RECOMMENDATIONS

The following steps, based on the approach outlined in Figure 3, are recommended for the development of useful soil/land indicators in Alberta:

1) **Identify and involve end users.** "Indicators cannot be developed without a clear context and purpose, in terms of the information to be transferred and the types of target users" (Crabtree and Brouwer 1999). End users must be involved to ensure that selected indicators are effective at communicating the relevant messages. In particular, involvement is necessary to ensure that the goals for outcomes of soil functions are real, clear and practical. Early involvement is necessary for the design of useful indicators. Type, scale and level of aggregation are all functions of end user needs and wants. Feedback should be obtained on existing and prototype indicators before considerable efforts are expended in the development of new indicators.

2) **Formulate appropriate goals for outcomes of soil functions**. Goals will have to be formulated at several spatial and temporal scales, e.g., province-wide vs. field-scale goals, short-term vs. long-term goals.

3) **Understand which variables and relationships are most important in controlling outcomes.** This understanding should be expressed in mathematical models. Many different models are available for most goals related to soil functions, and the inclusion of different models is recommended to ensure that an optimum solution is obtained and to provide additional validation.

4) **Assemble relevant databases.** Databases consisting of observed outcomes and the variables controlling outcomes should be assembled from studies relevant to Alberta conditions. Possible sources of data include benchmark studies, long-term crop rotation studies, research trials, and outputs from reliable models. Substitution of missing data using validated models or proxy variables may be necessary in some cases.

5) **Test candidate indicators.** Candidate indicators for outcomes of each soil function can be obtained from previous studies or derived from appropriate models. Three basic questions must be addressed when testing candidate indicators (Bockstaller and Girardin 2003):

   a. Is it scientifically founded?
      Addressed through peer review and comparison of approaches (design validation).

   b. Does it inform about the reality? Is it realistic?
      Addressed through comparison with actual observations or output from reliable models (output validation).

    c. Is it useful? Does it improve decisions cost-effectively?
       Addressed through tests with end users and estimation of costs (end-use
       validation).

6) **Aggregate indicators.** Indicators for different goals should only be aggregated after they have been validated for individual goals. Aggregation first requires an assessment of the relations among goals. Indicators of outcomes that are negatively correlated need to be aggregated in a different way than indicators of outcomes that are positively correlated. Aggregation also requires an assessment of the relative value of the different goals. Failure to achieve goals might be of minor importance for some goals, but of great importance for other goals. Different end users may have highly divergent viewpoints on the importance of different goals. The aggregation of divergent goals is inherently difficult and may not be valid or necessary.

These recommendations for the development of useful indicators for soil quality may appear formidable. However, considerable information is available from previous efforts in this area, and further improvement based on a sound approach is likely to progress quite rapidly.