

A Society for Ecological Restoration Publication: Guidelines for Developing and Managing Ecological Restoration Projects

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The following guidelines are suggested for conceiving, organizing, conducting, and assessing ecological restoration projects. Adherence to these guidelines will reduce errors of omission and commission that compromise project quality. The guidelines are applicable to any ecosystem, terrestrial or aquatic. They are useful in any context - public works projects, stewardship programs, mitigation projects, private land initiatives, etc. The guidelines are generic and were developed as essential background for managers, policy makers, and the interested public as well as for professional and volunteer restoration practitioners. Design issues and the details for planning and implementing restoration projects lie beyond the scope of these guidelines. We leave such complexities to the authors of manuals and the presenters of workshops who address these topics.

The mission of every ecological restoration project is to reestablish a functional ecosystem of a designated type that contains sufficient biodiversity to continue its maturation by natural processes and to evolve over longer time spans in response to changing environmental conditions. The two attributes of biodiversity that are most readily attained by restoration are species richness and community structure. The restoration ecologist must assure adequate species composition and species abundance to allow the development of suitable community structure and to initiate characteristic ecosystem processes. Concomitantly, the restorationist must provide appropriate physical conditions to sustain these species.

If restoration cannot be fully achieved, then the project should be re-designed as rehabilitation, which we define as any ecologically beneficial treatment short of full restoration. Management actions that cause ecological damage do not qualify as restoration. Unfortunately, restoration is applied inappropriately to projects that sacrifice biodiversity and impair ecological functions to accomplish single-species management or to attain economic objectives. Continued indiscriminate use will cause ecological restoration to lose its meaning as a creditable conservation

strategy. Restoration projects can accommodate particular species and can satisfy economic objectives as long as ecosystem integrity is not compromised. Once a project site is restored, it may require periodic management, as do many other natural areas, to maintain ecosystem health in response to continuing human-mediated impacts. These guidelines do not address post-project management specifically, although some of the guidelines are readily adaptable for that purpose. The project guidelines are numbered for convenience; they do not necessarily have to be initiated in numerical order. We recommend that a narrative be written in response to the issues raised in each guideline. Collectively, these narratives will comprise a comprehensive guidance document for planning and executing the project.

CONCEPTUAL PLANNING

Conceptual planning identifies the reasons why restoration is needed and the general strategy for conducting it. Conceptual planning is conducted when restoration appears to be a feasible option but before a decision has been made to exercise that option. The written conceptual plan captures the essence and character of the potential restoration.

1. Identify the project site location and its boundaries. Project boundaries are delineated, preferably on a large-scale aerial photograph and also on soil and topographic maps that show the watershed and other aspects of the surrounding landscape.

2. Identify ownership. The name and address of the landowner is given. If an organization or institution owns or manages the land, the names and titles of key personnel are listed. The auspices under which the project will be conducted are noted - public works, mitigation, etc.

3. Identify the need for restoration. Tell what happened at the site that warrants restoration. State the intended benefits of restoration.

4. Identify the kind of ecosystem to be restored and the type of restoration project. The ecosystem to be restored is designated along with any particular habitats and plant or animal communities of that ecosystem that are targeted for restoration. The type of restoration is selected from the following list of five options. It is important to make this initial distinction to avoid misunderstandings later. Restoration projects at diverse project sites may include more than one of these options:

- **Repair of a damaged ecosystem.** This option attempts to return a site to its historic or preexisting condition. Commonly a few minor aspects of the preexisting ecosystem cannot be fully restored. These should be identified and accepted as exceptions. Restoration work takes place at the same site where damage occurred. Such restoration has been termed in-kind (the historic type of ecosystem is restored) and onsite (restoration occurs at the same location where the historic ecosystem was damaged). Restoration with respect to the following four options is not necessarily on-site, and some are not in-kind.

- **Creation of a new ecosystem of the same kind to replace one that was entirely removed.** The term creation signifies that the restored ecosystem must be entirely reconstructed on a site denuded of its vegetation (terrestrial systems) or its benthos (aquatic systems). Creations are commonly conducted on surface mined lands and in brownfields (severely damaged urban and industrial lands).
- **Creation of another kind of regional ecosystem to replace one which was removed from a landscape that became irreversibly altered.** This option is important for restoring natural areas in an urban context where, for example, original hydrologic conditions cannot be restored.
- **Creation of a replacement ecosystem where an altered environment can no longer support any previously occurring type of regional ecosystem.** The replacement ecosystem may consist of novel combinations of indigenous species that are assembled to suit novel site conditions as, for example, at a retired solid waste disposal site.
- **Creation of a replacement ecosystem, because no reference system exists to serve as a model for restoration.** This option is relevant in densely populated regions of Eurasia, where many centuries of land use have obliterated all remnants of original ecosystems.

5. Identify restoration goals, if any, that pertain to social and cultural values. Goals are the ideals that a restoration project attempts to achieve. Goals relating to social and cultural values may be prescribed as long as they are congruent with the primary goal of reestablishing a functional ecosystem that contains sufficient biodiversity to continue its maturation by natural processes and to evolve over longer time spans in response to changing environmental conditions. Social values are largely economic. They may consist of the production of goods such as timber, forage, and fisheries at restored sites. Or they may comprise natural services including the protection of recharge areas and potable water supplies, detention of floodwaters, attenuation of erosion and sedimentation, noise reduction, immobilization of contaminants, transformation of excess nutrients, generation of pollinators for crops, generation of predators of crop pests, and provision of recreational opportunities and consequent tourism. They can also conserve germ plasm of economic species and serve as refugia for wildlife and for rare species. Cultural values include aesthetic amenities and the revival of historical environments as aspects of preserving cultural heritage. If the goal is to restore a fixed cultural landscape, then the project may have to be re-designated as rehabilitation.

6. Identify physical site conditions in need of repair. Some examples of conditions that are amenable to restoration are improvements in water quality, removal of structures to reestablish a more natural hydrologic regime, and improvements to the soil in terms of compaction, organic matter content, and nutrient content.

7. Identify stressors in need of regulation or re-initiation. Stressors are re-occurring external conditions that maintain the integrity of an ecosystem by discouraging the establishment of competitive species that cannot tolerate particular stress events. Examples are fires, anoxia caused by flooding or prolonged hydroperiods, periodic drought, salinity shocks associated with tides and coastal aerosols, freezing temperatures, and unstable substrates caused by water, wind or gravity as on beaches, dunes, and flood plains.

8. Identify biotic interventions that are needed. Some characteristic species of plants and animals may require reintroduction or their existing populations need to be augmented. Nuisance species and exotic species may require removal or control. Mycorrhizal fungi, N-fixing bacteria, and other microbial species may need to be introduced.

9. Identify landscape restrictions, present and future. The biota at a project site is affected by off-site conditions, particularly land usage. Restoration should not be attempted in landscapes that can no longer support the kind of ecosystem designated for restoration or which will likely be compromised later by the effects of land usage offsite. To the extent possible, future threats to the integrity of the restored ecosystem should be minimized by mechanisms such as zoning or binding commitments from neighboring landowners.

Some aquatic ecosystem restoration depends entirely on improving the watershed, and all restoration work is accomplished offsite. Examples of impacts from offsite include water pollution, turbidity, and agricultural runoff. The hydrologic regime in any project site can be altered offsite by dams, drainage projects, diversions of runoff caused by highways and other public works, and by the impervious surfaces characteristic of developed land. Water tables are lowered by transpiration from trees and are raised, sometimes dramatically, by timber harvest. Fire frequency is reduced by intentional suppression and by landscape fragmentation that interrupts the cover of flammable vegetation. Exotic species colonization onsite is commonly traced to infestations offsite. The presence or abundance of birds and other mobile animals depends on the health of other ecosystems in the landscape upon which they partially depend.

10. Identify project-funding sources. Potential external funding sources should be listed if internal funding is inadequate.

11. Identify labor sources and equipment needs. New personnel may have to be hired, volunteers invited, and other labor contracted. The availability of special equipment must be determined.

12. Identify biotic resource needs. Biotic resources include seeds, other plant propagules, nursery-grown planting stocks, and animals for establishment at the project site.

13. Identify the need for securing permits required by government agencies. Dredge and fill permits may be required for tasks involving rivers and wetlands. Other permits may be applicable for the protection of endangered species, historic sites, etc.

14. Identify permit specifications, deed restrictions, and other legal constraints. If restoration is being conducted as mitigation, compliance with permit

specifications must be incorporated into the restoration plan or re-negotiated. Restrictive covenants and zoning regulations may preclude certain restoration activities. Legal restrictions on ingress and egress could prevent some restoration tasks from being accomplished. If the restoration is being placed under conservation easement, the timing of the easement must be satisfied.

15. Identify project duration. Short-term restoration projects are generally more costly than longer-term projects. The longer the project, the more the practitioner can rely on natural processes and volunteer labor to accomplish specific restoration objectives that are identified below in Guideline #27. In accelerated restoration programs such as mitigation projects, costly interventions must substitute for these natural processes.

16. Identify strategies for long-term protection and management. Restoration is futile without reasonable assurance that the project site will be protected and properly managed into the indefinite future. Protection could be secured with conservation easements or the legal transfer of the property to a public resource agency or non-governmental organization.

PRELIMINARY TASKS

Preliminary tasks are those upon which project planning depends. These tasks form the foundation for well-conceived restoration designs and programs. Preliminary tasks are fulfilled after conceptual planning results in the decision to proceed with the restoration project.

17. Appoint a restoration ecologist who is responsible for technical aspects of restoration. Restoration projects are complex, require the coordination of diverse activities, and demand numerous decisions owing in part to the stochastic nature of ecological processes. For these reasons, leadership should be vested in an individual who maintains overview of the entire project and who has the authority to act quickly and decisively. The restoration ecologist may delegate specific tasks but retains the ultimate responsibility for the attainment of objectives. Nonetheless, restoration responsibilities are sometimes divided according to the organizational charts of larger corporations and government bureaus. Pluralistic leadership augments the potential for errors in project design and implementation. In mitigation projects, agency personnel become silent co-partners with the restoration ecologist when they mandate particular restoration activities as permit specifications. This practice reduces the restoration ecologist's capacity for flexibility and innovation, including the prompt implementation of adaptive management actions. The preparation of a written guidance document, based upon responses to these guidelines, will help promote the judicious execution of the restoration project in cases of pluralistic leadership and in negotiating permit specifications with government agencies.

18. Appoint the restoration team. The team includes the restoration ecologist, the project manager, other technical personnel who may contribute to the project, and anyone else whose input will critically affect the project. It is essential that the responsibilities of each individual are clearly assigned and that each person be given concomitant authority. The restoration ecologist and the project manager should maintain open lines of communication. If restoration is one component of a larger project, the restoration ecologist should enjoy equal status with other project planners to prevent actions that could compromise restoration quality or inflate costs.

19. Prepare a budget to accommodate the completion of preliminary tasks.

Time and resources as well as funding need to be allocated for these tasks.

20. Document existing project site conditions and describe the biota.

Project evaluation depends in part upon being able to contrast the project site before and after restoration. Properly labeled and archived photographs are fundamental. Camera locations should be recorded, so that before and after photos can be compared. Videotapes, aerial photographs, and oblique aerial photos from a low-flying aircraft are helpful. Soils and other physical site conditions should be described. To the extent possible, species composition should be listed and species abundance estimated. The structure of all component communities should be described in sufficient detail to permit objective means of evaluating the performance of projects subsequent to their implementation.

21. Document the project site history that led to the need for restoration.

The years in which impacts occurred should be recorded. Historical aerial photos are helpful. Disturbance features should be photographed.

22. Conduct pre-project monitoring as needed.

Sometimes it is useful or requisite to obtain baseline measurements on such parameters as water quality and groundwater levels for a year or more prior to initial project installation. If so, these measurements will continue after the project begins as part of the monitoring program.

23. Gather baseline ecological information and conceptualize a reference ecosystem from it upon which the restoration will be modeled and evaluated.

The kind of ecosystem that has been selected for restoration must be described in sufficient detail to develop restoration objectives and to serve as a comparison for evaluating the completed restoration project. Documentation of the pre-project site conditions (Guideline #20) may contribute substantially to the reference. Generally, no one site contains the range of variability that is representative of the ecosystem designated for restoration. Therefore, the reference system should be conceptualized from the collective attributes of several sites. These attributes should include both the biotic and abiotic (physical) components. They should include seral (developmental) descriptions, because a comparison between an ecologically young restoration site and a mature reference system requires assumptions that are difficult to substantiate. The description of the reference system can be the citation of existing documents, a report of baseline ecological studies conducted by the restoration team, or a combination thereof.

24. Gather pertinent auto-ecological information for key species.

The restoration ecologist should have access to whatever knowledge is available regarding the recruitment, maintenance, and reproduction of key species. If necessary, trials and tests can be conducted by the restoration team prior to project installation.

25. Conduct investigations as needed to assess the effectiveness of restoration methods.

Novel and unusual restoration methods may require testing prior to their implementation at the project site.

26. Decide if ecosystem goals are realistic or if they need modification.

On the basis of information gained from carrying out the aforementioned guidelines, the project team should conduct a feasibility study to determine if the type of restoration

(Guideline #4) and the original project goals (Guideline #5) were realistic. If not, modifications should be proposed.

27. Prepare a list of objectives designed to achieve restoration goals.

Objectives are the specific activities to be undertaken for the satisfaction of project goals. The restoration ecologist should list all objectives needed to achieve each project goal. Objectives may be executed directly through the establishment of project features or passively through suitable project design. In either case, objectives are explicit, measurable, and have a designated time element. Objectives can cover a wide array of specific actions. They may be hydrological, e.g., the filling of a drainage ditch to improve sheet flow; pedological, e.g., the amendment of organic matter to improve soil texture; or biological, e.g., the prompt removal of a particular exotic species that threatens ecosystem integrity. Other objectives may pertain to re-introducing fire according to a specific prescription, removing an abandoned road, or establishing a windbreak. Certain objectives may require actions that take place offsite to improve conditions onsite. Some restoration projects can be accomplished with one or few objectives. For example, perhaps all that is needed is to install culverts beneath a road to improve drainage, assuming the vegetation can recover passively.

28. Secure permits required by regulatory and zoning authorities. These are the permits identified in guidelines #13 and #14.

29. Establish liaison with other interested governmental agencies. Potential interested agencies should be notified of the project. Later, site tours can be conducted for agency personnel and progress reports dispatched to them. This networking could expedite assistance, should it become needed.

30. Establish liaison with the public and publicize the project. Local residents automatically become stakeholders in the restoration. They need to know how the restored ecosystem can benefit them personally. For example, the restoration may attract ecotourism that will benefit local businesses, or it may serve as an environmental education venue for local schools. If residents favor the restoration, they will protect it and vest it with their political support. If they dislike the restoration, they may vandalize or otherwise disrespect it.

31. Arrange for public participation in project planning and implementation.

The restoration team should make every effort to involve local residents or other interested members of the public to participate in project planning and installation. By doing so, the participants develop a feeling of ownership, and they will be more likely to assume a stewardship role for the completed project. Volunteer labor by local residents or by ecotourists may reduce overall project costs. However, such labor requires coordination, special supervision, and additional liability insurance.

32. Install roads and other infrastructure needed to facilitate project implementation. The degree to which infrastructure is provided should be weighed against the costs of down time caused by its absence and against considerations of safety and opportunities for public relations tours.

33. Engage and train personnel who will supervise and conduct project installation tasks. Project personnel who lack restoration experience or knowledge of particular methods will benefit from attending workshops and conferences that

provide background information. Otherwise, the restoration ecologist should provide training.

INSTALLATION PLANNING

Installation plans describe how the project will be implemented, i.e., project design. The care and thoroughness with which installation planning is conducted will be reflected by how aptly project objectives are realized.

34. Describe the interventions that will be implemented to attain each objective. The restoration ecologist should identify all actions and treatments needed to accomplish each objective listed in Guideline #27. Detailed instructions are prepared for implementing each of these interventions. Concomitantly, the needs for labor, equipment, supplies, and biotic stocks are identified.

Restoration projects should be designed to reduce the need for mid-course corrections that inflate costs and cause delays. Special care should be given to describing site preparation activities, i.e., those interventions that precede the introduction of biotic resources. Once biotic resources are introduced, it may become exceedingly difficult to repair dysfunctional aspects of the physical environment.

Some interventions can be accomplished concurrently and others must be done in sequence. The need for sequencing should be clearly identified. Some restoration activities require follow-up activities or continuing periodic maintenance following installation. These tasks are predictable and can be written into the implementation plans under their respective objectives. Examples of maintenance tasks include the repair of erosion on freshly graded land and the removal of competitive weeds and vines from around young plantings.

35. State how much of the restoration can be accomplished passively.

Restoration tasks initiate or accelerate natural processes. Nearly all manifestations of restoration are accomplished by these processes and not by the direct artifice of the restorationist. For example, a small quantity of plants may be introduced as nursery stock with the expectation that these plants will propagate and increase substantially in density. Many restoration projects make no provision for introducing species of animals. The assumption is that, 'if we build it, they will come.' The restoration plan should acknowledge those aspects that are expected to develop passively, i.e., without intervention. If passive restoration is not realized, then additional interventions must be prescribed (see Guideline #47).

36. Prepare performance standards and monitoring protocols to measure the attainment of each objective. A performance standard (also called a design criterion) provides evidence on whether or not an objective has been attained. This evidence is gathered by monitoring in accord with a prescribed protocol or methodology. Performance standards require careful selection for their power to measure the completion of an objective. Monitoring tells the restoration ecologist to what degree a given objective has been attained. It is essential that performance standards and monitoring protocols be selected prior to any project installation activity. Otherwise, the objectivity of the performance standard will be compromised by the initial results of installation. Monitoring protocols must be geared specifically to performance standards. Other information is extraneous and inflates project costs. Monitoring protocols should be designed so that data are readily gathered, thereby reducing monitoring costs. They should be empirical to facilitate their objective interpretation.

37. Schedule the tasks needed to fulfill each objective. Scheduling can be complex. Planted nursery stock may have to be contract-grown months or longer in advance of planting and must be delivered in prime condition. Older, root-bound stocks are generally worthless. If direct seeding is prescribed, seed collecting sites will have to be identified. The seed must be collected when ripe, possibly stored, and perhaps pre-treated. Site preparation for terrestrial systems cannot be scheduled when conditions are unsuitable. For example, soil manipulations cannot be accomplished if flooding is likely, and prescribed burning must be planned and conducted in accordance with applicable fire codes. The availability of labor and equipment can further complicate scheduling. Workdays may have to be shortened for safety during especially hot weather and in lightening storms. Wet weather may cause equipment to bog down. Schedules should reflect these eventualities.

Most objectives are implemented within the first or second year of installation. Some objectives may have to be delayed. For example, the re-introduction of plants and animals with specialized habitat requirements may have to be postponed several years until habitat conditions become suitable.

38. Procure equipment, supplies, and biotic resources. Care should be taken to assure that regional ecotypes of biotic resources are obtained to increase the chances for genetic fitness and to prevent needless and harmful introductions of non-indigenous ecotypes and species.

39. Prepare a budget for installation tasks, maintenance events, and contingencies. Budgeting for planned objectives is obvious. However, budgeting for unknown contingencies is just as important. No restoration project has ever been accomplished exactly as it was planned. Restoration is a multivariate undertaking, and it is impossible to account for all eventualities. Examples of contingencies are severe weather events, depredations of deer and other herbivores on a freshly planted site, colonization by invasive species, vandalism, and unanticipated events elsewhere in the landscape that impact the project site. The need to conduct at least some remediation is a near certainty. Generally, the cost of remediation increases in relation to the time it takes to respond after its need is discovered. For these reasons, contingency funds should be available on short notice.

INSTALLATION TASKS

Project installation fulfills installation plans. If planning was thorough and supervision adequate, installation will generally proceed smoothly and within budget.

40. Mark boundaries and secure the project area. The project site should be staked or marked conspicuously in the field. Fencing and fire lanes should be installed as needed. This guideline is sometimes ignored until it results in a contingency, such as a neighbor's cattle escaping into a freshly planted project site.

41. Install monitoring features. Permanent transect lines, staff gauges, piezometer wells, etc., need to be installed and marked.

42. Implement restoration objectives. Restoration tasks were identified in Guideline #34. The restoration ecologist must supervise project installation or delegate supervision to project team members. Responsibility for proper implementation should not be entrusted to subcontractors, volunteers, and labors crews who are doing the work. The cost of retrofitting exceeds the cost of appropriate supervision.

POST-INSTALLATION TASKS

The attainment of objectives may depend as much on follow-up activities as it does to the care given to initial installation activities. The importance of post-installation work cannot be overemphasized.

43. Protect the project site against vandals and herbivory. Project sites attract dirt bike riders, feral swine, deer, geese, nutria, etc. Beaver can destroy a newly planted site by plugging streams and culverts. Appropriate preventive actions should be taken.

44. Perform post-implementation maintenance. Conduct maintenance activities that were described in Guideline #34.

45. Reconnoiter the project site regularly to identify needs for mid-course corrections. The restoration ecologist needs to inspect the project site frequently, particularly during the first year or two following an intervention, to schedule maintenance as needed and to react promptly to contingencies.

46. Perform monitoring as required to document the attainment of performance standards. Measurements of water levels and certain water quality parameters are generally conducted on a regular schedule. Otherwise, monitoring should not be required until monitoring data will be meaningful for decision-making. Monitoring and the reporting of monitoring data are expensive. Regular reconnaissance (Guideline #45) negates the need for frequent monitoring.

47. Implement adaptive management procedures as needed. Adaptive management as a restoration strategy is essential, because what happens at one stage in restoration dictates what needs to happen next. A restoration plan must contain built-in flexibility. If reconnaissance or monitoring reveal that objectives are not being met, then alternative interventions may have to be attempted. The project manager should realize that restoration objectives may never be realized for reasons that lie beyond the control of the restoration ecologist. If so, then new goals (Guideline #5) and objectives (Guideline #27) may have to be adopted if a functional ecosystem is to be returned to the project site.

EVALUATION

The installation of a project does not guarantee that its objectives will be attained or its goals achieved. Restoration differs from most civil engineering projects for which the results are more predictable. Restored ecosystems are dynamic and require evaluation within the context of an indefinite temporal dimension.

48. Assess monitoring data to determine if performance standards are being met. If performance standards are not being met within a reasonable period of time, refer to Guideline #47.

49. Describe aspects of the restored ecosystem that are not covered by monitoring data. This description should commence when project work has been essentially completed. The description should compliment the documentation that was conducted prior to the initiation of restoration activities (Guideline #20) to allow before and after comparisons.

50. Determine if project goals were met, including those for social and cultural values. Based on monitoring data and other documentation (Guidelines

#46, #49), evaluate the restoration with respect to its project goals. These will include the primary goal to restore a functional ecosystem that emulates the reference ecosystem at a comparable ecological age (Guideline #4). They will also include any secondary goals with respect to social and cultural values (Guideline #5).

51. Publish an account of the restoration project and otherwise publicize it.

Publicity and documentation should be incorporated into every restoration project for the following reasons: Published accountings are fundamental for instituting the long-term protection and stewardship of a completed project site. Policy makers and the public need to be appraised of the fiscal and resource costs, so that future restoration projects can be planned and budgeted appropriately. Restoration ecologists improve their craft by becoming familiar with how restoration objectives were accomplished.

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