at the LFL have been carried out by the FSC. In addition to research, demonstration and outreach have been important purposes of the LFL. Although research by Dr. Harwood's group has diminished since his retirement, Dr. Steve Hamilton began an experimental liming study on the LFL site in March 2003 and as of 2005 continues to sample infiltrating soil water from the plots, which have been maintained under the same long-term agronomic protocols.

The KBS Long-Term Ecological Research (LTER) project is part of the national LTER Network supported by the U.S. National Science Foundation, with 28% of the total costs shared by MSU (MAES). Research at the KBS LTER is done on both experimental and reference sites and is directed towards understanding ecological interactions underlying the productivity of both annual and perennial field crops. These include corn, soybean, and wheat rotations, alfalfa, and poplar plantations. Agronomic treatments range from conventional, high-chemical-input cropping systems to alternative low- and zero-chemical-input protocols. Comparisons with parallel studies of forests of varying age, successional old fields, historically never-tilled fields, and larger-scale agricultural fields reveal the effects of agricultural management. One of the organizing questions of the KBS LTER centers on the role of biodiversity in the agricultural landscape, and in particular on the functional significance of diversity with respect to ecosystem functions and services. Agronomic management decisions at the LTER site are made by the KBS LTER Executive Committee, in consultation with the Agronomy Committee which includes faculty from the MSU campus.

The Kellogg Bird Sanctuary serves the dual purposes of supporting research on wildlife as well as being a popular education, extension, and recreational site for the public. The property has been managed by MSU since 1928. Education and outreach are accomplished through organized programs (often involving K-12 students) as well as self-guided tours. Research at the Bird Sanctuary and its environs is conducted by MSU faculty and students, in cooperation with state and federal agencies, and has included internationally recognized programs on waterfowl conservation. In addition to research on wildlife, Wintergreen Lake at the Bird Sanctuary has been and continues to be an important site for research in limnology, aquatic ecology and microbial ecology. Trails and displays are open daily to the public, including a recently established segment of the North Country Trail.

The Lux Arbor Reserve was given to MSU in 1990 with the explicit purpose of supporting KBS programs. The deed has general restrictions[4] upon use of the property that extend through 2020, including stipulations that the property "shall be used solely and exclusively for purposes similar to those of the W.K. Kellogg Biological Station…". The deed specifically states that the property "shall not become or be used as a public park, a hunting and fishing preserve (except for fishing on public waters), or used in any manner, including recreation, by the general public…'. Exceptions to this policy include day use at Hawk Island on Lower Crooked Lake, lake access at the Parker Road crossing, and selective hunting "for species population control and/or the protection of ecological balance of the Donated Property and its environment…". Current policy permits access only for university faculty, employees, enrolled students, and adult participants in MSU programs. The property includes a heterogeneous distribution of row crops, successional fields, conifer plantations, deciduous woods, and ponds. Facilities on the site include the manager's house and several outbuildings housing equipment for grounds maintenance. Five residences that came with the property are rented, with preference given to KBS students and personnel. Although public access by land is not allowed at Lux Arbor, boaters can access the lake system via Lower Crooked Lake, which has a DNR public access site, or the Parker Road crossing on the northeast end, where MSU maintains a small parking lot for use by the public. To facilitate access by boat, MSU removed a culvert from the narrow straight between the lower and middle lake basins in 1996.

The W.K. Kellogg Experimental Forest is managed by the MSU Department of Forestry for research, outreach, and recreation. The Kellogg Forest has a long history of research and was originally established as part of W.K. Kellogg's efforts to demonstrate practices to restore degraded farmland; the main tract has been managed for silviculture by MSU since 1932. Virtually all of the land is forested and most is used for some form of research or demonstration. Large tracts of mature trees were felled in an exceptionally strong wind event in October 2001, negatively affecting many long-term plots but also creating new opportunities to demonstrate and study natural forest recovery. Trails are open daily for public access, and the reach of Augusta Creek within the Forest is popular for trout fishing (the stream is regularly stocked by the Michigan DNR).

[4] See LAR deed for specific limitations (1991) and memo from Drs. Bernie Knezek and Mike Klug (11 November 1993) for interpretation of these restrictions. Copies are available from the KBS Director Office or LMO.

The Brook Lodge property was given to MSU in 2000 by Pharmacia Corporation (which had bought the former Upjohn Company and is now part of Pfizer). Brook Lodge includes a full-service hotel and conference center operated by the MSU Kellogg Center as well as extensive undeveloped land beyond the ca. 40 acres of conference center grounds. The northernmost part of the tract includes 7 forest genetics plantations that were established by the Kellogg Forest in the early 1980s under a lease with the Upjohn Company. Those forest plantations are still managed (but only require occasional thinning). During 2004 there also was selective logging of hardwoods to generate revenue for the Brook Lodge Conference Center (via the Land Management Office), but beyond that the property has changed little since acquisition. The nearby Sherman Lake YMCA uses the property for outdoor recreational activities through a lease arrangement that was originally negotiated prior to MSU taking ownership of the land. Ransom Creek passes through the undeveloped property at Brook Lodge before reaching the conference center, and thereafter it enters Augusta Creek. Impoundments along the stream system create extensive flooded areas on the property, and there is also a natural lake (Douglas Lake) along the stream south of 41st Street. Public access is not permitted beyond the conference center grounds, although anglers and duck hunters continue to access the lake by boat from EF Avenue, as they did when the land was in corporate ownership.

4. Creation of a GIS on KBS land cover and use

The Geographic Information System (GIS) has become an essential tool for land-use planning. As part of this report, Suzanne Sippel has created a new KBS GIS using ArcGIS 8.3 software. These GIS-based maps served as the basis for evaluation of current land use and cover in this inventory[5]. Each of the various GIS data layers includes metadata documenting its origin, and only an overview will be provided in this report. The GIS has been designed to be updated and expanded in the future, and can be used to make customized combinations of data layers to support decisions on land use as well as research and education. In addition, quantitative information for polygons representing land units can readily be derived from any of the spatial data using the GIS, and secondary analyses can be carried out to determine spatial relationships. The available GIS data layers are summarized in **Table 2**.

The first step in developing the KBS GIS was to orthorectify the aerial photos to remove geometric distortion and allow cross-comparison with other data layers. Color-infrared aerial photos taken in August 2003 by Abrams Aerial Surveys were orthorectified by placing targets on the ground during the overflight (LTER site only), by selecting landmarks of known coordinates, and by incorporating a digital elevation model (DEM) to account for topography. Other spatial data were then co-registered to the orthorectified photos.

Property boundaries for the KBS Main Site were digitized from the Abrams 1979 topographic survey map, which required some updates and revisions. Lux Arbor property boundaries were digitized from a 1998 aerial photo using as guidance those

[5] The acres reported in this report are all based on GIS calculations of area; these may differ slightly from areas reported and recorded on deeds and other transactions of property at MSU. They are not to be used as official or legal measures of land/habitat area, but can provide a guide for making land and site use requests for projects and programs.

depicted in Bryan Foster's vegetation map. For the land adjoining Lower Crooked Lake, the 1998 upland/water boundary was traced except where the property line extends eastward across a narrow straight of open water. Brook Lodge property boundaries were digitized from a stake survey map that had been conducted when the property was given to MSU.

Table 2. Major data layers in the KBS GIS.

GIS Layer	KBS Main Site	Lux Arbor Reserve	Kellogg Forest	Brook Lodge
Agricultural fields	x	x	---	---
Aerial photo, rectified – 1998 DOQQ	x	x	x	x
Aerial photo, rectified - 2003 color-infrared	x	x	x	x
Buildings	x	x	x	NA
Digital elevation model	x	x	x	x
Forest plantations and woodlots	x	x	x	x
Lakes and wetlands	x	x	x	x
Major research sites	x	x	---	---
LTER study areas	x	---	---	---
North Country Trail	x	---	x	---
Outreach and education sites	x	---	---	---
Pasture	x	---	---	---
Ponds – Lux Arbor	---	x	---	---
Property boundaries	x	x	x	x
Roads	x	x	x	x
Satellite image - IKONOS	x	x	x	x
Satellite image – Landsat TM	x	x	x	x
Soils	x	x	x	x
Slope	x	x	x	x
USGS Topographic Quads (DRG)	x	x	x	x
Vegetation cover	x	x	x	x[1]

x = data are in the GIS; NA = data not available; --- = not relevant.
[1] Because no vegetation surveys have been done for Brook Lodge, we used the 1996 Land Use/Cover for vegetation classification.

Agricultural row-crop and pasture fields were digitized on the orthorectified aerial photos using information from Jim Bronson (Dairy fields) and Greg Parker (FSC fields). The total area of row-crop fields as determined in the GIS agreed closely with independent estimates made by Bronson using crop yield monitor data. Managed forest stands were delineated and digitized in the same manner using information from Greg Kowalewski of the Kellogg Forest. Suzanne Sippel had previously delineated the LTER research areas. Particular sites used for research, teaching and extension were located by consulting various faculty and students at KBS, MSU, and other institutions.

A digital elevation model (DEM) with 10-meter pixels was prepared from a scan of the 10-foot contours of the USGS topographic maps by MSU's Center for Remote

Sensing and GIS. A data layer showing slope was prepared from the DEM. Soils data were digitized from the Kalamazoo and Barry County soil surveys (for Lux Arbor a more detailed soil survey is also available in the GIS). Non-agricultural land cover was derived from different sources: 1) For the KBS Main Site, land cover had previously been digitized from the map by Diane Burbank et al. (1992); 2) for Lux Arbor, Suzanne Sippel digitized Bryan Foster's vegetation map, including the land/water boundaries on that map; 3) for Kellogg Forest, a GIS layer previously prepared by Dr. Carl Ramm was obtained from Greg Kowalewski; and 4) for the Brook Lodge property, a preexisting GIS layer of 1996 land cover for Ross Township, created by the Department of Geography at WMU, was used in lieu of more specific information.

Boundaries of lakes and wetlands digitized from the National Wetlands Inventory were obtained from the Michigan Center for Geographic Information. For Lux Arbor, where wetland and pond boundaries fluctuate considerably from year to year, land-water boundaries were more precisely delineated by visual inspection of a 1998 aerial photo (Digital Orthoquad Quad or DOQQ). USGS topographic maps were imported as Digital Raster Graphic images. An IKONOS digital satellite image was obtained from Dr. Jiaquo Qi of the MSU Center for Remote Sensing and Earth Observation.

5. Current land use and cover at Kellogg Biological Station (KBS)

GIS-based maps are presented and current land use is discussed for the four major properties considered in this report: 1) KBS Main Site, 2) Lux Arbor Reserve, 3) Kellogg Forest, and 4) Brook Lodge. The latter two are adjacent and therefore were combined in one map.

5a. KBS Main Site

The base map in **Figure 2** shows the boundaries and major facilities on the KBS Main Site, overlain on an IKONOS satellite image with three bands combined to resemble true color. Habitat areas reported here and later are derived from the GIS data and may disagree slightly with previous data, which were obtained by other means. Units are acres (A) and can be converted to hectares (ha) by multiplication by 0.4047 ha/A. The total area of the KBS Main Site is 1702 acres, of which 873 acres are in agriculture and 96 acres are lakes (mainly Wintergreen and Duck lakes) and wetlands. Major facilities that have not already been described in this report include the Education Center (which encompasses the research labs, KBS Land and Water Program, conference center, apartments and dorms, and the Manor House), the Experimental Pond Facility (managed by Dr. Gary Mittelbach for aquatic research and also the regional site of precipitation chemistry monitoring for the National Atmospheric Deposition Program/National Trends Network), and the Terrestrial Ecology Lab (managed by Dr. Kay Gross for field research and experiments on plant ecology and evolutionary biology). Built-up sites are included in the 1702 acres cited above.

Subsequent maps use a 2003 color-infrared aerial photo as a base, rendered in grayscale to facilitate color overlays of various themes. Lands managed for row crop production, pasture, forestry, or agroecological research are delineated in **Figure 3**. Fields managed by the KBS Dairy are numbered in accordance with the field numbering

system used in and pre-dating the 1984 Land-Use Plan. Pasture fields include one subdivided into rotational grazing paddocks (field 23-8) for the research by Dr. Rich Leep (Department of Crop and Soil Sciences, adjunct at KBS). Agricultural research and demonstration plots maintained by the FSC are coded in a separate system by Greg Parker. Boundaries of the LFL and LTER treatment replicates are not shown here but are included in the GIS. The Kellogg Forest staff manages the deciduous and coniferous forest plantations on the KBS Main Site; there are also unmanaged conifer plantations throughout the property. Conifer stand management policies at the KBS Main Site as well as at Lux Arbor have been prescribed by the Kellogg Forest staff at the request of the Land Management Office. The total areas of managed lands on the KBS Main Site are given in **Table 3**.

Table 3. Managed lands on the KBS Main Site. Percentages are based on a total area of 1702 acres. Acres can be converted to hectares by multiplication by 0.4047 ha/A.

KBS Main Site: Management	**Total area (acres)**	**% of total KBS Main Site land**
Dairy farmed fields[1]	608	35.7
Forest plantations	29	1.7
FSC farmed plots[2]	129	7.6
LTER experimental areas[3]	136	8.0

[1] Does not include the 134 acres of fields on the Turner property (west of the Main Site) that have been farmed to date by KBS under a lease agreement that expires in 2005 and may not be renewable.

[2] Includes the grassland between FSC fields 27-D and R-B.

[3] Includes the Biodiversity plots and the area of alleyways between plots; does not include the LTER unmanaged forest study sites.

All non-agricultural vegetation including managed forest plantations is called "natural vegetation" in this report. Natural vegetation cover on the KBS Main Site is depicted in **Figure 4**. Details on the classification are given in Burbank et al.'s 1992 report. This map excluded a few areas, including the vicinity of the Education Center, the Living Field Lab, and a parcel in the far northeast corner that was acquired later. The Burbank et al. vegetation map was made more than ten years ago, and we were not able to field-check its accuracy. Some successional fields likely have more shrubs and trees now, and the fields of annual-biennial herbs may now have become populated by perennial herbs. Nevertheless, a cursory inspection indicates that forested areas are little changed, and that the map appears to give a good overall picture of the current vegetation on the KBS Main Site. Conifers are not native to uplands in this area and all stands mapped here and elsewhere on KBS lands were originally planted; the conifer stands include native and non-native species. Wetland vegetation mapped by Burbank et al. does not include areas with standing water. **Table 4** summarizes the abundance of natural vegetation types based on **Figure 4**, with additional information on wetlands from the National Wetland Inventory (NWI).

Table 4. Natural vegetation on the KBS Main Site. Percentages are based on a total area of 1702 acres.

KBS Main Site: Natural vegetation	# of mapped units	Total area (acres)	% of total KBS Main Site land
Uplands (Burbank et al. 1992 map):			
Annual-biennial herbs	7	6	0.4
Perennial herbs	155	84	4.9
Perennial herbs-Woody plants	61	48	2.8
Shrub woodland	97	54	3.2
Mid-successional forest	118	68	4.0
Mixed hardwood forest	54	119	7.0
Lowland (hardwood) forest	27	14	0.8
Mixed conifer - hardwood forest	44	29	1.7
Coniferous forest	55	68	4.0
Wetlands (Burbank et al. map):			
Herbaceous wetland	27	23	1.3
Shrub wetland	26	12	0.7
Wetlands (NWI):			
Herbaceous/shrub wetland[1]	--	22	1.3
Shallow open water[2]	--	74	4.3

[1] All classed as Palustrine Emergent wetland on NWI map but some wetland areas have been colonized by shrubs since 1982.

[2] Includes all of Wintergreen Lake, most of Duck Lake, and several small ponds.

In addition to its frontage on Gull Lake, the KBS Main Site includes two smaller lakes (**Figure 5**). Wintergreen Lake (37 acres), which is surrounded by the Bird Sanctuary, has long been an important site for migratory waterfowl and is the focus of educational and research programs at the Bird Sanctuary. This lake is distinctive for its high nutrient concentrations and consequent biological productivity. Since the 1970's the lake has been the focus of ecological, limnological and microbiological research. The

Wintergreen Lake outflow enters Gull Lake, and concerns among some Gull Lake landowners about possible excessive growth of algae near the outflow led to the construction of a pipe in 1995 to deliver the nutrient-rich outflow waters beneath the surface of Gull Lake at an offshore location. Duck Lake (29 acres, not including two intermittently flooded bays), is south of the Dairy and is markedly different in limnological features than Wintergreen Lake. It also has been regularly used for limnological studies and field courses at KBS. There is some private property along its southeast shore.

Wetlands with emergent herbaceous vegetation or shrubs occupy 22 acres on the KBS Main Site and include several that are notable for their use in research and education (**Figure 5**). Turkey Marsh, just north of the Education Center, is regularly used for research and teaching. This isolated depressional wetland retains water throughout most years, but occasional drying and perhaps winterkill under ice prevent fish from persisting. Fishless wetlands with open water develop distinctive invertebrate biota and hence are of particular interest for research and education. Turkey Marsh is also an interesting site for hydrological and biogeochemical research and field courses because it intercepts groundwater that is flowing toward Gull Lake, changing the water quality before that water reaches the lake. Another distinctive wetland known recently as the "LTER Kettle Hole" lies in a depression just northwest of the LTER experimental site; this ephemeral wetland has undergone striking ecological changes in concert with climatic variation over the past 10 years. Other wetlands on the KBS Main Site include several ponds around Wintergreen Lake, most of which have been modified in the past for rearing waterfowl, and shallow coves on the south end of Duck Lake that contain standing water when lake levels are high. Artificial ponds at KBS include the 21 plastic (PVC)-lined ponds of the Experimental Pond Facility (constructed in 1971 and renovated in 1987 and 2000 with NSF and MSU funds), and a demonstration pond near the entrance to the Bird Sanctuary.

Major ongoing research activities that utilize specific sites on the KBS Main Site are delineated in **Figure 6**. These sites include agricultural fields maintained for research purposes, unmanaged mature forests and successional ecosystems on upland areas, and surface water bodies. Among the unmanaged sites are early successional ecosystems dominated by herbaceous vegetation (e.g., Louden Field). Such sites have been popular for field research and may require periodic removal of trees in the future to prevent them from turning into forest, although the long-term research design of the LTER must be considered in designing any such intervention (see next paragraph). In contrast, several woodlots containing older deciduous forest are valuable representatives of mature forested ecosystems that likely covered much of this region before settlement.

Long-term research plots studied as part of the LTER experimental design are nested within the best examples of unmanaged vegetation (**Figure 6**). Forested areas that contain long-term plots for the KBS LTER include mature deciduous forest (Long Woods, Louden Woods, and Turkey Woods) as well as successional forests and planted conifer stands (Turner Field, Cantlon Field, Louden Field, and unnamed conifer stands north of Turkey Marsh, north of Kettle Woods, and on the north boundary of the Bird Sanctuary). Logging or other disturbances in these areas could compromise their research value, and even downed timber should not be removed without consulting the

researchers working on the sites. Buffers of similar vegetation are required around the LTER plots, and ancillary research is often conducted within the buffers to minimize disturbance of the LTER plots, on the premise that the buffer areas are similar to the land within the plots where baseline measurements are made. Therefore the entire polygons within which LTER plots are nested, as delineated in **Figure 6**, should receive the same management as the LTER plots they encompass.

Experimental agricultural fields include the LTER Main Experimental Site, Living Field Lab, rotational grazing fields northwest of the Dairy, and numerous small research plots dedicated to diverse agricultural research and demonstration. The smaller plots have been grouped according to either focus of the research (where multiple investigators are involved) or the principal investigators most closely involved with them (where one is dominant). Rotational grazing research has been led by Dr. Rich Leep (Department of Crop and Soil Sciences), vegetable crop research by Dr. Darryl Warncke (Crop and Soil Sciences), LTER research by Dr. Phil Robertson (KBS and Crop and Soil Sciences), insect/plant interactions research by Dr. Stuart Gage and Dr. Doug Landis (Entomology), and organic agriculture research by Dale Mutch (MSU Extension). Several successional fields on the KBS Main Site have been much studied over the years, particularly by Dr. Kay Gross (KBS and Plant Biology) and her students and postdocs, and have also been utilized by Drs. Deborah Goldberg (Univ. Michigan) and Jeff Conner, Doug Schemske, and Tom Getty (all of KBS). The LTER maintains long-term research plots embedded within larger representative areas of unmanaged successional and mature forest vegetation, and maintenance of undisturbed buffers around those plots is imperative. Smaller research plots are maintained at the Living Field Lab, and the managed forest plantations shown earlier in **Figure 2** serve for silvicultural research. The most important sites for aquatic research, which were discussed above, are also noted in **Figure 6**.

Many of the important research sites on the KBS Main Site discussed above also serve as field sites for outreach and education, but several sites that are particularly accessible for K-12 and public education and outreach are marked in **Figure 7**. Areas with public access are used for formal programs but also offer educational opportunities to casual visitors, while non-public areas are used in class field trips or other guided tours. Besides the Education Center, the Bird Sanctuary receives the most visitors, followed by the Dairy Center, but most visitors to these two facilities stay within the built-up areas and paved trails. A segment of the interstate North Country Trail, maintained by a local volunteer group with sponsorship by the National Park Service, passes through the Main Site as well as Kellogg Forest. KBS maintains a shorter "succession trail" with interpretive signage just east of the Education Center that demonstrates ecological succession from field to forest. Numerous guided field tours utilize the LTER, LFL, and other agricultural research and demonstration plots. The KBS waterfront on Gull Lake is also invaluable for research, teaching and outreach, including access by boat for water sampling, experimental studies with exotic zebra mussels (which can be done here because Gull Lake already has them), and a recently constructed demonstration of lakeshore landscaping.

5b. Lux Arbor Reserve

The base map in **Figure 8** shows the boundaries of the KBS Lux Arbor Reserve, overlain on the 2003 color-IR aerial photo. The total area of the Lux Arbor Reserve is 1557 acres, of which 271 acres are shallow waters of Middle Crooked Lake (which has been essentially permanent in recent years) and a number of ponds of variable extent, persistence, and connectivity with the Crooked Lake system. A recently established private dairy operation to the southeast of Lux Arbor is visible on the aerial photo.

Subsequent maps use the same aerial photo as a base, rendered in grayscale to facilitate color overlays of various themes. Lands managed for row crop production (Dairy farm fields) or forestry are delineated in **Figure 9**. Fields farmed by the KBS Dairy are numbered according to the system used by Jim Bronson. The Kellogg Forest staff manages the coniferous forest plantations at Lux Arbor; there are also unmanaged conifer plantations throughout the property. The total areas of managed lands at Lux Arbor are given in **Table 5.**

Agricultural fields at Lux Arbor had been farmed prior to acquisition of the property in 1991. A few acres of fields were later abandoned because of their slope, poor soils, or proximity to water bodies. The aforementioned "1991 Recommendations" as well as several memoranda dating from 1991-96 that were provided to the committee detail the decisions that were made at that time about the continuation of production agriculture on the site. Few changes in agronomic protocols for row crops at Lux Arbor have occurred since their establishment in the 1990's.

Table 5. Managed lands on the Lux Arbor Reserve. Percentages are based on the total Lux Arbor property area of 1557 acres, which includes 271 acres of lakes, ponds, and wetlands.

Lux Arbor Reserve:

Management	Total area (acres)	% of total area
Dairy farm fields	306	19.7
Managed conifer plantations	365	23.4

There are at least 45 conifer forest plantations at Lux Arbor. Most of these existed when the property was acquired, including several hundred acres of Christmas trees planted in three distinct areas in the late 1980's. Some of these stands were subsequently harvested while others now have become too old for use as Christmas trees. New plantings by KBS have included double rows of conifers between agricultural fields and public roads. The 1991 report by Bryan Foster recommended that the area of non-native conifer plantations be reduced over time, although this recommendation never became policy. Greg Kowalewski of the Kellogg Forest wrote a conifer management plan in 1995-96 that proposed eventual saw-log production as the goal for most of the plantations. Conifer forest management has included timber stand improvement (thinning and pruning) as a step toward eventual commercial harvest. Proceeds from harvest of conifers go into the LMO revolving account to be used for future needs at Lux Arbor.

Natural (unmanaged) vegetation on the Lux Arbor Reserve is depicted in **Figure 10**. This layer was digitized from the vegetation map was made by Bryan Foster in 1993. A more detailed vegetation classification map is available in paper form. Foster did not map much of the wetland vegetation; water levels at the time of the mapping were near the maximum of their interannual range of ca. 5 feet. The uplands of Lux Arbor are a complex mosaic of land cover that includes representation of most of the major land cover of the area, together with an abundance of land-water interfaces. Hardwood forest generally occupies the more sloping terrain along water bodies and much of this is quite mature (i.e., older than 75 years). Extensive conifer plantations exist on relatively recently abandoned agricultural fields. Successional fields and shrub woodlands in transition towards forest are interspersed throughout the property. In some areas, such as the southwest corner of the property, conifers occur in a sparser and more haphazard arrangement as a result of selective harvest and/or resprouting after harvest. **Table 6** summarizes the abundance of natural vegetation types at Lux Arbor based on **Figure 10**.

Table 6. Natural vegetation at Lux Arbor Reserve. Percentages are based on the total Lux Arbor property area of 1557 acres.

Lux Arbor Reserve:		
Natural vegetation	**Total area (acres)**	**% of total Lux Arbor land**
Uplands[1]:		
Successional fields	231	14.8
Deciduous forests	309	19.8
Native conifers.	84	5.4
Non-native conifers	224	14.4
Mixed native and non-native conifers	69	4.4
Lakes, ponds, and wetlands[2]:	271	17.4

[1] Upland vegetation determined by manual digitization of the map by made Bryan Foster.

[2] Wetland, pond, and shallow lake areas determined from the National Wetlands Inventory. The area of Crooked Lake represents area within Lux Arbor property boundaries, which were arbitrarily drawn along the southern edge. The area of aquatic environments fluctuates from year to year.

Lux Arbor has a diversity of lake and wetland environments (**Figure 11**). The total area of aquatic environments within the Lux Arbor Reserve boundaries as delineated in **Figure 8** was 271 acres at the time of the National Wetlands Inventory (1981). Bryan Foster's map, made from an aerial photo from the early 1990's, reflects land-water boundaries at a time of higher water levels, and the total aquatic environment area on that map is 334 acres. The smaller water bodies ("ponds") were numbered in the 1990's and that system is depicted here. The limnological and ecological diversity of the lakes and

ponds at Lux Arbor provides an excellent setting for comparative field studies, and has been exploited by several research projects as well as field courses. Water sources to the ponds range from largely groundwater to greater importance of direct precipitation inputs, and some ponds are intermittently flooded while others are as permanent as the adjoining lake system. The vegetation within the ponds and lakes that is visible on the aerial photo is mainly composed of floating and submersed plants that grow in water less than about 2 meters deep. Emergent wetland vegetation lines the banks of most water bodies, and became more abundant after a period of low water levels in 1998-99 promoted establishment on exposed sediments. Some of the ponds are presently fishless (e.g., ponds 8-11) either because they completely dry on occasion or suffer from episodic summer or winter oxygen depletion. Water levels in Middle and Lower Crooked lakes dictate water levels in most of the nearby ponds and wetlands because of surface or groundwater connections. The raised causeways of the access roads lack culverts and eliminate surface water connectivity in some cases, which likely enhances the limnological and ecological divergence of ponds that would otherwise connect to the lake system.

Current and recent research on particular water bodies and upland areas at Lux Arbor are indicated in **Figure 12.** This map does not convey the number and diversity of research projects that have used the property because terrestrial research and field course activities at Lux Arbor often have taken advantage of the opportunity to conduct studies across the heterogeneous landscape, and therefore have not focused on specific plots or sites. Aquatic researchers are attracted to the high diversity of water bodies in close proximity. The lack of public access enhances the value of Lux Arbor for wildlife observational studies, field experiments, and instrument deployment that might otherwise be subject to disturbance.

Examples of terrestrial ecology research at Lux Arbor include studies of songbird nesting success and predation (Dr. Chris Rogers, Wichita State University), life history evolution in birds (Dr. Robert Ricklefs, University of Missouri at St. Louis, with co-PIs from Princeton and Oregon State), behavioral ecology of house wrens (Dr. Tom Getty, KBS and Department of Zoology), and biogeochemistry of forest soils (Dr. Sherri Morris, Bradley University). Much of the research on successional fields and field/forest boundaries at Lux Arbor has taken place on the “island”, and hence the two areas with these fields are delineated on **Figure 12**. The northern end includes numerous planted conifers that may need to be reduced or removed in the future because they are expanding at the expense of open fields. The agricultural fields at Lux Arbor are little used for research or outreach, although they contribute to the landscape diversity that attracts researchers.

Mature deciduous forest occurs in the central “island” of Lux Arbor, along the shores of Crooked Lake, and these areas are mostly too sloping or close to the water for logging or agricultural use. They have increasingly been utilized for research. In the future, these areas should be allowed to become “old-growth” forests with no harvest of trees or removal of dead wood; such areas are uncommon in southern Michigan and would be attractive for research and teaching and would help promote use of Lux Arbor. As large trees mature and die, they form important wildlife habitat, first as standing dead trunks used by diverse animals such as woodpeckers, wood ducks, and bats, and later as

fallen wood supporting decomposer communities and associated predators such as salamanders. Ultimately the dead wood forms an important component of the forest nutrient cycle. An additional advantage of leaving these forests alone is that they are highly visible to boaters and residents of Lower Crooked Lake, enhancing the scenic beauty of the lake.

Aquatic research at Lux Arbor has focused primarily on the smaller ponds. Numerous studies have examined population and community ecology of pond biota (led by Dr. Mathew Liebold (University of Texas); Dr. Gary Mittelbach (KBS and Zoology); and Dr. Alan Tessier (formerly of KBS, now at NSF). Research on aquatic ecosystem ecology and biogeochemistry, including monitoring of water levels in the lakes and ponds since 1996, has been performed by Dr. Steve Hamilton (KBS and Zoology).

Faculty and graduate students have sampled and conducted field experiments in all of the ponds at Lux Arbor, but a subset of the ponds has been the focus of most of the research and teaching because of their ecological characteristics and accessibility. Ponds 8, 9, and 10 are closely situated and have contrasting water quality and distinctive biota. Pond 26 is readily accessible, which facilitates its use for field mesocosm experiments. Pond 23 has a distinct water quality and submersed plant community (dominated by the stonewort, *Chara* spp.). KBS summer courses in ecology, limnology, and biogeochemistry regularly sample these sites. In addition, temporary ponds 11, 13, 14, and 29 have been studied extensively.

Lux Arbor has occasionally been used for outreach programs, usually wagon tours or short-term field-based activities. The variety of unique land forms and habitats, and accessibility through the extensive road network, offer excellent outreach program opportunities. However, outreach activity at Lux Arbor has been somewhat limited by the lack of classroom and restroom facilities.

A deciduous forest dominated by oaks in the northwest corner of the Lux Arbor property is being managed to demonstrate proper silvicultural practices for owners of small woodlots (**Figure 9**). An initial management plan was devised in 2004 by Greg Kowalewski and Dean Solomon and includes a comparison of: 1) management of trees of all ages, including selective harvest; 2) woodscape management; and 3) no management. In the all-age management area, three alternatives for treatment of logging residue are being demonstrated. Proceeds from the sale of this hardwood timber go into the Lux Arbor land management revolving account.

5c. Kellogg Experimental Forest

The base map in **Figure 13** shows the boundaries of the Kellogg Forest, overlain on a 2003 color-IR aerial photo. Subsequent maps use the same aerial photo as a base, rendered in grayscale to facilitate color overlays of various themes. The total area of the Kellogg Forest is 728 acres, of which 114 acres comprise a noncontiguous parcel to the southeast designated as the Goodwin/Angell Tract (these areas were calculated by Dr. Carl Ramm). The main Kellogg Forest property includes a residence for the manager, offices, a classroom, a maple syrup processing cabin, outbuildings for forestry equipment, and parking and picnic areas for the public. Walking trails for public access extend throughout the Kellogg Forest, including the Goodwin/Angell Tract (accessible from a small parking area on 44th Street), and some have interpretive signage. There is a

ruffed grouse management area on the Goodwin/Angell Tract. A major new residential development (ca. 485 units) is being planned on a large parcel of land east of and adjacent to the Kellogg Forest.

Managed land in the Kellogg Forest is largely forested, and the management units are delineated as "forest compartments" in **Figure 14**. Most of the larger open areas visible in the photo are recent clearcuts and are or will be replanted with trees. Areas that are not marked as forest compartments tend to be either floodplain along the Augusta Creek corridor, or land that is too steeply sloping for forestry. Some successional fields are present in the Goodwin/Angell Tract.

From the perspective of forestry research and education, the forest compartments that comprise most of the main Kellogg Forest property are invaluable because of their diversity, and the long and well documented history of research that has been conducted there. In addition to research on particular plots, many research projects have taken advantage of this complex mosaic of forest stands, making them valuable well beyond their original planned purposes. Specific descriptions of these forest plots are beyond the scope of this report but have been integrated into the overall KBS GIS, imported from a GIS layer built by Dr. Carl Ramm (Forestry).

Most of the 58 acres of wetland on the Kellogg Forest property is the forested floodplain lining Augusta Creek, which flows from north to south and passes the main entrance and office (**Figure 15**). In addition to being prized as one of a few local streams that supports a trout fishery, Augusta Creek has been an important research site for stream ecology since the inception of the discipline, and numerous studies have been conducted in the reach passing through the Kellogg Forest. The floodplain along Augusta Creek is distinct from other wetlands on KBS properties; it is rarely inundated by the stream but its soils tend to be saturated all year due to local groundwater emergence, and seeps and springs are abundant. Forest or shrubs largely cover the floodplain but the northern end also contains sedge meadows. Several managed forest compartments are located on the floodplain.

The Kellogg Forest also has two artificially created ponds. One is located at the entrance and receives water diverted from Augusta Creek. Another pond is located west of 42nd Street and became a wetland by sedimentation of a basin behind an old earthen dam. The latter site has been used by Dr. Steve Hamilton for biogeochemistry research and teaching and is of particular interest because it receives emerging groundwater. It has also been the site of research on control of Purple Loosestrife (*Lythrum salicaria*).

5d. Brook Lodge

The total area of the Brook Lodge property is 654 acres, of which about 40 acres are the buildings and ground of the conference center and 162 acres are wetlands and lakes (**Figure 13**). Facilities include the conference center complex and a house and maintenance building across 42nd Street. The value of this property for research and education has yet to be fully appreciated, perhaps because no research unit manages it.

The uplands on the Brook Lodge property are largely forested although there are some open areas, including a large patch of successional field in the center of the property. The forest includes naturally regenerated hardwood forests as well as planted

conifers, and much of it lies on gently rolling terrain. The Kellogg Forest manages several stands at the northern end, mostly as forest genetic plantations (**Figure 14**).

Much of the total area of the Brook Lodge property is covered by the wetlands and the lake upstream of 41st Street (known as Douglas Lake), which lie along the Ransom Creek system that flows through the conference center grounds and then into Augusta Creek (**Figure 15**). Of the 162 acres classed as wetland in the National Wetland Inventory, 95 are shallow open waters (including Douglas Lake), 50 are covered by emergent herbaceous plants, and 17 are occupied by shrubs or trees. Much of the shallow open water becomes filled with aquatic plants by late summer. In addition to Douglas Lake, which may be a natural lake, shallow standing water is created by the impoundment above Douglas Lake (where an old railroad bed bisects the stream). The wetlands above that point are known as Sherman Lake Marsh. Impoundments also exist below Douglas Lake, where flow is constrained by a culvert under the road, and further downstream at the reflection pond on the conference center grounds. The standpipe at the railroad bed was designed to store water upstream and thereby ensure continuous outflow throughout the year, which was desired to maintain the flushing of the reflection pool. That short reach remains classified as a county drain.

A study conducted by Tessier and Creed (1989) for the Upjohn Company analyzed water and nutrient movement through the hydrologic system of the Brook Lodge property. In addition to nutrient concentrations, the report has measurements of depth and discharge and maps of aquatic vegetation. The problems with excessive algal growth in the reflection pond were ascribed to high phosphorus concentrations, which in turn were shown to originate upstream of the Brook lodge property and attenuated in transit through the impounded wetlands and lake mainly during lower flow conditions.

The wetlands of Brook Lodge offer some unique opportunities for research and education that have yet to be well exploited, although Drs. Alan Tessier, Gary Mittelbach, and Steve Hamilton of KBS have sampled Douglas Lake or its surrounding wetlands in the course of their research. The overall system is ideal to study the impact of stream impoundment on water quality, and could be a wetland restoration site as well. Douglas Lake is surrounded by strongly groundwater-fed wetlands known as fens, covered by a mixture of herbaceous vegetation, tamarack trees (*Larix laricina*), and shrubs. Smaller fen areas with tamarack trees occur in the far northwestern corner of the property. These kinds of fens support distinct plant communities and are considered key points for alteration of nutrient movement from groundwater to surface waters. Dead tamarack trees upstream of the railroad-bed impoundment suggest that some fen wetland was lost to inundation. High-quality fens are not represented on the other KBS properties; there is a small area of fen at the northern end of the Kellogg Forest, most of which is becoming forested. MSU does not own the entire fen wetland around the lake; the northeast end is privately owned.

5e. Summary of land cover information

The areas of major land cover types in the four properties are summarized in **Table 7**, and for the KBS Main Site and Lux Arbor these areas are also depicted as pie charts in **Figure 17**. The most evident needs for improvements in these data include the identification of successional fields that have become colonized by shrubs and trees since

maps were made (KBS Main Site and Lux Arbor), and the elaboration of a terrestrial land cover map for the Brook Lodge property.

6. Special considerations and constraints

There are a number of considerations that must be taken into account in development of land and site use planning at KBS, including our interface with local landowners and the public at large, issues of ecosystem management that extend beyond our boundaries, and a few special species that occur on KBS lands and warrant concern. These are discussed in this section if they have not already been covered.

Table 7. Summary of land cover information.

Land cover	Total acreage: KBS Main Site	Lux Arbor	Kellogg Forest	Brook Lodge
Successional fields	90	231	--	?[2]
Fields with shrubs	102	?[1]	--	?[2]
Deciduous forest	230	309	--	?[2]
Conifer stands	68	377	--	?[2]
Wetlands + lakes	96	271	58	162
Dairy farm fields	602	306	--	--
FSC fields	92	--	--	--
LTER fields	136	--	--	--
Other	280[3]	63[4]	--	40
Total property	1702	1557	728	654

[1] Successional fields and fields with shrubs were not distinguished at Lux Arbor in the same manner as they were on the KBS Main Site; Lux Arbor fields contain variable shrub cover as well.

[2] The upland land cover data for Brook Lodge are too coarse to derive area estimates; the wetland data are more accurate for this purpose.

[3] Includes the Education Center campus, Bird Sanctuary, Dairy Center, FSC, and residences.

[4] For Lux Arbor, comparison of the National Wetlands Inventory boundaries for open water and wetlands with the boundaries on the Foster map indicate that 63 more acres of shoreline were inundated at the high water levels of the early 1990's.

The relationship between KBS and the public, and in particular local landowners, has generally been good in the past and for obvious reasons we should work to maintain that into the future. Lands with public access as well as areas visible to the public should serve to demonstrate good land stewardship. Areas used by the public for recreation should be managed to preserve those uses. It is also imperative to seek good

relationships with the leadership of local political units (mainly the boards and planning commissions of the four townships around KBS). They can be sensitive to the issue of state-owned land that is exempt from taxation, and can enact zoning ordinances that impact activities and land use on the MSU properties.

Future challenges as well as opportunities are likely to involve the growing influx of new residents to the area. The lands surrounding KBS properties are at the forefront of suburban growth emanating outward from the Kalamazoo and Battle Creek areas, and this area is likely to continue to increase in residential populations in the near future. The number of neighbors with land bordering KBS lands is increasing dramatically, and their composition is changing, with many more "ex-urbanites" and fewer farmers and other traditional rural residents. An example is the large residential development being planned for the former Hillcrest Orchard land east of the Kellogg Forest, which is expected to bring numerous new residents into the vicinity of the Forest properties. These new residents often have different perspectives and priorities that cause them to view activities at KBS in a different light, and over the long term, land-use planning (not to mention KBS programs directed at the public) must account for the changing cultural and socioeconomic environment. Changing local land use patterns also offer excellent opportunities to engage new residents in KBS land-based research, education and outreach activities, and to develop programs and demonstrations relevant to new land stewardship challenges.

Ecosystem management often entails considerations that extend beyond jurisdictional boundaries, and in some respects KBS is both affected by and affects neighboring properties. Challenges that KBS may encounter in the future as residential development intensifies in the environs could involve deer herd management, groundwater pollution by agriculture, and odors generated by animal agriculture. These are the same kinds of issues that arise between private agriculture and new rural residents. MSU and KBS could turn these challenges into opportunities by using the KBS land base, infrastructure, and outreach capabilities to demonstrate innovative approaches to dealing with these issues.

Nitrate contamination of groundwater is a common problem in agricultural landscapes of the Midwest US, and there is evidence of this problem in the vicinity of the KBS Main Site. Some domestic water-supply wells at KBS-owned residences along 40th Street have shown nitrate concentrations above 10 mg N/L, requiring their replacement with deeper wells. Although the source of this nitrogen pollution is not known, caution is warranted in considering new activities that might add to the nitrogen loading of groundwater in the area.

Some animal and plant species that occur on KBS lands are sufficiently uncommon to warrant special consideration in land-use planning. Populations of Blanchard's Cricket Frog (*Acris crepitans blanchardi*) have been regularly observed calling along the shores of the more permanent Lux Arbor ponds (Ponds 26 and 5; Hamilton, personal observation). This small frog is a state-listed species of special concern because its populations evidently have declined greatly in recent decades. Alteration or manipulation of these ponds, including their shorelines, should be considered in light of the habitat requirements of this species. The distribution of cricket frogs throughout Lux Arbor has yet to be assessed. Other species of special concern that

recently have been observed in or adjacent to KBS include: 1) Spotted Turtles (*Clemmys guttata*), state-listed as threatened; two sitings by Hamilton near Duck and Wintergreen lakes; 2) a wetland plant (*Berula erecta*, the cut-leaf water-parsnip) observed in 2004 by Eric Thobaben along Douglas Lake (Brook Lodge), state-listed as a threatened species; 3) the Eastern Massasauga Rattlesnake (*Sistrurus catenatus*), a state-listed species of special concern that also is a candidate species for listing under the Federal Endangered Species Act, appears to be particularly common along the Augusta Creek system. The combination of fen wetlands and upland fields and forests that is found at Brook Lodge is ideal for this species, but surveys have yet to be conducted there. If it proved to be common, there may be opportunities for education and outreach regarding the preservation of rattlesnake habitat, which would become much more important if it were to become federally-listed as endangered.

7. Future opportunities involving the KBS land base

The tripartite mission of KBS to promote research, education and outreach that fosters better understanding of ecological interactions and processes in natural and managed sites was reaffirmed at the "visioning and planning retreat" in March 2004. It is imperative that future KBS land use decision criteria focus on balancing those three elements and promote uses that provide opportunities to integrate them. The following section gives an overview of several pending and possible alternatives for future land use at KBS. These are not offered as recommendations but as directions to be considered, taking into account the assets and capacities of the KBS land base that are highlighted here. The Kellogg Forest is not included in this discussion of scenarios because of its separate management by the MSU Department of Forestry. Nonetheless, there are many opportunities for collaboration with MSU faculty at the Kellogg Forest, and for development of complementary research, education and outreach efforts.

7a. Business-as-usual scenario

If the KBS activities described in this report should continue into the future more or less as they are conducted at present, immediate changes in land management are not needed. KBS and MSU presently strike a good balance among competing land uses, and management for agriculture and forestry is competently performed and is generally compatible with research and educational programs. However, as residential development proceeds on lands adjacent to the KBS properties, options for land use increasingly may be constrained, at least along the boundaries. This will be a gradual process in the coming years, but ultimately needs to be a consideration in KBS land use policy.

The assembly of spatial data and information into a GIS for this report hopefully also will serve to make opportunities for research, education and outreach more apparent, and to recognize potential conflicts among these activities. Until now it has been difficult to view and compare all of the available KBS lands for the purposes of selecting study sites, making decisions about land use, or considering the impacts of proposed uses of the land. In addition, few at KBS have even visited the recently acquired Brook Lodge property beyond the conference center, yet this tract offers some distinct features that offer unique opportunities for research and outreach; the maps in this report should help

raise awareness of those features but more work is needed to document the ecological features of the Brook Lodge property.

7b. Pending and Proposed Projects

Expansion of LTER Experimental Treatments **-** In 2004 the National Science Foundation renewed the KBS LTER project for another 6-year funding cycle, and an integral part of the new research phase is an expansion of the agricultural treatments to broader areas beginning in 2005. This expansion has been called the "LTER Scale-up" because it would provide a test of the viability of low-chemical-input, biologically-based management (Treatment 3) and the low-chemical-input, organic management (Treatment 4) in comparison to the high-chemical, conventional management (Treatment 1) on row-crop fields of larger and more variable dimensions than the 1-hectare rectangular plots available on the experimental site. The low-input treatments are designed as a more environmentally benign alternative to the conventional high-input row-crop agriculture, which is represented by Treatment 1 at the KBS LTER. The scale-ups would test the agronomic and economic viability of T3 and T4 at realistic scales, and also reveal the ecological implications of interactions between agronomic treatments and field size, shape and context (surrounding land cover).

A scientifically rigorous evaluation of the performance of T3 and T4 at varying spatial scales requires either a broad range of field dimensions or some kind of split-plot design in which a given field is divided into low-input (T3 or T4) and conventional-input (T1) treatments. The renewal proposal stated that half of 18 fields ranging in size from 3 to 29 acres (ca. 225 acres total) currently farmed by the KBS Dairy would be converted to low-input, biologically-based management (T3); the other half of each field will be farmed with our conventional chemical input treatment (T1). The T4 scaleup requires similar considerations. The experimental design and land requirements for the T3 and T4 scaleups remain under discussion.

W.K. Kellogg Foundation proposal for Rural Revitalization **-** Agricultural land use at KBS could be affected by a new initiative in Sustainable Agriculture and Food Systems led by MSU's College of Agriculture and Natural Resources. As part of this initiative, a proposal focused on Rural Revitalization has been prepared for consideration by the W.K. Kellogg Foundation. It would focus specifically on dairy production, and would form part of a broader MSU Sustainable Agriculture and Food Systems Initiative. The initiative proposes to build a new animal agriculture program at KBS designed to compare grazing-based and grain-based dairy production. The proposal may include a request to add a resident faculty position in "animal systems ecology", and to foster interaction of this animal agriculture initiative with the KBS LTER program, which has heretofore focused on row-crop agroecosystems and is being regarded as a model for the animal agriculture initiative. The latest estimates suggest that approximately 150-200 acres of tillable land would be dedicated to pasture for this initiative, provided that it could be irrigated.

7c. National Ecological Observatory Network (NEON)

The National Science Foundation (NSF) is seeking to implement a new research and education platform known as NEON, the National Ecological Observatory Network,

which would be unprecedented in its scale and scope. Funding would come from NSF's Major Research Equipment and Facilities Construction account and is anticipated to be around $500 million. NEON is envisioned as (NSF 04549, 2004):

> "…a continental scale research instrument consisting of geographically distributed infrastructure, networked via state-of-the-art communications. Cutting-edge lab and field instrumentation, site-based experimental infrastructure, natural history archive facilities and/or computational, analytical and modeling capabilities, linked via a computational network will comprise NEON. NEON will transform ecological research by enabling studies on major environmental challenges at regional to continental scales. Scientists and engineers will use NEON to conduct real-time ecological studies spanning all levels of biological organization and temporal and geographical scales. NSF disciplinary and multi-disciplinary programs will support NEON research projects and educational activities."

NEON is now in the planning stages and its design will become more evident within the next 6-12 months. As proposed it likely will entail a distributed network of monitoring activities linked to central regional hubs, which in turn would be linked to each other across the US. NEON is conceived as a long-term observatory, and as such would retain some level of recurrent funding after the initial investment in infrastructure.

The prospect of establishing a Regional Ecological Observatory within the Great Lakes and Midwest as a component of NEON has stimulated the organization of a regional NEON group led by Dr. Phil Robertson of KBS and Dr. Knute Nadelhoffer (Director of the University of Michigan Biological Station), with input from other regional scientists and institutions. The boundaries of a Great Lakes NEON region remain under negotiation as of this writing.

The KBS land base would be a crucial asset in the decision of whether to designate KBS as a regional locus of NEON activities. Specific estimates of how the KBS land base might be used in a NEON program must await the outcome of the planning process at the national level, so at this point it is advantageous to maintain as much future flexibility in land use as possible. NEON monitoring activities would tie in with LTER sites such as the one at KBS, which already is engaged in long-term observations of agricultural ecosystems, but they also would expand into other environments representative of the region. Field stations and their associated properties would be invaluable as sites where long-term observations and measurements could easily be instituted, instrumentation can safely be deployed in the field, and monitoring sites are less likely to be compromised by future changes in land tenure and management. The diverse landscape at KBS, including managed as well as unmanaged lands juxtaposed in a complex mosaic, is especially attractive for the study of environmental change. Examples of monitoring activities that are likely to fall under the NEON umbrella include instrumented towers to monitor gas exchange between landscapes and the atmosphere, instrumented watersheds to track changes in hydrology and nutrient storage and movement, and field deployment of innovative sensors to measure ecological phenomena in real time.

7d. Conservation and Restoration Ecology as a future focus

As agricultural lands increasingly give way to residential development in southern Michigan, a pattern that is quite apparent in the vicinity of KBS, the landscape is transforming into a patchwork of innumerable private land holdings. Many of these landowners are interested in maintaining and enhancing the environmental condition as well as the economic values on their land, even though it may only be a few acres. Thus an important new constituency has arisen that desires information and guidance on land management, but from a decidedly distinct perspective than that of the traditional farmer or land manager.

At a KBS retreat in March 2004, KBS Acting Director Dr. Kay Gross proposed that one of 3 focal areas for KBS programs should be species conservation and habitat restoration (see Introduction). A research, education and outreach program at KBS in Conservation and Restoration Ecology would increase the impact of KBS research and outreach programs in the face of the changing needs of the local community. The KBS land base offers a number of opportunities to develop restoration research and education programs in a variety of terrestrial and wetland habitats that are typical of local landscapes. Coordination with local resource managers, landowners, land use planners, and conservation organizations would allow them to gain restoration experience, and potentially provide opportunities for the development of certification programs for conservationists. The discovery-based element of this program could focus on the evaluation of innovative approaches and alternative strategies to attain restoration goals, including not only how to manage the land but also how to engage small landowners, developers, farmers, businesses, and local government units in restoration endeavors.

The KBS land base includes a variety of settings where restoration could be demonstrated at small or large spatial scales. At the largest scale of ecosystem restoration, conversion of agricultural fields to native grasslands at a tract the size of Lux Arbor could provide sufficient habitat for the return of grassland birds that are known to be sensitive to habitat area. Dr. Chris Rogers of Wichita State University has surveyed grassland birds at Lux Arbor and found few species, but in a report he notes that relationships between species abundance and grassland area suggest that Lux Arbor could support more area-sensitive grassland bird species if much of the current agricultural land were converted to successional fields or restored prairies (Rogers 1998). If combined with efforts to restore forests and oak savannahs, Lux Arbor could become the focus for research and demonstration on ecological restoration. The Merry Lea Center at Goshen College offers a model for how this might be designed (Drs. Doug Schemske and Doug Landis of MSU, personal communication).

Alternatively, restoration efforts could be directed at smaller scales, perhaps as a distributed set of demonstration projects, each located in appropriate settings and including at least some sites that are accessible to the public. Relatively small, homogeneous areas of an acre or even less could be bisected by an access trail and the restoration conducted on one side of the trail, leaving the other side as a control. Replication for research purposes would be achieved by creating several spatially distinct but otherwise similar areas. Examples of restoration projects include:

1) Woodlot management to restore native understory plants in forests heavily impacted by deer and invasive plant species such as Oriental Bittersweet and Garlic Mustard (sites found throughout KBS) and to improve senescent conifer plantations (Tappen Woods);

2) Successional field management to encourage wildlife and prevent natural conversion to shrubs and trees (Sites found throughout KBS);

3) Prairie restoration (certain sites with the most appropriate soils may exist although prairie vegetation can be maintained almost anywhere with enough effort);

3) Wetland management to selectively remove invasive species (e.g., buckthorn on the Augusta Creek floodplain) or maintain herbaceous vegetation by periodic burning (e.g., Augusta Creek floodplain, Turkey Marsh, Brook Lodge fens).

The Conservation and Restoration Ecology focus would establish KBS as a place where landowners can observe research-validated demonstration projects and learn concepts and techniques for sustainable natural resource stewardship and habitat/species restoration. These new efforts would build on the rich history of the Kellogg Bird Sanctuary and Kellogg Experimental Forest, where natural resources conservation and species and habitat restoration research have benefited Michigan residents for decades.

8. Recommendations for evaluation of future land use requests

An improved system is needed to evaluate requests to use the KBS lands for research, education or outreach, and to keep records of previous and ongoing land uses so that conflicts can be avoided and the history of use at a particular site can be reconstructed. A Site Use Request Form (**Table 8**) should be required for all users engaged in field activities, be they from KBS or elsewhere. The Site Use Request should include specific locations of the proposed use, either as a sketch map on a copy of an aerial photo or as coordinates of points or polygons obtained using an inexpensive (<$200) Global Positioning System (GPS) unit that can transfer data directly into the KBS GIS. Once entered into the GIS, the proposed use can be compared with other activities in the vicinity.

A small committee (KBS Site Use Committee) would review the Site Use Request and map, consulting the pertinent land managers as well as researchers who might be affected by the proposed use. The committee would then make its recommendation to the KBS Director, who would make the final decision on approval, perhaps conditional on certain changes.

The Site Use Request could be incorporated into a GIS-based record of KBS land use. The locations of all such activities would be displayed as a GIS layer, and the corresponding Site Use Requests for each activity could be accessed via the GIS. Site Use Requests could be updated if needed, or carried over into subsequent years. Each calendar year would begin a new GIS layer of Site Use Requests, such that records of activity in previous years could be accessed by year.

The KBS Site Use Committee as well as a GIS specialist would need to be on call throughout the year to ensure the timely processing of requests. The GIS specialist might spend an average of 4-8 hours per month on this duty, with more time needed early in the summer and less during the fall and winter. Even if funding for the GIS work were not

available, the data on geographic coordinates of field site uses should be gathered to permit entry into a GIS at a later date.

Currently there is a general KBS Site Use and Research Space Request Form as well as a KBS LTER Site Use Request Form. Site use requests could be streamlined by separating requests for field site use from requests for use of labs and other infrastructure, and devising a single Site Use Request Form and GIS-based tracking system that serves both for LTER and other field sites across the KBS properties. The Kellogg Forest maintains its own system to evaluate site use since it is managed separately from the rest of the KBS lands discussed in this report.

If in the future the KBS GIS were to include not only physical characteristics and research and educational activities but also actual data collected at field sites (e.g., agronomic yields or soil variables), then the design of the system would require further consideration. The KBS LTER already has a robust data management system that possibly could be expanded to the overall KBS land base.

Table 8. Minimum information needed in a Field Site Use Request Form.

Start date of project:
End date of project:
Title of project:
Principal Investigators/Leaders:
Email addresses of contact person(s):
Proposed use(s) of field site:
General location(s) of field site:
Geographic coordinates of field site:
Will there be any lasting impacts of this use?
Funding sources
KBS support staff needs

Criteria need to be established to aid in decisions on land use requests, such as:

1) Is the proposed activity or use consistent with the KBS mission?

2) Will the proposed activity or use negatively affect other activities or uses? Will it produce any significant or lasting environmental impact?

3) Is there some way in which the impact could be reduced, or is there a better location?

4) Does the proposed activity require a permit from MSU, or local or state agencies? Examples include work involving animals (Animal Use and Care permit from MSU; vertebrate collecting permits from the Michigan DNR), land clearing of >1 acre (soil erosion permit from the county Drain Commissioner), addition of any quantity of chemical to surface waters (permit from Michigan DEQ), and most wetland dredging or filling (permit from the MDEQ).

5) Are there any safety issues affecting the participants or others within or outside MSU property? Does the area need to be demarcated to maintain its integrity or protect others?

In the case of outreach and educational activities involving students and the public, additional criteria apply:

1) Is access to the site by program participants easy and safe? Can arrangements be made for persons with disabilities? Is the parking adequate?

2) Is the location appropriate relative to classroom and restroom facilities?

9. Summary and conclusions

This report has inventoried the multifarious assets of the KBS land base and nearby MSU properties. The GIS layers and maps prepared for this report should make those assets more apparent to persons seeking sites for research, education or outreach. Several key opportunities for future directions were also discussed. Overall, the KBS land base and nearby MSU properties offer outstanding research, education, and outreach opportunities not available at other MSU field stations or perhaps any other field station in the Midwest U.S. The greatest assets and opportunities afforded by this land base can be summarized as follows:

1) The extensive and diverse land cover and use includes a complex mosaic of managed and unmanaged lands and is representative of the broader southwest Michigan landscape;

2) The close proximity of these diverse land covers and uses facilitates comparative study as well as research that explicitly addresses landscape heterogeneity;

3) The required infrastructure and expertise is in place to support research, education and outreach involving land use, management, and conservation, including agricultural activities;

4) The Long-Term Ecological Research site maintains sustained experimental treatments and data collection that provides a valuable baseline from which other research can be leveraged;

5) The large contiguous area of the properties enables studies that require large spatial scales (e.g., tracking wildlife movements or study of metapopulation dynamics across the landscape);

6) The lack of public access to some of the land base facilitates research activities such as wildlife observational studies, field experiments, and instrument deployment that might otherwise be subject to disturbance.

7) The public access to and visibility of other areas allows for structured and passive educational and outreach programs.

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Figure captions:

Fig. 1. Map showing the locations of the KBS Main Site, Lux Arbor Reserve, Kellogg Experimental Forest, and Brook Lodge.

Fig. 2. KBS Main Site property boundaries and major infrastructure identified on a satellite image (IKONOS).

Fig. 3. KBS Main Site managed lands, including land farmed for the Dairy or for research as well as managed forest plantations. Fields managed by the KBS Dairy are numbered in accordance with field numbering used in the 1984 Land-Use Plan. Agricultural research and demonstration plots maintained by the FSC are coded in a separate system used by Greg Parker.

Fig. 4. KBS Main Site natural vegetation, based on a 1992 map by Burbank et al. This map did not cover the entirety of the present KBS property.

Fig. 5. KBS Main Site lakes and wetlands, based on the National Wetlands Inventory interpretation of aerial photos taken in 1981.

Fig. 6. KBS Main Site major research sites. These are the most heavily utilized sites, based mainly on the information compiled from researchers for the period since 1990.

Fig. 7. KBS Main Site outreach and education sites where activities are conducted in the field.

Fig. 8. Lux Arbor Reserve aerial photo showing property boundaries.

Fig. 9. Lux Arbor Reserve managed lands, including land farmed for the Dairy as well as managed conifer forest plantations.

Fig. 10. Lux Arbor Reserve natural vegetation cover, based on a 1993 map by Bryan Foster. This map is a generalized version of a more detailed vegetation map.

Fig. 11. Lux Arbor Reserve lakes and wetlands, based on National Wetlands Inventory interpretation of aerial photos taken in 1981.

Fig. 12. Lux Arbor Reserve major research sites. These are the most heavily utilized sites, based mainly on the information compiled from researchers for the period since 1990.

Fig. 13. Kellogg Forest and Brook Lodge aerial photo, showing property boundaries and locations of the Kellogg Forest office and public entrance and the Brook Lodge Conference Center.

Fig. 14. Kellogg Forest and Brook Lodge managed forest stands.

Fig. 15. Kellogg Forest and Brook Lodge lakes and wetlands, based on National Wetlands Inventory interpretation of aerial photos taken in 1981.

Fig. 16. Brook Lodge land cover, based on a 1996 map of Ross Township prepared by Western Michigan University. This is a generalized land cover map and should be interpreted with caution.

Fig. 17. Pie charts summarizing the distribution of land use and cover on the KBS Main Site and Lux Arbor Reserve.