Excerpts from: Clewell, A. F. and J. Aronson. 2013. Ecological restoration: principles, values, and structure of an emerging profession 2nd edition, Island Press, Washington D.C.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration, Science and Policy Working Group. 2004. The SER Primer on Ecological Restoration. http://www.ser.org/).

Ecosystem Response to Disturbance

Disturbance of many kinds can occur, each with different levels of intensity. They provoke varying levels of damage and elicit a broad array of responses from ecosystems. Disturbance (excluding normal disturbance regimes) can be roughly divided into three ascending categories:
1. stress that maintains ecosystem integrity;
2. moderate disturbance from which an ecosystem can recover in time without assistance; and
3. impairment, a more severe case, where human intervention may be needed to prevent unacceptable transformation to an alternative and probably less ecologically vigorous state.

We have demonstrated the initial degradation and ongoing impairment in the area

An ecological restoration project begins with a representation from nature that guides all aspects of project planning and implementation. That representation is called the ecological reference, and it reveals ecosystem states and indicates what is known about underlying processes.

The ecological reference can assume many forms and can be prepared from both primary and secondary sources of information. Primary sources are actual ecosystems, called reference sites. Written ecological descriptions of reference sites also qualify as primary sources, as long as they contain adequate information for preparing restoration plans. Secondary sources consist of any other information that contributes in some way to the description of an ecosystem prior to its impairment. More specifically, an ecological reference may consist of the following:

- an ecological description of the ecosystem to be restored before it was impaired
- remnants of that same ecosystem that survived impairment
- another intact ecosystem of the same type in the general vicinity
- a combination of the above elements or their ecological descriptions
- any of these choices with additions of secondary information or with modifications specified to accommodate changing or recently altered environmental conditions or constraints
- synthesis of secondary information in instances when reference sites or their ecological descriptions are unavailable

We have assembled and digested considerable information, including a pilot study to evaluate the method of restoring wetlands, prepared broad-scale and fine-scale plans, and set targets

The selection of the reference is rightfully the responsibility of stakeholders and members of the local community, who will necessarily live with—and provide stewardship for—the ecosystem that is restored.

Managers at multiple levels and with multiple foci are onboard and the community has been engaged as soon as we had sufficient information

White and Walker (1997) proposed a formal classification of reference sites consisting of four categories. They are (1) same place, same time; (2) different place, same time; (3) same place, different time; and (4) different place, different time.

We have some of (1) and more of (3)

In ecological restoration project work, we assist the recovery of impaired ecosystems (SER 2004). In chapter 4 we raised the question concerning how much assistance we should apply to recover an impaired ecosystem. This chapter explores that question at some length. Thereafter, we introduce the framework approach to restoration, and the chapter concludes by examining the sources of knowledge used in ecological restoration and how these sources influence our approaches to performing restoration.

What level of effort is needed to accomplish ecological restoration? As with everything else in ecological restoration, the answer is site specific; there is no rule or recipe that fits all sites. We approach this topic by describing four levels or intensities of effort that can be applied or attempted, levels borrowed from similar schemes for this purpose that were proposed by T. McDonald (2000) and by Prach et al. (2007):

1. Prescribed natural regeneration
2. Assisted natural regeneration
3. Partial reconstruction: Projects designated as partial reconstructions rely partly on technical solutions and partly on natural regeneration. Technical solutions may include the mechanized repair of the physical environment using civil engineering methods. For example, stream banks may be reshaped and ditches filled.
4. Complete reconstruction

We're doing 3

The selected approach may depend on a variety of factors and influences, including these:

1. budget constraints (prescribed natural regeneration is the least expensive option);
2. time limitations (reconstruction is accomplished in the least time);
3. availability of labor and equipment (prescribed natural regeneration requires the least of each);
4. specified project goals (goals, other than attainment of biophysical attributes of a restored ecosystem, may require intensive interventions);
5. level of disturbance (repair of the physical environment requires more effort than manipulations of the biota);
6. landscape context (intensive interventions may be needed to compensate for reduced exchanges of organisms and materials in urbanized and highly impaired landscapes);
7. availability of technological options (research and development for new methods will increase costs);
8. contractual, legal, and administrative realities (permit conditions may preclude some restoration options);
9. political realities (restoration tasks that require prescribed fire may be forbidden on account of political pressures);
10. ecological issues (e.g., there may be need for rapid, intensive implementation in order to deter colonization of open habitat by invasive species, or to conduct planting during brief periods on account of restrictions of weather or climate);
11. socioeconomic priorities (the need to accelerate restoration to retain flood water, prevent erosion, or provide another ecosystem service).

If none of these issues is applicable, the preferred level of intensity is to make only those manipulations that are needed to reengage ecological processes in a manner that relieves the need for human subsidy thereafter. This strategy was advocated in the 1960s by two sisters from Australia, Joan and Eileen Bradley (Bradley 1971), and it continues to serve as the guiding principle for the restoration of natural areas on public lands in Australia today. This policy warrants emulation elsewhere and deserves consideration whenever latitude exists to select the intensity of restoration effort.

We've considered the various factors, including conducting a pilot study to assess the viability of the method, and we're doing a partial reconstruction

Table 5.1. Ecological attributes of restored ecosystems

Directly attained attributes

Species composition: The restored ecosystem contains a comprehensive assemblage of potentially coadapted species as informed by the reference model. The species include representatives of all known functional groups. The species are indigenous, and invasive organisms are absent insofar as possible.

Community structure: Species populations are established in sufficient abundance and distributed across the project site adequately to facilitate structural development in the biotic community.

Abiotic environment: The abiotic environment has the physical capacity to sustain the biota of the restored ecosystem.

Landscape context: The restored ecosystem is suitably integrated into a larger ecological matrix or landscape with which it interacts through abiotic and biotic flows and exchanges as informed by the reference model. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape are eliminated insofar as possible.

Indirectly attained attributes

Ecological functionality: Ecological processes in the restored ecosystem occur normally for its ecological stage of development, and signs of dysfunction are absent.

Historic continuity: Biodiversity recovers to the point that the historic ecological trajectory of the ecosystem, which was interrupted by impairment, is reestablished.

Ecological complexity: The ecosystem develops complex ecological structure that facilitates niche differentiation and habitat diversity.

Self-organization: The ecosystem develops feedback loops that increase its capacity to conserve its resources and increase its potential for autonomy.

Resilience: The restored ecosystem is sufficiently resilient to resist or self-recover from all but the most severe disturbance events and to benefit from stress events that maintain ecosystem integrity.

Self-sustainability: The restored ecosystem is self-sustaining to the same degree as its reference ecosystems and has the potential to persist indefinitely. Aspects of its biodiversity may fluctuate or change in response to internal flux and external environmental changes.

Biosphere support: The restored ecosystem generates atmospheric oxygen, absorbs $CO2$, facilitates thermal reflectance, and provides habitat for rare species.

We have evidence that wetlands restored in the same manner successfully attain the direct attributes, which suggests that over time the restored wetlands will attain the indirect attributes

Responses to: Clewell, A., J. Rieger and J. Munro. 2005. Guidelines for developing and managing ecological restoration projects, 2nd edition. www.ser.org and Tucson: Society for Ecological Restoration International.

Conceptual Planning

Conceptual planning identifies the restoration project site, specifies restoration goals, and provides relevant background information. Conceptual planning is conducted when restoration appears to be a feasible option but before a decision has been made to exercise that option. Conceptual planning provides preliminary information such as observations from site reconnaissance and perhaps a few representative measurements. Detailed, systematic inventories of ecosystem properties and the biota are not included in this phase of activity. Written responses to Guidelines #1 through #16 collectively comprise the conceptual plan and broadly characterize the proposed restoration project.

1. Identify the project site location and its boundaries. Delineate project boundaries and portray them as maps, preferably generated on a small-scale aerial photograph and also on soil and topographic maps that show the watershed and other aspects of the surrounding landscape. Use of GPS (Global Positioning System), land survey, or other measurement devices as appropriate is encouraged.

Done, with initial broad-scale planning done in 2007 and more detailed planning undertaken as required resources were identified and confirmed

2. Identify ownership. Give the name and address of the landowner(s). If an organization or institution owns or manages all or part of the site, give the names and titles of key personnel. Note the auspices under which the project will be conducted—public works, environmental stewardship, mitigation, etc. If there is more than one owner, make sure that all are in agreement with the goals and methods proposed for the restoration program.

Done, with work taking place on state lands

3. Identify the need for ecological restoration. Tell what happened at the site that precipitated the need for restoration. Describe the improvements that are anticipated following restoration. Benefits may be ecological, economic, cultural, aesthetic, educational, and scientific. Ecological benefits may amplify biodiversity; improve food chain support, etc. Economic benefits are natural services (also called social services) and products that ecosystems contribute towards human wellbeing and economic sustainability. Ecosystems in this regard are recognized and valued as natural capital.

Cultural improvements may include social performance and rituals, passive recreation, and spiritual renewal. Aesthetic benefits pertain to the intrinsic natural beauty of native ecosystems. Educational benefits accrue from advances in environmental literacy that students gain from participating in, or learning about, ecological restoration. Scientific benefits accrue when a restoration project site is used for demonstration of ecological principles and concepts or as an experimental area.

Done, with emphasis on ecological benefits

4. Identify the kind of ecosystem to be restored. Name and briefly describe the kind of ecosystem that was degraded, damaged, or destroyed, for example, tropical dry forest, vernal pool, semiarid steppe, shola (India), chalk meadow (Europe), cypress swamp (USA), etc. Other descriptors should be added to facilitate communication with those who may not be familiar with the natural landscapes in the

bioregion. These descriptors should include the names of a few characteristic or conspicuous species and should indicate community structure (desert, grassland, savannah, woodland, forest, etc.), life form (herbaceous perennial, succulent, shrub, evergreen tree, etc.), predominant taxonomic categories (coniferous, graminaceous, etc.), moisture conditions (hydric, xeric, etc.), salinity conditions (freshwater, brackish, saline, etc.), and geomorphologic context (montane, alluvial, estuarine, etc.). Reference to readily accessible published descriptions can augment or replace some of these descriptors.

Done, with herbaceous coastal wetland as the focus

5. Identify restoration goals. Goals are the ideal states and conditions that an ecological restoration effort attempts to achieve. Written expressions of goals provide the basis for all restoration activities, and later they become the basis for project evaluation. We cannot overemphasize the importance of expressing each and every project goal with a succinct and carefully crafted statement. All ecological restoration projects share a common suite of ecological goals that consist of recovering ecosystem integrity, health, and the potential for long-term sustainability. They are listed as the attributes of restored ecosystems in Section 3 of the SER International Primer. They deserve to be restated for each restoration project. Otherwise, they can be underappreciated or overlooked by authorities and other interested parties who are not well versed in ecological restoration. A project may have additional ecological goals, such as to provide habitat for particular species or to reassemble particular biotic communities.

Statements of ecological goals should candidly express the degree to which recovery can be anticipated to a former state or trajectory. Some ecosystems can be faithfully restored to a known or probable historic condition, particularly when degradation or damage is not severe and where human demographic pressures are light, plant species richness are low on account of rigorous environmental conditions, and where the ecologically young vegetation in a newly restored ecosystem tends to resemble the mature vegetation of the pre-disturbance state. Even so, the restored ecosystem will undoubtedly differ in some respects from its model, owing to the complex and seemingly random (stochastic) aspects of ecosystem dynamics. Other restorations may not even approximate a historical model or reference, because contemporary constraints or conditions prevent restoration to a former, historic condition.

Restoration can be conducted in any of five contexts. The appropriate context should be identified in the project goals in order to underscore the intent of restoration and to avoid or minimize subsequent misunderstandings, conflict and criticisms. They are:

a) Recovery of a degraded (subtle or gradual changes that reduce ecological integrity and health) or damaged (acute and obvious changes) ecosystem to its former state.

b) Replacement of an ecosystem that was entirely destroyed (degradation or damage removes all macroscopic life), and commonly ruins the physical environment) with one of the same kind. The new ecosystem must be entirely reconstructed on a site that was denuded of its vegetation (terrestrial systems) or its benthos (aquatic systems). Replacements are common on surface-mined lands and brownfields (severely damaged urban and industrial lands).

c) Transformation (conversion of an ecosystem to a different kind of ecosystem or land use type) of another kind of ecosystem from the bioregion 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.

d) Substitution of a replacement ecosystem where an altered environment can no longer support any naturally occurring type of ecosystem in the bioregion. The replacement ecosystem may consist of novel combinations of indigenous species that are assembled to suit new site conditions as, for example, at a retired solid waste disposal site.

e) Substitution of a potential 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.

All ecological restoration projects have cultural goals (see Guideline #3), even though such goals may be implied in the enabling legislation that authorizes public agencies to conduct or permit project work. All cultural goals should be stated clearly, because they provide the basis for public understanding of the benefits of a project. Public appreciation is conducive to garnering fiscal support, to accommodation of project activities by public agencies, to attracting stakeholder participation in project planning and implementation, and to commanding respect for the restored ecosystem by local residents.

Done, with emphasis on recovery of a degraded system that is continuing to degrade and creation of a sustainable system that contributes to a park

6. Identify physical site conditions in need of repair. Many ecosystems in need of restoration are dysfunctional on account of damage to the physical environment, such as soil compaction, soil erosion, surface water diversion, and impediments to tidal inundation. The physical environment must be capable of sustaining viable, reproductive species populations that comprise the biota of the restored ecosystem.

Done, with a focus on converting two disparate habitats back into a sustainable habitat that can follow the same trajectory as similar habitats that have not been disturbed

7. Identify stressors in need of regulation or re-initiation. Stressors are recurring factors in the environment that maintain the integrity of an ecosystem by discouraging the establishment of what would otherwise be competitive species. Examples are fires, anoxia caused by flooding or prolonged hydroperiod, 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. In some ecosystems, stressors may include sustainable cultural activities, such as the periodic harvest of biotic resources and the ignition of fires. These should be identified as stressors of cultural origin.

No such stressors known

8. Identify and list the kinds of biotic interventions that are needed. Many restoration projects require manipulation of the biota, particularly vegetation, to reduce or eradicate unwanted species and to introduce or augment populations of desirable species. Invasive non-native species generally require extirpation. Other species, native or non-native, may be removed if they retard or arrest biotic succession. Species that may need introduction include mycorrhizal fungi, N-fixing bacteria, other soil microbiota and, in aquatic environments, benthic infauna (animals that live in sediments). Mobile animals generally colonize restored habitats spontaneously; however, animal introductions are

sometimes needed. Animals can be enticed to colonize project sites by providing perches for birds, distributing coarse detritus for small animal cover, preparing a variety of different substrates in streams as habitat for macroinvertebrates, etc.

Done, with evidence from previous work indicating that grading to the proper elevation in preparation for natural recruitment is an effective and efficient approach, which does not introduce an initial bias into the plant assemblage or lead to damage to the restored surface

9. Identify landscape restrictions. Population demographics of many species at a project site may be adversely affected by external conditions and activities offsite in the surrounding landscape. Land and water usage are commonly at fault. Restoration should not be attempted if the landscape is likely to be heavily compromised.

Restoration of some aquatic ecosystems depends entirely on making ecological improvements elsewhere in the catchment, and all restoration work is accomplished offsite. An example of an impact from offsite would be discharge of turbid or polluted water such as agricultural runoff that reaches a proposed project site. Another example would be recurrent flooding and consequent sedimentation in a lowland site that was caused by unrestrained runoff following harvest of montane forest. In this instance, restoration efforts might be better directed at afforestation (forest recovery) in highlands. 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 impervious surfaces on developed land. Water tables can be depressed gradually by transpiration following reforestation and can be raised acutely after timber harvest or after ditches are filled. Fire frequency is reduced by intentional suppression and by landscape fragmentation that interrupts the cover of flammable vegetation. Fire hazards develop in the form of dense brush in response to fire suppression. Exotic species colonization onsite is commonly traced to infestations offsite. The presence or abundance of birds and other mobile animals in the restored ecosystem depends on the health of other ecosystems in the landscape that comprise parts of their territories.

Hazards elsewhere in the landscape such as these should be identified and evaluated in terms of their potential to compromise restoration efforts, and the possibility that they can be ameliorated should be assessed realistically.

No external restrictions identified

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

Done, with multiple partners contributing to the project

11. Identify labor sources and equipment needs. Personnel may have to be hired, volunteers invited, and other labor contracted. Determine the need and availability of special equipment.

Done, with a specialized piece of equipment specified and obtained

12. Identify biotic resource needs and sources. Biotic resources may include seeds, other plant propagules, nursery-grown planting stocks, and animals for establishment at the project site. Some stocks are commercially available. Others, such as seeds of native plants, may have to be collected from other natural areas.

Done, although experience indicates that biotic resources are not needed

13. Identify the need for securing permits required by government agencies. Permits may be required for tasks such as the excavation or filling of streams and wetlands, other earthwork activities, herbicide use, and prescribed burning. Other permits may be applicable for the protection of endangered species, historic sites, etc.

Done, with all permits being in place

14. Identify permit specifications, deed restrictions, and other legal constraints. Zoning regulations and restrictive covenants may preclude certain restoration activities. Legal restrictions on ingress and egress could prevent the implementation of some restoration tasks. If the restoration is to be placed under conservation easement, the timing of the easement must be satisfied and manipulations to the environment may have to be completed prior to the effective date of the easement. If restoration is to be conducted under contract or as mitigation or mitigation banking, contract conditions and permit specifications must be compatible with the restoration plan and incorporated into it. If they are not, negotiations may have to be conducted with the agency in charge.

Done, with the project being conducted on state lands and in a park

15. Identify project duration. Project duration can greatly affect project costs. Short-term restoration projects can be more costly than longer-term projects. The longer the project, the more the practitioner can rely on natural recovery 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.

Done, with work planned for one year

16. Identify strategies for long-term protection and management. Ecological restoration is meaningless without reasonable assurance that the project site will be protected and properly managed into the indefinite future. To the extent possible, threats to the integrity of a restored ecosystem on privately owned land should be minimized by mechanisms such as conservation easements or other kinds of zoning. External threats can be reduced by buffers and binding commitments from neighboring landowners. Alternatively, the restored ecosystem could be legally transferred to a public resource agency or non-governmental organization. However, the protection and management of restored ecosystems on public lands are not guaranteed, and a formal commitment for that purpose by the responsible agency is desirable.

Done, with the surrounding waters to be protected by the Florida Department of Environmental Protection and the project located on state lands and in a park

Preliminary Tasks

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

17. Appoint a restoration practitioner who is in charge of all technical aspects of restoration. Restoration projects are complex, require the coordination of diverse activities, and demand numerous decisions

owing in part to the complex nature of ecosystem development. For these reasons, leadership should be vested in a restoration practitioner who maintains overview of the entire project and who has the authority to act quickly and decisively to obviate threats to project integrity. Many smaller projects can be accomplished by a single practitioner who functions in various roles—from project director and manager to field technician and laborer. Larger projects may require the appointment of a chief restoration practitioner who oversees a restoration team that includes other restoration practitioners. The chief practitioner may delegate specific tasks but retains the ultimate responsibility for the attainment of objectives.

Ideally, the expertise of the chief practitioner should be solicited by project planners. If restoration is a subcontract component of a larger project, the chief practitioner should enjoy equal status with other subcontractors to prevent actions that could complicate scheduling, compromise restoration quality, and inflate costs. In any event, the chief practitioner and the project manager should maintain open lines of communication.

Practitioner 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 chief practitioner when they mandate particular restoration activities as permit specifications. This practice reduces the chief practitioner's capacity for flexibility and innovation, including the prompt implementation of mid-course corrections. 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.

Done, with multiple professionals involved

18. Appoint the restoration team. For larger projects, the chief practitioner may need the collaboration of other practitioners to supervise labor crews and subcontractors and also of technical personnel with critical skills and expertise. Collectively, they comprise the restoration team. It is essential that the responsibilities of each individual are clearly assigned and that each person be given concomitant authority.

Done, with multiple professionals involved

19. Prepare a budget to accommodate the completion of preliminary tasks. The budget addresses labor and materials and includes funds needed for reporting. It recommends or specifies a schedule of events.

Done

20. Document existing project site conditions and describe the biota. This guideline builds on preliminary information in the responses to guidelines #3 and #4 and is significantly more comprehensive and detailed. Documentation for this guideline should include a systematic inventory that quantifies the degree of degradation or damage. Species composition should be determined and species abundance estimated. The structure of all component communities should be described in sufficient detail to allow a realistic prediction of the effectiveness of subsequent restoration efforts. Soils, hydrology, and other aspects of the physical environment should be described. Such information is critical later in project evaluation, which depends in part upon being able to contrast the project site before and after restoration.

Properly labeled and archived photographs are essential for documenting any restoration project. Numerous photos should be taken with care during good photographic conditions prior to conducting any restoration work. Photographic locations and compass directions should be recorded, so that before and after photos can be compared. Close-up and wide angle photos should be included, with some taken from an elevated position as from the cargo bed of a truck. Videotapes, aerial photographs, and oblique aerial photos from a low-flying aircraft are helpful.

Done, with an emphasis on analysis of aerial photographs

21. Document the project site history that led to the need for restoration. Site history that was identified for Guideline #3 is expanded, if necessary, to provide a comprehensive overview. The years during which impacts occurred should be recorded. Historical aerial photos that show the pre-disturbance state and that show disturbance events are helpful.

Done, with aerial photographs clearly showing the need for restoration

22. Conduct pre-project monitoring as needed. Often it is useful or requisite to obtain baseline measurements on such parameters as water quality, groundwater elevation, and gross metabolism of soil organisms for a year or more prior to initial project installation. If so, these measurements will continue throughout the life of the project as part of the monitoring program. Unanticipated extremes in data can indicate problems that might require mid-course correction to prevent the collapse of the project. Upon project completion, the data are assessed to help evaluate the effectiveness of restoration.

Done, with water quality being measured as part of ongoing efforts and results from previous work supplying the knowledge needed for other elements (note the "as needed")

23. Establish the reference ecosystem or "reference." The reference model represents the future condition or target on which the restoration is designed and which will serve later as a basis for project evaluation. The reference can consist of the pre-disturbance condition if it is known, one or more undisturbed sites with the same type of ecosystem, descriptions of such sites, or another document, as described in Section 5 of the SER International Primer. The reference must be sufficiently broad to accommodate the amplitude of potential endpoints that could reasonably be expected from restoration.

The selection of the reference increases in difficulty in instances where contemporary constraints and conditions alter the historic trajectory or in other instances where the bioregion lacks comparative ecosystems of the kind being restored. In extreme cases, the only concrete reference data may consist of a list of native species that could potentially contribute to the assembly of an ecosystem with the intended community structure. The degree to which the reference can serve as a model for a restoration project and for its evaluation depends on its specificity and its appropriateness, and both can vary widely among projects. In some projects, the reference can serve almost as a template. In others, it can only hint at the direction of development.

Done via multiple previous projects

24. Gather pertinent autecological information for key species. The chief practitioner should access whatever knowledge is available regarding the recruitment, maintenance, and reproduction of key

species. If necessary, trials and tests of species establishment and growth can be conducted by the restoration team prior to project implementation.

Done in multiple previous projects

25. Conduct investigations as needed to assess the effectiveness of restoration methods and strategies. Innovative restoration methods may require testing prior to their implementation at the project site. Experimental plots or small-scale “pilot projects” may demonstrate feasibility or reveal weaknesses in restoration design and execution prior to attempting larger-scale restoration. Pilot projects are particularly useful in attempting the restoration of a particular kind of ecosystem for the first time in a bioregion.

Done in a targeted, pilot study and multiple previous projects

26. Decide whether ecosystem goals are realistic or whether they need modification. The selection of realistic goals is crucial. The potential for the achievement of some goals that were identified during conceptual planning (Guideline #5) may now appear unrealistic in light of more thorough information generated subsequently. Other goals could be added. At this time, the project team should reassess the selection of goals in Guideline #5 and make modifications if warranted.

Done, with an emphasis on providing the key structural habitat, i.e., herbaceous coastal wetland

27. Prepare a list of objectives designed to achieve restoration goals. In order to achieve restoration goals, explicit actions are undertaken to attain specific end results. Each end result is called an objective. For example, if the goal is to recover the former forest ecosystem on land that was converted for the production of row-crops, one objective might be to establish tree cover with a designated species composition and species abundance at a finite location in that field. In restoration projects that are conducted under contract, objectives are ordinarily “time certain,” meaning that they are to be done within a specified length of time in order to accommodate project planning, budgeting, and regulatory concern.

Objectives are subject to precise empirical determination, as will be described in Guideline #36. Objectives are selected with the anticipation that their completion will allow the fulfillment of project goals. Goals are less amenable to precise empirical determination, because they require measurements of innumerable parameters that are constantly subject to change on account of ecosystem dynamics. For that reason, objectives are used as indicators of the achievement of goals.

Ecological objectives are realized by manipulating the biota and/or the physical environment. Some are executed at the beginning of restoration, such as removing a road, filling a previously excavated canal, or adding organic matter or lime to the soil. Other objectives require repetitious actions, such as the periodic ignition of prescribed fires or the removal of recurring invasive species that threaten the establishment of desirable vegetation. Some objectives may require actions that take place offsite to improve conditions onsite. The number of ecological objectives for an ecological restoration project may vary from one to many, depending upon project goals and the degree to which the ecosystem was degraded or damaged.

Cultural objectives pertain to the realization of cultural project goals. These objectives may involve publicity campaigns, public celebrations of restoration in progress, participation of stakeholders and school children in restoration implementation and monitoring, and other actions that ensure cultural intimacy with ecosystem recovery.

Done, with previous work indicating little to no need for repeated maintenance and the cultural aspects being handled by the park

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

Done

29. Establish liaison with interested public agencies. Ecological restoration is necessarily an endeavor of public concern, even if it is conducted on privately owned land without public expenditure. A restored ecosystem provides beneficial natural services well beyond property boundaries. Since restoration generally contributes to public wellbeing, public agencies that are responsible for natural resource protection and management should be aware of any restoration projects within their jurisdictions, regardless of ownership and funding. Upon their recognition, restoration projects can be afforded protection, favorable publicity, attentive management, or other favorable accommodation by public agencies. Site tours, websites, newsletters, and press releases are ways of establishing liaison with public agencies. Interagency memoranda can inform other agencies of restoration projects initiated by a sponsoring agency on public land.

Done

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 are unaware of the restoration and its public benefits, they may vandalize or otherwise disrespect it.

Underway and conducted for previous projects

31. Arrange for public participation in project planning and implementation to fulfill cultural goals. Many ecological restoration projects are conducted in technocratic manner; particularly those that are intended to satisfy contract conditions and permit stipulations required by public agencies. The public is commonly excluded except at legally required and sometimes perfunctory public hearings. Restoration is planned, implemented, and monitored by trained professionals without the assistance of volunteers from the public who may be perceived as liability risks for insurance purposes and who could complicate scheduling and supervision. Public participation could increase project costs and threaten timely project completion. However, the exclusion of the public can cause other problems such as those mentioned in Guideline #30. Public agencies should consider incentives for the restoration team to incorporate local residents and other stakeholders in all phases of project work. By doing so, the public will develop a feeling of ownership, and participants may assume a stewardship role for the completed project.

Underway and conducted for previous projects

32. Install roads and other infrastructure needed to facilitate project implementation. Ordinarily, restoration projects remove roads and other infrastructure. However, improvements or new

construction may be necessary to provide access to project sites or otherwise facilitate project implementation and maintenance. For instance, infrastructure improvement could reduce down time, improve safety, create opportunities for public relations tours, reduce trafficking through sensitive habitats, and discourage erosion from surface runoff on exposed land. Haul roads, staging areas, and fire lanes should be constructed as needed. To the extent possible, infrastructure should be removed in a subsequent task during project implementation.

No infrastructure issues, but continued access has been addressed

33. Engage and train personnel who will supervise and conduct project implementation 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 chief practitioner should provide or arrange for training. Ideally, everyone who engages in the restoration, including laborers, should be briefed on project goals and objectives.

Done, with training to occur before work begins and ongoing oversight

Implementation Planning

Implementation plans describe the tasks that will be performed to realize project objectives. These tasks collectively comprise the project design. The care and thoroughness with which implementation planning is conducted will be reflected by how aptly implementation tasks are executed.

34. Describe the interventions that will be implemented to attain each objective. The chief practitioner designates and describes all actions, treatments, and manipulations needed to accomplish each objective listed in Guideline #27. For example, if the objective is to establish tree cover with a designated species composition and species abundance on former cropland, one intervention could be to plant sapling trees of the designated species at specified densities.

Restoration projects should be designed to reduce the need for mid-course corrections that inflate costs and cause delays. In that regard, special care should be given to the design of site preparation activities that precede the introduction of biotic resources. Once biotic resources are introduced, it may become exceedingly difficult and expensive to repair dysfunctional aspects of the physical environment on account of inadequate site preparation.

Some restoration interventions require aftercare or continuing periodic maintenance after initial implementation. 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.

Done, with past work indicating no need for maintenance

35. Acknowledge the role of passive restoration. Commonly, some but not all aspects of an ecosystem require intentional intervention to accomplish restoration. For example, if a correction to the physical environment is all that would be needed to initiate the recovery of the biota, then the practitioner would limit restoration activities to making that correction. To ensure that all aspects of ecosystem recovery have been considered, the restoration plan should acknowledge those attributes that are expected to develop passively without intervention. In the example, the practitioner would state that no manipulations were needed for the recovery of the biota.

Realize that ecological restoration is an intentional process that involves at least modest intervention on the part of a practitioner. If recovery occurs without any intervention, it should be called natural reestablishment or designated by another term besides ecological restoration.

Done, with natural revegetation considered the best option

36. Prepare performance standards and monitoring protocols to measure the attainment of each objective. A performance standard (also called a design criterion or success criterion) is a specific state of ecosystem recovery that indicates or demonstrates that an objective has been attained. For example, if the objective is to reestablish tree cover with a particular species composition and abundance on former cropland (as stated in the example for Guideline #27) and an intervention to realize that objective is to plant tree saplings of particular species at specified densities (as stated in the example for Guideline #34), then a plausible performance standard would be the establishment of a young forest that contained certain species of trees with minimal thresholds for tree species density, tree height, and collective canopy closure within a specified timeframe. Another potential example of performance standards would be the attainment of a threshold percentage of herbaceous vegetative cover in a seeded area within a given timeframe.

Satisfaction of some performance standards can be attained by a single observation—for example, to determine whether a canal has been filled. Other performance standards require a series of monitoring events to document trends towards the attainment of a specified numeric threshold for a physical parameter or for a particular level of plant abundance or growth.

Performance standards require careful selection so as to engender confidence in their power to measure the attainment of an objective. Otherwise, the objectivity of the performance standard may be biased by the initial results of implementation.

Monitoring protocols should be geared specifically to performance standards. Other monitoring generates extraneous information and inflates project costs. Monitoring protocols should be selected that allow data to be gathered with relative ease, thereby reducing monitoring costs. When a monitoring protocol is selected, a procedure for the analysis of monitoring data should be specified. For example, a statistical procedure could be designated—and a confidence interval stipulated—for determining significant differences.

Performance standards are of particular utility in restoration projects that are conducted by contractors or that are required to satisfy permit conditions. The attainment of performance standards represents hard evidence that objectives have been met, that contractors can be paid, and that permit holders can be released from regulatory liability. Conversely, non-attainment demonstrates non-compliance that can lead to enforcement actions and legal sanctions.

In a less technocratic context, the need for inclusion of performance standards in a restoration project diminishes. In smaller, less complex projects, or in projects where time of completion is not an issue, performance standards need not be specified. Instead, an ecological evaluation can be substituted in accord with Guideline #49.

Done for implementation and some key ecological elements (i.e., turbidity) and under discussion for other elements

37. Schedule the tasks needed to fulfill each objective. Scheduling can be complex. Some interventions can be accomplished concurrently and others must be done sequentially. Planted nursery stock may have to be contract-grown for months or longer in advance of planting and must be delivered in prime condition. If planting is delayed, planting stocks may become root-bound and worthless. If direct seeding is prescribed, seed collecting sites will have to be identified. The seed must be collected when ripe and possibly stored and pre-treated. Site preparation for terrestrial systems should not 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 temporary unavailability of labor and equipment can further complicate scheduling. Workdays may have to be shortened for safety during especially hot weather and in lightning storms. Wet weather may cause equipment to become mired. Schedules should reflect these eventualities.

Tasks for most objectives are implemented within a year or two. Some tasks may have to be delayed. For example, the re-introduction of plants and animals that require specialized habitat requirements may have to be postponed several years until habitat conditions become suitable.

Done

38. Obtain equipment, supplies, and biotic resources. Only appropriate items should be procured. For example, machinery should be selected that does not compact the soil inordinately or damage it when making turns. Degradable materials such as organic mulch are generally preferable to persistent ones such as plastic ground covers. Nursery-grown plants should be accepted only in peak condition, and their potting soil should consist of all natural materials. Care should be taken to ensure that regional ecotypes of biotic resources are obtained to increase the chances for genetic fitness and to prevent introduction of poorly adapted ecotypes. However, a wider selection of ecotypes and species may be advantageous in order to pre-adapt the biota at project sites undergoing environmental change. Nurseries sometimes supply superior trees that have been selected for timber quality. These may have to be inter-planted with “inferior” stock to facilitate ecosystem processes other than fiber production. For instance, deformed trees may be valuable for their wildlife cavities. Named cultivars and hybrids are unacceptable other than as temporary cover or nurse crops, because they do not represent natural species or taxa.

Done

39. Prepare a budget for implementation tasks, maintenance events, and contingencies. Budgeting for planned implementation tasks is obvious. However, budgeting for unknown contingencies is equally 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 land use activities elsewhere in the landscape that impact the project site. The need to make at least some repairs is a near certainty. Generally, the cost of repair increases in relation to the time it takes to respond after its need is discovered. For these reasons, contingency funds should be budgeted for availability on short notice.

Done

Implementation Tasks

Project implementation fulfills implementation plans. If planning was thorough and supervision is adequate, implementation can proceed smoothly and within budget.

40. Mark boundaries and work areas. The project site should be staked or marked conspicuously in the field, so that labor crews know exactly where to work.

Ongoing during implementation

41. Install permanent monitoring fixtures. The ends of transect lines, photographic stations, bench marks, and other locations that will be used periodically for monitoring are staked or otherwise marked on-site and, if possible, identified with GPS coordinates. Staff gauges, piezometer wells, or other specified monitoring equipment is installed, marked, and their locations identified with GPS coordinates.

Potential for some areas to be marked depending on what is planned

42. Implement restoration tasks. Restoration tasks were identified in Guideline #34, and these are now implemented to fulfill the ecological restoration objectives. The chief practitioner supervises project implementation or delegates supervision to project team members. Responsibility for proper implementation generally 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.

Implementation to be tracked by multiple personnel

Post-implementation Tasks

The attainment of objectives may depend as much on aftercare as it does to the care given to the execution of implementation tasks. The importance of post-implementation work cannot be overemphasized.

43. Protect the project site against vandals and herbivory. Security of the project site should be reviewed following project implementation. Vandalism may include youths who use project sites for recreational activities (e.g., camp fires, dirt bike riding). Grazing animals include domestic livestock, feral swine, deer, elephants, geese, nutria and many others. Beaver can destroy a newly planted site by plugging streams and culverts. Nuisance animals may require trapping and relocation or the construction of fenced exclosures.

Minimal targets for vandals and grazing is not anticipated to be a major issue

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

Past projects indicate that maintenance is not necessary

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

Oversight planned throughout the implementation

46. Perform monitoring as required to document the attainment of performance standards. Monitoring and the reporting of monitoring data are expensive. For that reason, monitoring should not be required

until the data will be meaningful for decision-making. Regular reconnaissance (Guideline #45) may negate the need for frequent monitoring. Not all monitoring can be postponed. Some factors, such as water elevations and water quality parameters, are usually measured on a regular schedule to provide interpretable data. Sometimes monitoring is required to document survival of planting stock. A more effective substitute would be to require the replacement of stock that did not survive in lieu of monitoring.

Turbidity to be monitored

47. Implement adaptive management procedures as needed. Adaptive management as a restoration strategy is highly recommended, if not essential, because what happens in one phase of project work can alter what was planned for the next phase. A restoration plan must contain built-in flexibility to facilitate alternative actions for addressing underperformance relative to objectives. The rationale for initiating adaptive management should be well documented by monitoring data or other observations. The project manager should realize that restoration objectives may never be realized for reasons that lie beyond the control of the chief practitioner. If so, then new goals (Guideline #5) and objectives (Guideline #27) may have to be substituted to ensure the recovery of a functional, intact, and otherwise whole ecosystem.

An adaptive approach is built into the implementation, e.g., areas with insufficient spoil will be bypassed

Evaluation and Publicity

Assessments are conducted to ensure the satisfaction of project objectives and goals. The project is publicized for public and technical consumption.

48. Assess monitoring data to determine whether performance standards are met and project objectives are attained. The results of data analysis should be documented in writing. If performance standards are not met within a reasonable period of time, refer to Guideline #47. Guideline #48 is ignored for smaller projects for which no performance standards were specified in Guideline #36.

Planned as executed for previous projects

49. Conduct an ecological evaluation of the newly completed project. This guideline requires satisfaction for those projects for which no performance standards were specified in Guideline #36. The evaluation should compare the restored ecosystem to its condition prior to the initiation of restoration activities (Guideline #20). The evaluation should determine whether or not the ecological goals from Guideline #5 were met, including the ecological attributes of restored ecosystems. Technical publication is normally the way that an evaluation is presented. To satisfy the requirements of scientific rigor that some journals expect, this evaluation may require more documentation of site conditions than those that are available from monitoring data. For that reason, an ecological investigation is apropos for all completed restoration projects. Some restoration projects are conducted by enduring institutions that have the capacity for follow-up investigations to provide a conservation perspective on the valued ecosystems after they have undergone restoration. To facilitate this possibility, care should be given to use inventory protocols that can be readily repeated for comparative purposes.

Not necessary due to the presence of performance standards

50. Determine whether cultural project goals were met. These goals were specified in Guideline #5.

Planned, with emphasis on the viewpoint of the park

51. Publicize and prepare written accounts of the completed restoration project. All too often, project personnel walk away from a completed project to begin another without stopping to consider the magnitude of their work and its benefits to the public and the environment. Sometimes a final report is required by contract or as a permit condition. Even if it is not, preparation of a final report is warranted to serve as an archival record of the project. The public deserves to be informed of a completed project and the benefits that accrue from it. News releases, media events, and public celebrations are all in order. Popular articles for public consumption can be prepared in non-technical language. Such publicity keeps ecological restoration in the public eye. If policy makers and politicians are aware of successfully completed projects, they will be more inclined to promote and fund new projects. Technical accounts of the project are equally important. Case histories become a treasure trove of information for all restoration practitioners who want to improve their professional proficiency. Case histories can be published in technical journals, trade journals, and posted on internet sites. Papers and posters can be presented at conferences.

Planned as executed for previous projects