CHAPTER 5 – MONITORING TECHNIQUES, DATA INTERPRETATION, AND EVALUATIONS

CONSERVATION VALUE OF WILDLIFE CROSSINGS

Some basic rules about monitoring the function of wildlife crossings and assessing their conservation value were provided in Forman et al. (2003). The criteria used to measure their function or conservation value, however, will depend on the intended purpose of the wildlife crossings, the taxa of interest and the biological level of organization most relevant to monitoring and research goals.

Monitoring needs to be an integral part of a highway mitigation project, even long after the measures have been in place. Mitigation is costly, generally requiring a large investment of public funds. Post-construction evaluations are not only necessary but also a judicious use of public infrastructure funds and can help agencies save money in future projects (see Adaptive Management below).

Monitoring and research can range from a simple, single-species population within the highway corridor to more complex ecological processes and functions within regional landscapes of conservation importance.

Wildlife crossing structures are, in essence, site-specific movement corridors strategically placed over highways that bisect important wildlife habitat as Figure 28 shows. Like wildlife corridors, crossing structures should allow for the following five biological functions:

1. Reduced mortality and increased movement (genetic interchange) within populations;

2. Meeting biological requirements such as finding food, cover and mates;

3. Dispersal from maternal or natal ranges and recolonization after long absences;

4. Redistribution of populations in response to environmental changes and natural disturbances (e.g., fire, drought); movement or migration during stressful years of low reproduction or survival; and

5. Long term maintenance of metapopulations, community stability, and ecosystem processes.

These functions encompass three levels of biological organization—genes, species/population, community/ecosystem—which form the basis for developing natural resource management and conservation plans.

From these five functions it is possible to set performance objectives, determine best methods to monitor, develop study designs, and resolve the management questions associated with the project objectives.

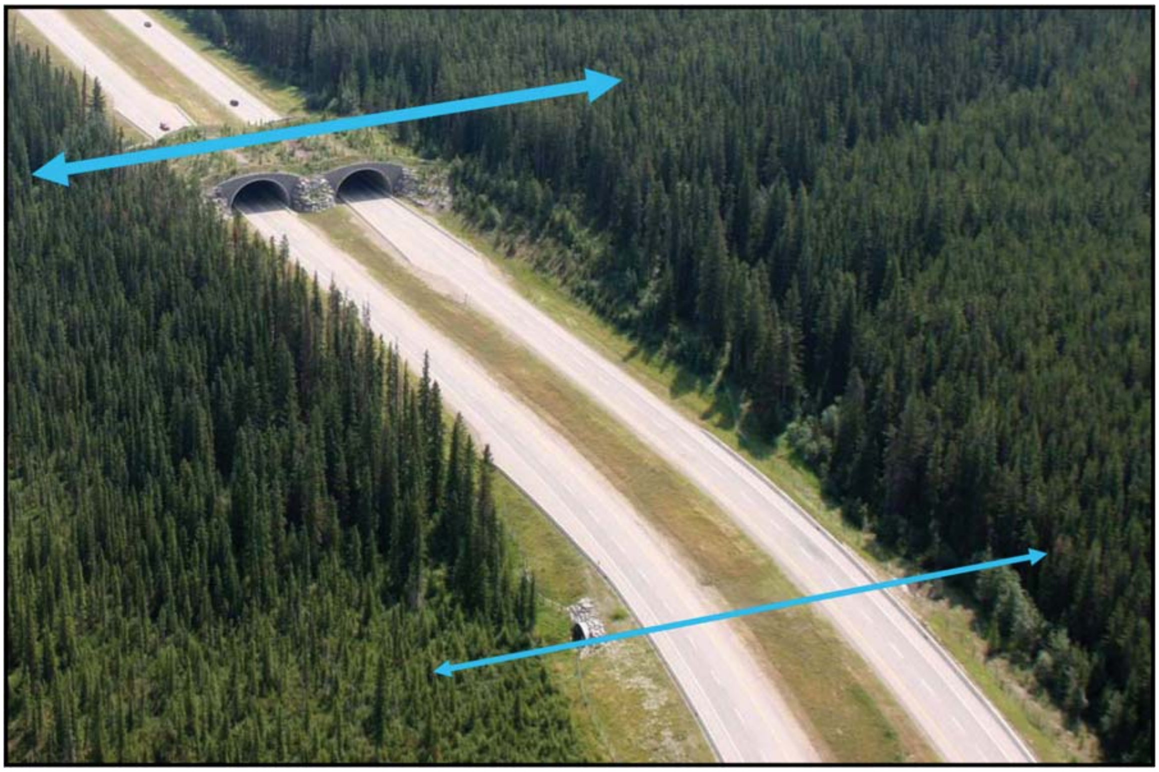

Figure 28. Photo. Crossing structures are site-specific movement corridors that link wildlife habitat separated by pavement and high-speed vehicles (Credit: Jeff Stetz).

Note that these functions increase both in complexity and in the cost and time required to properly monitor whether they are being facilitated as shown in Table 6. Not all ecological functions may be of management concern for transportation agencies, particularly those at the more complex end of the scale; however, they will be of concern for land and natural resource management agencies.

Simple and low-cost techniques using remote cameras can be used to detect animals using wildlife crossing structures, i.e., level 1 - *genes*. However, information about numbers of distinct individuals, their gender and genetic relationships cannot be reliably obtained using remote cameras.

A non-invasive genetic sampling method was used to assess population-level benefits (level 2 – *species/populations*, Table 6) of 20 wildlife crossings on the Trans-Canada Highway in Banff National Park, Alberta (see Appendix E, Figures 78 and 79; Clevenger and Sawaya 2009).

LEVELS OF BIOLOGICAL ORGANIZATION AND ROAD IMPACTS

A recent U.S. National Academies report on assessing and managing the impacts of roads recommended using the three levels of biological organization as a framework to design future research to assess the ecological effects of paved roads (NRC 2005).

Table 6. Levels of conservation value for wildlife crossing systems as measured by ecosystem function achieved, level of biological organization targeted, type of connectivity potential, and cost and duration of research required to evaluate status.

Level	Ecosystem Function (simple to complex)	Level of Biological Organization[a]	Level of Connectivity[b]	Cost and Duration of Research[c]
1a	Movement within populations and genetic interchange	Genetic	Genetic	Low cost – Short term
1b	Reduced mortality due to roads	Genetic & Species/population	Genetic & Species/population	Low cost – Short term
2	Ensure that the biological requirements of finding food, cover and mates	Species/population	Demographic	Moderate-to-High cost – Long term
3	Dispersal from maternal ranges and recolonization after long absences	Species/population	Functional	Moderate-to-High cost – Long term
4	Populations to move in response to environmental changes and natural disasters;	Ecosystem/community	Functional	High cost – Long term
5	Long term maintenance of metapopulations, community stability, and ecosystem processes	Ecosystem/community	Functional	High cost – Long term

[a] See Noss 1990, Redford and Richter 1999.
[b] Genetic: Predominantly adult male movement across road barriers; Demographic: Genetic connectivity with confirmed adult female movement across road barriers; Functional: Genetic and demographic connectivity with confirmed dispersal of young females that survive and reproduce.
[c] Based on studies of large mammals. Cost and duration will largely be dependent upon area requirements, population densities, and demographics.

AN APPROACH FOR MONITORING IMPACTS

Roads and traffic affect wildlife at multiple levels of biological organization: therefore different management questions require different types of research and mitigation measures. Certain questions can be "big" or general and may require answers from multiple scales and perspectives. However, big picture research is not necessarily general in nature. General principles have to be well founded, and they are often based on thorough studies of the life histories of wildlife species.

This hierarchical approach covers the entire biological spectrum from genes on up to higher levels of communities and ecosystems. It is well suited to answering most transportation and natural resource agency management needs of reducing road impacts on wildlife populations. It can provide guidelines and decision support regarding the monitoring and evaluation of wildlife crossings.

Another value of the hierarchy approach is the recognition that effects of roads and traffic can reverberate through other levels, often in unpredictable ways, as secondary and cumulative effects. Specific indicators can be identified at multiple levels of organization to monitor and assess the performance of mitigation designed to reduce road-related mortality, and restore movements and interchange within populations.

MONITORING AND ASSESSMENT GUIDELINES

The guidelines below are designed for monitoring plans evaluating the conservation value and efficacy of wildlife crossings. This framework can be used to formulate management questions, select methodologies, and design studies to measure performance of wildlife crossings in mitigating road impacts.

1. *Establish goals and objectives.* What are the mitigation goals? Generally the goals are to reduce wildlife–vehicle collisions and/or reduce barrier effects to movement and maintain genetic interchange.
2. *Establish baseline conditions.* Determine the extent, distribution and intensity of road and traffic impacts to wildlife in the area of concern. The impacts may consist of mortality, habitat fragmentation (reduced movements) or some combination thereof. In most cases, the conditions occurring pre-mitigation will comprise the baseline or control.
3. *Identify specific management questions to be answered by monitoring.* These questions will be formulated from the goals and objectives identified in Step 1 and conditions identified in Step 2. Some questions might include:
    - Is road-related mortality increasing or decreasing as a result of the mitigation measures?
    - Is animal movement across the road increasing or decreasing?
    - Are animals able to disperse and are populations able to carry out migratory movements?

Before starting a monitoring program, specific benchmarks and thresholds should be agreed upon that trigger management actions. For example, >50% reduction in road-kill would be acceptable, but <50% reduction would trigger additional management actions to improve mitigation performance. Normally a power analysis is also performed to determine if these reductions can actually be detected (see below).

4. *Select indicators.* Identify indicators at the appropriate level(s) of biological organization (i.e., genes, species/population, and community/ecosystem) that correspond to the specific goals and objectives identified in Step 1 and the questions developed in Step 3. For example:
   - Gene flow and genetic structure may indicate whether exchange of genes (i.e., breeding or movement of individuals) occurs across the highway;
   - Population distribution, abundance and within-population movement data, as well as demographic processes such as dispersal, fecundity, survivorship, and mortality rates, may permit the assessment of species or population-level connectivity; and
   - Herbivory and predation rates may indicate whether exchange across highways contributes to more stable ecosystem processes and community dynamics.
5. *Identify control and treatment areas.* If pre-mitigation data are available, then indicator response in adjacent "control" areas may be compared with treatment areas—i.e., road sections with wildlife crossings. It will be important to control for differences in habitat type and population abundance between treatment and control areas. Therefore controls and treatments should comprise similar habitats, and some means of obtaining population abundance indices to control for confounding effects should be used.
6. *Design and implement a monitoring plan.* Apply principles of experimental design to select sites for monitoring the identified goals and objectives from Step 1 and questions in Step 3. Although treatments and controls should ideally be replicated, this may not always be possible.
7. *Validate relationships between indicators and benchmarks.* Research carried out over the short and long term will be needed to determine whether the selected indicators are meeting the management goals and objectives.

SETTING MONITORING AND PERFORMANCE TARGETS

Developing Performance Targets – Who Defines Them?

Few studies have rigorously monitored and researched the performance of highway mitigation measures using study designs with high inferential strength. For some agencies, monitoring has not been a priority, much less research—if circumstantial evidence suggested that animals appeared to use wildlife crossings, then they were deemed effective.

One of the difficulties in developing performance targets is agreeing on what defines a "reduction" in wildlife–vehicle collisions and an "increase" in landscape connectivity or animal movements across a highway. Transportation agencies tend to have relatively relaxed targets or expectations for how well crossing structures perform. In contrast, resource and land management agencies generally require more science-based evidence that wildlife crossings or other measures result in positive changes to wildlife movements and regional population connectivity.

Reliably Detecting Change in Target Parameters

A decrease in road-related mortality and an increase in the frequency of highway crossings by focal species may generally be considered performance targets for mitigation efforts. Broad definitions such as these can be used to measure the effectiveness of mitigation measures and whether targets are being met.

However, properly designed monitoring programs with research-specific study designs and predefined performance targets will have the greatest ability to evaluate whether mitigation efforts are meeting their targets (Appendix D).

Developing Consensus-Based Performance Targets

The lead agency and other stakeholders need to know how their mitigation investment dollars are being spent and how the technology can be transferred to future projects. Taxpayers will also want to know whether the measures are effective.

Targets designed to evaluate whether the amount of observed change is acceptable should be determined *a priori* by the transportation agency responsible for the project with the concerns of the natural resource management agency and other project stakeholders in mind.
The agreed-upon targets need to be scientifically defensible. Without specific targets and a means to track performance, transportation and resource management agencies can come under scrutiny for not having objectively defined targets or performance standards.

Because landscape conditions and population dynamics vary over time, short- and long-term monitoring and performance targets should be assessed periodically and readjusted accordingly.

FOCAL SPECIES

All species from a project area cannot be monitored. The selection of focal species should result in monitoring data that will be most relevant to either the greatest number of species in the area, or to those species that are the most sensitive to the process being monitored, e.g., ability to cross highways. Table 7 provides some criteria to help guide the selection of focal species.

Selected focal species are indicators of changes—positive or negative—that result from efforts to mitigate road impacts in the project corridor.

The selected survey methods should permit the collection of data from a large number of species—e.g., most medium and large mammals. Rigorous evaluation of these data will, however, be limited to those species that generate sufficient amounts of data for statistical analyses and inference. In these cases, focal species will not be identified until pre-mitigation population surveys have begun or pilot data is collected in the project area.

Another consideration is how monitoring focal species can translate into direct management benefits and support from outside the project as shown in Table 7. Some wildlife species may resonate with the public and information about them may help generate support for the project. While this is a secondary criterion, it is important to consider in the selection process.

Table 7. Guide to selecting focal species based on monitoring criteria and ecosystem context.

1. Monitoring	
Primary Criteria	
Ecological Attributes	Which focal species will serve as the best indicators of change and maintenance of ecological processes?
Sample Size Requirements	Which focal species will provide large enough datasets to permit sufficiently accurate and precise analyses for the monitoring needs?
Secondary Criteria	
Benefits to Management	Will the information acquired from monitoring the selected focal species provide benefits to (a) local management (e.g., DOT, land management agency) and/or (b) management elsewhere, such that it will have broader research application (e.g., significant contribution to knowledge base and science of road ecology)?
Public Profile and Support	Is at least a subset of the selected focal species high-profile and charismatic such that they resonate with the general public and help to gain public and private support for the project (e.g., cougar, wolverine)?
2. Ecosystem Context	
Taxonomic Diversity	Do the selected focal species represent a diversity of taxonomic groups?
Levels of Biological Organization (see Noss 1990)	Do the selected focal species provide information suitable for addressing questions aimed at the first two levels of biological organization (genes/individuals, species/populations)?

Monitoring information must be of value at the project level, as managers are interested in project-specific applications. However, some results will have management benefits beyond the project area boundaries and have national or international significance in advancing knowledge of wildlife crossing mitigation. Attempts should be made to choose focal species and management questions that have impacts at the project and national or international scale.

After identifying suitable focal species, a second consideration relates to how well the focal species fit within an ecosystem context. For each of the management questions it will be important to maximize the taxonomic diversity represented in the suite of focal species, e.g., amphibians, reptiles, small to large mammals. Road effects on wildlife populations are scale-specific, and such an approach will, therefore, help to ensure that some of the more important scale-related issues (spatial and temporal) of the investigation are adequately addressed.

MONITORING TECHNIQUES

There are a variety of wildlife survey methods available today. These methods range from the relatively simple (reporting of wildlife–vehicle collisions by transportation agency personnel) to the complex (capture and global positioning system [GPS] collaring of individual animals). Whatever the monitoring objective and focal species, the selection of appropriate survey methods is critically important as Table 8 shows.

In some cases multiple methods exist for a given objective–species combination and researchers will have the luxury of balancing cost with specific data requirements and available funding or personnel.

For some methods, most costs occur at the onset of monitoring efforts (e.g., purchase of remote cameras), whereas for others the costs are largely distributed throughout the monitoring period (e.g., snow tracking).

Appendix E describes many methods that can be used to meet a number of basic monitoring objectives. Decisions as to the best methods must be made based on the particular objective, focal species, season, cost, and location.

Table 8. Summary of available monitoring methods, the appropriate time to employ them (pre- or post-construction), potential target species, and cost estimates for conducting wildlife monitoring. See Appendix E for detailed description of each monitoring method (From Clevenger et al. 2008).

Monitoring purpose	Available monitoring methods	Timing	Target species	Check frequency	Area of use	Estimated cost	Cost loading
Assess wildlife–vehicle collision rate							
	Carcass removal by maintenance crews and natural resource agency staff	Pre; post	Elk, deer, black bear and other large species when possible	As occurs	Median/right-of-way	Low	Continuous
	Wildlife–vehicle collision reports by highway patrol	Pre; post	Elk, deer, black bear and other large species when possible	As occurs	Median/right-of-way	Low	Continuous
	Systematic driving surveys	Pre; post	Medium to large mammals	1–7 days	Median/right-of-way	High	Continuous

Assess use/effectiveness of wildlife crossing structures (existing and proposed)							
	Remote still cameras or video	Pre; post	Medium to large mammals	Weekly	Wildlife crossings/Culverts	Medium	Front-loaded
	Track beds	Pre; post	Medium to large mammals	1–3 days	Wildlife crossings/Dry culverts	Medium	Continuous
	Unenclosed track plates	Pre; post	Medium to large mammals	1–3 days	Wildlife crossings/Dry culverts	Medium	Continuous
	Enclosed track plates	Pre; post	Smaller mammals	1–3 days	Small dry culverts	Medium	Continuous
	Hair collection devices with DNA methods	Pre; post	Select medium to large mammals	3–5 days	Wildlife crossings/Culverts	Medium to high*	Continuous and end-loaded
	Trap, tag, and recapture/resight	Pre; post	Amphibians, reptiles, small mammals	Select times	Ponds and water bodies within or adjacent to highway	Low	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded

Assess rate of at-grade highway crossings by wildlife							
	Remote still cameras or video (deployed randomly)	Pre**	Medium to large mammals	Weekly	Right-of-way	Medium to high	Front-loaded
	Remote still cameras or video (deployed at targeted locations)	Pre**	Medium to large mammals	Weekly	Right-of-way	Medium to high	Front-loaded
	Track beds (deployed randomly)	Pre**	Medium to large mammals	1–3 days	Right-of-way	Medium to high	Continous
	Track beds (deployed at targeted locations)	Pre**	Medium to large mammals	1–3 days	Right-of-way	Medium to high	Continous
	Snow track transects	Pre**	Medium to large mammals active in winter	3–5 times per winter***	Right-of-way	Medium	Continous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded

Monitor wildlife use of locations throughout and adjacent to the project area							
	Remote still cameras or video at scent stations	Pre; post	Medium to large mammals	Weekly	Within 1 mile of highway	Medium	Front-loaded
	Track plots or track plates at scent stations	Pre; post	Small to large mammals	1–3 days	Within 1 mile of highway	Medium	Continous
	Hair collection devices with DNA methods	Pre; post	Small group of targeted species	3 days	Within 1 mile of highway	Low to high*	Continuous and end-loaded
	Snow tracking	Pre; post	Medium and large mammals active in winter	3–5 times/winter	Within 1 mile of highway	Medium	Continous
	Scat detection dogs with DNA methods	Pre; post	3-4 targeted mammals	1 full season	Within 1 mile of highway	Medium to high*	Front-loaded
	Trap, tag, and recapture/ resight	Pre; post	Amphibians, reptiles, small mammals	Select times	Ponds and water bodies within or adjacent to highway	Low	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded

Evaluate effectiveness of wildlife fencing							
	Highway maintenance crews report animals inside fencing	Post	Medium to large mammals	As occurs	Median/right-of-way	Medium	Continuous
	Highway patrol report animals inside fencing	Post	Medium to large mammals	As occurs	Median/right-of-way	Medium	Continuous
	Systematic checks of fence integrity	Post	Medium to large mammals	Monthly	Fenceline	Medium	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded
Evaluate effectiveness of jump-outs							
	Remote still cameras or video	Post	Medium to large mammals	Weekly	Jump-outs	Medium	Front-loaded
	Track beds on top of jump-outs	Post	Medium to large mammals	1–3 days	Jump-outs	Medium	Continuous

* Cost depends largely on objectives—species-specific identification via DNA methods costs less than individual identification. Both can be cost effective when compared with more labor-intensive methods.
** Although these methods can be used to monitor post-construction, it is assumed that wildlife fencing will so dramatically reduce at-grade highway crossing attempts as to make monitoring unnecessary and extremely cost-ineffective.
*** Will depend on statistical power considerations, number and timing of snow events, and time constraints.

CAMERA VS. TRACK-PAD MONITORING

A recent paper compared the overall efficiency of wildlife monitoring activity using track pads and motion-sensitive cameras, based on the estimated number of detections by each method (Ford et al. 2009). Mammals coyote-sized and larger were used in the analysis. Cameras outperformed track pads by most performance metrics. The only instances where track pads were preferred were at sites where security (e.g., high risk of theft or vandalism) was a concern. One of the most important factors limiting the use of track pads is the frequency of field visits required. Monitoring based on track pads needs to keep the checking intervals short enough to minimize trampling of tracks and loss of data. Increasing the frequency of visits to each site becomes more costly for the project.

ADAPTATION PERIODS

Monitoring of wildlife crossing structures has shown that an adaptation period and learning curve does exist. The few studies that have obtained more than two years of monitoring data showed that animals require an adaptation period that varies in length between ungulates and carnivores. Most monitoring efforts do not sample for sufficient duration to adequately assess how wildlife utilize crossing structures because they don't give them enough time to adapt to the structures and the changes made to the surrounding habitat where they reside. Small sampling windows, typical of one- or two-year monitoring programs, are too brief, can provide spurious results and do not adequately sample the range of variability in a species' wildlife crossing structure use patterns in landscapes with complex wildlife–human interactions.

STUDY DESIGNS TO MEASURE PERFORMANCE

Inferential Strength

Inferential strength in the context of mitigation monitoring is the ability to accurately evaluate whether mitigation efforts have achieved their desired effect. Maximizing inferential strength depends both on the ability to minimize confounding effects and to maximize statistical power.

Monitoring designs with low inferential strength lead to situations where researchers either detect an effect that is not actually there (a Type I error) or fail to detect an effect that is actually present (a Type II error). Minimizing the likelihood of making either type of error is of critical importance to transportation managers and researchers if they are to reliably demonstrate that mitigation measures are effective.

Roedenbeck et al. (2007) addressed this subject by identifying relevant research questions in road ecology today, recommending experimental designs that maximize inferential strength, and giving examples of such experiments for each of five research questions.

Types of Study Design and Resulting Inferential Strength

There are several types of study designs for evaluating how well mitigation measures perform.

BACI Design

One design consists of measuring and comparing impacted areas (I) with non-impacted areas or control sites (C) and assessing how some variable of interest behaves before (B) and after (A) a management intervention such as highway construction or mitigation. In this "BACI" design, if the difference between the control and impact (often referred to as "treatment") site is greater after intervention than before, then there is strong evidence that intervention has had a causal effect.

To increase inferential strength BACI designs should sample at more than one paired treatment + control site. Locating suitable control sites unaffected by roads can be a challenge, particularly when studying impacts on wide-ranging large mammals.

BA Design

Of lower inferential strength than BACI is the before and after impact (BA) design. This requires sampling one site and evaluating how some environmental variable behaves before and after the impact. The impact could also be some form of management intervention, such as the implementation of mitigation measures. The BA design at one site can demonstrate that the environmental variable changed over time, but it cannot exclude the possibility that change was caused by some reason other than the observed impact.

CI Design

A third approach compares impacted (I) sites with control (C) sites (those that are non-impacted) using a CI design. Data are only collected or made available for the period after intervention or mitigation. The inference is that if the control and impact sites differ in some environmental variable of concern, this difference is, at least in part, due to the intervention. This inference is valid only if control and impact sites would be identical in the absence of intervention.

The study design options described run from high to low inferential strength: BACI, BA, and CI. The key monitoring and research questions identified earlier are found in Appendix D. The table provides a suggested framework for designing studies to evaluate whether the general objectives of highway mitigation are being met.

ADAPTIVE MANAGEMENT

Adaptive management consists of deriving benefits from measured observations from monitoring to inform decision-making with regard to planning and design of subsequent phases of a project. An example of adaptive management would be changing the design of wildlife crossing structures on subsequent phases of highway reconstruction after obtaining empirical data from the use of structures from earlier phases.

- Microhabitat elements within wildlife crossings may require changes if monitoring shows they do not facilitate movement of smaller wildlife.

- Monitoring of fencing may identify deficiencies that lead to revised design or materials used for construction in future phases.

- Pre-construction data on local species occurrence and wildlife movements may lead to changes in the locations and types of wildlife crossing structures (e.g., from small-sized to medium-sized culverts) should monitoring reveal previously undocumented unique populations or important habitat linkages.

Whatever the case may be, monitoring ultimately provides management with sound data for mitigation planning, helps to streamline project planning and saves on project costs.

Regular communication and close coordination between research and management is necessary for adaptive management to be effective. This will allow for timely changes to project design plans that reflect the most current results from monitoring activities.

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